VOL. 5

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Fisheries Science

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

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Agriculture and Allied Sciences

Volume-5

Restructured and Revised
Syllabi of Post-graduate Programmes

Fisheries Science

- Aquaculture
- Fisheries Resource Management
- Aquatic Environment Management
- Fish Genetics and Breeding
- Fish Nutrition and Feed Technology
- Aquatic Animal Health Management
- Fish Biotechnology
- Fish Processing Technology
- Fishing Technology and Engineering
- Fisheries Economics
- Fisheries Extension
- Fish Physiology and Biochemistry

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सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the

syllabus for all the disciplines:

	Masters' Programme	Doctoral Programme
(i) Course work		
Major courses	20	12
Minor courses	08	06
Supporting courses	06	05
Common courses	05	–
Seminar	01	02
(ii) Thesis Research	30	75
Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics*. CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4th and 6th semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:
   (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;
   (b) An application is made by the student concerned duly supported by the Advisory Committee;
   (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;
   (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Preamble and Acknowledgement
BSMA–Fisheries Science 2020

India's Fisheries sector includes aquaculture and capture fisheries with varied resources and potential, engaging over 14.50 million people at the primary level and many more along the value chain. This sunrise sector grew at an impressive Cumulative Average Growth Rate (CGAR) of 8% annually. Aquaculture has surpassed its production than capture fisheries in India by topping second in World's fish and shrimp production. India has witnessed strong growth in exports of fishery products in the last decade. The country is also foremost exporter of fish contributing 5.23% of the Gross Domestic Value to the agriculture sector and 0.96% to the GDP of the country. Indian Council of Agricultural Research, is spearheading national programmes on aquaculture and fisheries research, higher education and frontline extension through a network of Central Research Institutes and State Fisheries Universities.

Major Aquaculture components such as stock improvement, water, energy, health, and feed management and access processing machineries and export markets are responsible for the CGAR. Aquaculture feed and health management has become an important component for sustainable growth and development of the industry. Advanced genetic breeding programs have strongly supported industry growth in the last five years. Besides being a source of health as well as wealth, fisheries and aquaculture provide jobs and livelihood to millions. Globally, fisheries and aquaculture research and education has moved ahead at a rapid pace in response to the diversity and increasing specialisations in the fisheries sector.

Besides the core skills, the sector also requires human assets to support developmental and regulatory processes and entrepreneurship capacity. Highly specialised quality human resources will be one of the central engines which drive the research and development essential to enable fisheries and aquaculture to meet the future demands. The fisheries education curriculum provides the decent knowledge of the subject and the industry but practical skills in bringing entrepreneurial prospects is still lacking for the students. This compilation would pave way for attracting and retaining the talents to fisheries and aquaculture sector for improving fish productivity and consumption at the national level. Fisheries and aquaculture industry is looking for cream of the cream to improve its performance. Thus, the Fisheries education system should be subjected to constant innovations and reforms, particularly with respect to redesigning of curricula and syllabi, innovative pedagogy, developmental orientation, entrepreneurship, soft skill development, etc. It's imperative to prepare the graduates and equip them not only to effectively respond to the emerging needs and challenges, but also to become creative and proactive partners in piloting this knowledge-led revolution.

Presently, four year degree programme in Bachelor of Fisheries Science (B.F.Sc.) is being offered in 40 colleges, while PG programs are offered by 20 colleges. The present yearly intake capacity of B.F.Sc., M.F.Sc. furthermore, Ph.D. programs are around 1500; 500 and 200 respectively, while the yearly out-turn might be around 85-95% of intake. In addition to this, India's Gross Enrolment Ratio (GER) to higher education was found to be >25% and lags behind many developed and developing countries. As aquaculture sector is

rewarding the highest CGAR report to its allied farming sectors, it's inevitable that we need to produce more at least 10% of the total agri-graduates produced in the country. Apart from increasing the number of seats, maximum capacity utilization of the available infrastructure facilities would be a long-term value to Higher Education (HE). Strengthening the HE infra by government resources alone may not be adequate to cater to the requirement of human resource development in fisheries sector. All the Fisheries Colleges can take extra efforts to lift the standards of upbringing the competent fisheries professionals by adopting the appropriate Student: Teacher ratio less than 1: 10. Restructuring of postgraduate curricula and syllabi to upgrade the competence and standard of human resource in fisheries is also necessary and for this ICAR has constituted Broad Subject Matter Area specialists (BSMA) committee. The present exercise of revising and reorienting the postgraduate curricula was initiated by ICAR in 2007.

Present BSMA in Fisheries science has given a major thrust to restructuring of syllabus by introducing the contents catering the need of present scenario and future need keeping in view the environmental, societal issues and job opportunities. At present scenario committee recommends 12 disciplines, which is two disciplines less than the recommendation of previous BSMA committee (2013).

Fisheries sector is growing fast and hence it needs compatible and competent human resources for its sustainable development. A set target of 22 mmt has been assigned to achieve by 2030 under the Blue Revolution program of the Govt. Hence, higher education in Fisheries Science will be a driving force to achieve this huge target within coming 10 years. This coincides with the restructuring of the course curriculum of the Master and Ph.D. of Fisheries science as under taken by the BSMA committee. The workshop was fully dedicated for the syllabus revision activities and for discussing the academic reformations. The committee were concerned about sustainability, food safety, consumer demand, climate smart aquaculture, alternative sources and sensory evaluation for GM plants or animals.

Along with restructuring the syllabus some changes in academic rules have been proposed so as to strengthen the soft skill capability of the students. Considering the recent UGC guide lines for the Ph.D as the minimum qualification for the Assistant Professor, overall development of Ph.D students pertaining to quality research, teaching ability and leadership quality have been addressed. Teaching assistantship has been proposed to involve the Ph.D students in teaching programme so as to facilitate the Ph.D students to teaching programme before joining as a Assistant Professor in a college.

Fisheries colleges are rapidly coming up all over the country almost in all the states. ICAR's recommendations for starting of a new college are to be implemented still more effectively in our country. Similarly we cannot wait for a long to implement a newly recommended disciplines, which has its relevance in the present context and may loose its priority in due course of time. Hence, committee request ICAR to facilitate the implementation of these new programs by all the colleges in a specific period of time.

The key issues specially addressed in the revision of course curricula at PG and doctoral levels are: supply of high quality germplasm to farming community, compounded feed supply to intensive aquaculture production units, strategic bio-available micro-nutrient supplements, water use for super and supra intensive aquaculture, production designs for fish rearing amenable to automation and mechanization, clean fish production to be taken up as a national mission, phyto-sanitary measures for traceability and quality assurance of products of fish and fishery products, onward linkages for processing and marketing of the fishes, cold chain infrastructure for fish meats, entrepreneurship building and economic analysis of various fish production including pricing, insurance, credit, technological

backstopping and assessment of economic losses associated with inadequate prioritization of the aquaculture enterprise.

The implementation of the new and restructured post graduate course curricula is expected to build knowledge and skill portfolio of the students so as to enhance their employability and marketability as multi-service providers with practical skills and comprehensive knowledge of the entire subject area after masters. The doctorates should, in turn, prove as specialists, in the field of their specialization. The valuable inputs received from the stake holders, viz. eminent academicians, scientists, extension workers, pharmaceutical/aquaculture industry, leading consultants, state fisheries department etc. have immensely helped in preparation of this document.

We are thankful to Dr Arvind Kumar, Vice Chancellor, RLBCAU Jhansi, ICAR and all the members of the BSMA Committee on Fisheries Science and the participants of consultative workshop for their valuable suggestions and contributions for the development of the curricula and syllabi. Our thanks are due to Dr T. Mohapatra Secretary, DARE and D.G, ICAR and the DDG (Edn.), for their support in bringing out this document. We also thank Dr G. Venkateshwarlu Assistant Director General (EQR) Member Secretary, BSMA, for his untiring assistance throughout the consultation process till final documentation. The extensive help rendered by TNJFU and ICAR-CIFE, Mumbai for organizing various BSMA committee meetings with the students and faculty and industry personnels for the syllabus activities is duly acknowledged. We hope that this document will serve as a guide and help in achieving uniformly high standards in postgraduate education in Fisheries Science across the country.

ICAR also can issue a guidelines along with the revamped syllabus of BSMA -2020 to all the institutes to adopt the newly revised syllabus scrupulously with only a little flexibility of 10 %.

The BSMA Committee of Fisheries experts have been of great help for the past many months to work consistently with the Chairman and the Convener to give a shape to the curriculum for the PG and PhD programs of Fisheries Science.

We firmly believe that this exercise of major revamping of the PG and Ph.D Syllabus will naturally raise the bar for the students undergoing these programs and would ensure 'quality' in higher education offered in Fisheries Science.

Prof. S. Felix
Chairman

Date: 27.02.2021
Chennai

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Aquaculture

Preamble
(Aquaculture)

India's Fisheries sector includes aquaculture and capture fisheries with varied resources and potential, engaging over 14.50 million people at the primary level and many more along the value chain. This sunrise sector grew at an impressive Cumulative Average Growth Rate (CGAR) of 8% annually. Aquaculture has surpassed its production than capture fisheries in India by topping second in World's fish and shrimp production. India has witnessed strong growth in exports of fishery products in the last decade. The country is also foremost exporter of fish contributing 5.23% of the Gross Domestic Value to the agriculture sector and 0.96% to the GDP of the country. Indian Council of Agricultural Research, is spearheading national programmes on aquaculture and fisheries research, higher education and frontline extension through a network of Central Research Institutes and State Fisheries Universities.

Major Aquaculture components such as stock improvement, water, energy, health, and feed management and access processing machineries and export markets are responsible for the CGAR. Aquaculture feed and health management has become an important component for sustainable growth and development of the industry. Advanced genetic breeding programs have strongly supported industry growth in the last five years. Besides being a source of health as well as wealth, fisheries and aquaculture provide jobs and livelihood to millions. Globally, fisheries and aquaculture research and education has moved ahead at a rapid pace in response to the diversity and increasing specialisations in the fisheries sector.

Besides the core skills, the sector also requires human assets to support developmental and regulatory processes and entrepreneurship capacity. Highly specialised quality human resources will be one of the central engines which drive the research and development essential to enable fisheries and aquaculture to meet the future demands. The fisheries education curriculum provides the decent knowledge of the subject and the industry but practical skills in bringing entrepreneurial prospects is still lacking for the students. This compilation would pave way for attracting and retaining the talents to fisheries and aquaculture sector for improving fish productivity and consumption at the national level. Fisheries and aquaculture industry is looking for cream of the cream to improve its performance. Thus the fisheries education system should be subjected to constant innovations and reforms, particularly with respect to redesigning of curricula and syllabi, innovative pedagogy, developmental orientation, entrepreneurship, soft skill development, etc.Its imperative to prepare the graduates and equip them not only to effectively respond to the emerging needs and challenges, but also to become creative and proactive partners in piloting this knowledge-led revolution.

Presently, four year degree programme in Bachelor of Fisheries Science (B.F.Sc.) is being offered in 34 colleges as, while Master and Ph.D programme are offered by 19 and 8 colleges, respectively. Present yearly intake capacity of B.F.Sc., M.F.Sc. and Ph.D. programmes are 1, 079; 417 and 181 respectively, while the yearly outturn might be around 85-95% of intake. In addition to this, India's gross enrolment ratio to higher education was found to be >15% and lags behind many developed and developing countries. .As aquaculture

sector is rewarding the most highest CGAR report to its allied farming sectors, its inevitable that we need to produce more at least 10% of the total agri-graduates produced in the country.Increasing the number of seats alone will not be an ideal solution.Maximum capacity utilization of the available infrastructure facilities would be a long term value to Higher Education (HE) .Strengthening the HE infra by government resources alone may not be adequate to cater to the requirement of human resource development in fisheries sector.All the Fisheries Colleges can take extra efforts to lift the standards of upbringing the competent fisheries professionals by adopting the appropriate Student: Teacher ratio of 1: 10. Restructuring of postgraduate curricula and syllabi to upgrade the competence and standard of human resource in fisheries is also necessary and for this ICAR has constituted broad subject matter area specialists (BSMA) committee. The present exercise of revising and reorienting the postgraduate curricula was initiated by ICAR in 2007, but still more than 40% colleges have no Master programme and 80% have no Ph.D programme. It is high time to give utmost priority to the higher education in Fisheries Science in the country. Hence, ICAR should ensure the implementation of BSMA recommendation in all the fisheries colleges by adopting various strategies. It has been observed that some colleges have only one Master or Ph.D programme, which may not satisfy the credit requirement for major and minor subjects of the on-going programs. At this juncture we are unable to implement all the disciplines recommended by the BSMA on one hand and new emerging disciplines needs to be implemented on the other hand. Hence, a suggestive guidelines from ICAR to be followed for the quick implementation of all the discipline in a phasing manner with a total span of five years. Present BSMA in fisheries science has given a major thrust to restructuring of syllabus by introducing the contents catering the need of present scenario and future need keeping in view the environmental, societal issues and job opportunities. Considering the intensive aquaculture and increased consumption rate of fish in future, the committee felt the need of new courses like Fish Pharmacology and Toxicology and Fish Quality Assurance Management so as to ensure healthy fish production and quality fish products available to the consumer. It may not be easy to run these courses initially by all the colleges due to non-availability of faculty in these specialised disciplines, however, it can be initiated in some few colleges, who have the strength to run these courses and later by others. At present scenario committee recommends 15 disciplines which includes two more disciplines than the recommendation of previous BSMA committee (2013).

Fisheries sector is growing fast and hence it needs compatible and competent human resources for its sustainable development. A set target of 22 mmt has been assigned to achieve by 2030 under the Blue revolution programme of the Govt. Hence, higher education in Fisheries Science will be a driving force to achieve this huge target within coming 10 years. This coincides with the restructuring of the course curriculum of the Master and Ph.D of Fisheries science as under taken by the BSMA committee. The workshop was fully dedicated for the syllabus revision activities and for discussing the academic reformations. The committee were concerned about sustainability, food safety, consumer demand, climate smart aquaculture, alternative sources and sensory evaluation for GM plants or animals.

Along with restructuring the syllabus some changes in academic rules have been proposed so as to strengthen the soft skill capability of the students. Considering the recent UGC guide lines for the Ph.D as the minimum qualification for the Assistant Professor, overall development of Ph.D students pertaining to quality research, teaching ability and leadership quality have been addressed. Teaching assistantship has been proposed to involve the Ph.D students in teaching programme so as tofacilitate the Ph.D students to teaching programme before joining as a Assistant Professor in a college.

Fisheries colleges are rapidly coming up almost in every states. But running the fisheries colleges with inadequate facilities and with a very few faculty compromises the teaching quality for which students are deprived off getting complete knowledge on the whole subjects. ICAR's recommendations for starting of a new college are to be implemented still more effectively in our country. Similarly we can not wait for a long to implement a newly recommended disciplines, which has its relevance in the present context and may loose its priority in due course of time. Hence, committee request ICAR to facilitate the implementation of these new programs by all the colleges in a specific period of time.

The key issues specially addressed in the revision of course curricula at PG and doctoral levels are: supply of high quality germplasm to farming community, compounded feed supply to intensive aquaculture production units, adoption of Fish Pharmacology and Toxicology concepts, strategic bio-available micro-nutrient supplements, water use for super and supra intensive aquaculture, production designs for fish rearing amenable to automation and mechanization, clean fish production to be taken up as a national mission, phyto-sanitary measures for traceability and quality assurance of products of fish and fishery products, onward linkages for processing and marketing of the fishes, cold chain infrastructure for fish meats, entrepreneurship building and economic analysis of various fish production including pricing, insurance, credit, technological backstopping and assessment of economic losses associated with inadequate prioritization of the aquaculture enterprise.

The implementation of the new and restructured post graduate course curricula is expected to build knowledge and skill portfolio of the students so as to enhance their employability and marketability as multi-service providers with practical skills and comprehensive knowledge of the entire subject area after masters. The doctorates should, in turn, prove as specialists, in the field of their specialization. The valuable inputs received from the stake holders viz. eminent academicians, scientists, extension workers, pharmaceutical/aquaculture industry, leading consultants, state fisheries department etc. have immensely helped in preparation of this document.

We are thankful to Dr Arvind Kumar, Vice Chancellor, RLBCAU Jhansi, ICAR and all the members of the BSMA Committee on Fisheries Science and the participants of consultative workshop for their valuable suggestions and contributions for the development of the curricula and syllabi. Our thanks are due to Dr T. Mohapatra Secretary, DARE and D.G, ICAR. and Dr N.S. Rathore DDG (Edn.), for their support in bringing out this document. We also thank Dr G. Venkateshwarlu Assistant Director General (EQR) Member Secretary, BSMA, for his untiring assistance throughout the consultation process till final documentation. The extensive help rendered by TNJFU and ICAR-CIFE, Mumbai for organising various BSMA committee meetings with the students and faculty and industry personnels for the syllabus activities is duly acknowledged. We hope that this document will serve as a guide and help in achieving uniformly high standards in postgraduate education in Fisheries Science across the country.

Course Title with Credit Load
M.F.Sc. in Aquaculture

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
AQC 501	Freshwater Aquaculture Production Systems	2+1
AQC 502	Coastal Aquaculture and Mariculture Farming Systems	2+1
AQC 503	Hatchery Technology for Finfishes and Shellfishes	2+1
AQC 504	Aquaculture Policy and Planning	1+1
AQC 505	Fish Nutrition and Feed Technology	2+1
AQC 506	Soil and Water Quality Management in Aquaculture	2+1
AQC 507	Therapeutics and Health Management in Aquaculture	2+1
	Minor Courses (From the subjects closely related to a student's major subject)	**8 Credits**
AQC 508	Larval Nutrition and Live Feed Production	1+1
AQC 509	Aquaculture Engineering	1+1
AQC 510	Open Water aquaculture	1+1
AQC 511	Commercial Ornamental Fish Breeding and Culture	1+1
AQC 512	Computer Application in Aquaculture Data Processing	0+1
AQC 513	Inland Saline Aquaculture	1+1
AQC 514	Multilevel Integrated Aquaculture Systems	1+1
AQC 515	Coldwater Aquaculture and Recreational Fisheries	1+1
AQC 516	Recirculating Aquaculture Systems	1+1
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common courses (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques	**5 Credits**

Course Code	Course Title	Credit Hours
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters'seminar	**1 Credits**
AQC 591	Masters' Seminar	0+1
	Masters' Thesis Research	**30 Credits**
AQC 599	Masters' Research (Semester III)	0+15
AQC 599	Masters' Research (Semester IV)	0+15
	Total M.F.Sc Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Aquaculture

I. Course Title : Freshwater Aquaculture Production Systems

II. Course Code : AQC 501

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge and understand the recent advances in freshwater fish and prawn farming under different culture systems.

V. Theory

Unit I

Introduction: Present status, hindrances / problems / constraints and prospects for fish and prawn farming in global and Indian perspective. Development process, different supports and driving factors forproduction enhancement.

Unit II

Aquaculture systems: Extensive, semi-intensive and intensive culture of fish and prawn. Partitioned aquaculture systems: raceways, tanks, flow-through systems, polyculture, and composite fish culture. Cages and enclosure. Peri-urban aquaculture systems: aquaponics, RAS, flow- through systems, bio-floc technology and land based aquaculturesystems.

Unit III

Aquaculture practices for cultivable species: Carps, Catfish, Snakeheads, Featherbacks, Tilapia, Mahseer, Trouts and freshwater Prawn. Grow out practices: pre stocking, post stocking management, harvesting and BMP. Other alternative species for high production. Species selection and crop planning. Economics of different fish farming systems

Unit IV

Freshwater prawn farming: Monoculture practice of prawn in ponds, all-male culture and its advantages, polyculture with carps, prawn farming in inland saline soils. Nursery rearing, sex segregation, pond preparation, stocking, feeding and water quality management, disease prevention and treatment; Harvesting methods, handling and BMP.

Unit V

Integrated farming systems: Design, farming practices, constraints and economics of IFS of fish with vegetables, fodder, paddy, cattle, pig, poultry, duck, rabbit and quail. IMTA, Freshwater pearl culture, multi- level integrated system. Resource utilization and conversion of waste towealth.

Unit VI

Wastewater-fed aquaculture: Water treatment methods, species selection, culture practices, harvesting and depuration process. Merits and demerits of wastewater

fed aquaculture systems. Pre-requisites and precautions to be taken in the technology adoption.

VI. Practical

Identification of commercially important cultivable finfish and shellfish species; Assessment of seed quality- stress test; pre-stocking factors evaluation and observation; Calculating carrying capacity of pond and stocking density; Check tray assessment and feed ration calculation; Sampling process and species wise growth estimation; Farm feed production and feeding; Lime and fertilizer requirement calculations; Farm visits and observation; Records keeping and data analysis; Modelling of different culture systems.

VII. Suggested Reading

- AAHRI. 1998. *Health Management in Shrimp Ponds*. Aquatic Animal Health Research Institute (AAHRI), Department of Fisheries, Thailand.
- Agarwal SC. 2008. *A Handbook of Fish Farming*. 2nd Ed. Narendra Publ. House.
- Beveridge MCM and Mc Andrew BJ. 2000. *Tilapias: Biology and Exploitations*. Kluwer.
- De Silva SS. (Ed.). 2001. *Reservoir and Culture Based Fisheries: Biology and Management*. ACAIR Proceedings.
- FAO. 2007. *Manual on Freshwater Prawn Farming*.
- Midlen and Redding TA. 1998. *Environmental Management for Aquaculture*.Kluwer.
- New MB. 2000. *Freshwater Prawn Farming*. CRC Publ.
- Pillay TVR. 1990. *Aquaculture: Principles and Practices*. Fishing News Books, Cambrige University Press, Cambridge.
- Venugopal S. 2005. *Aquaculture*. Pointer Publ.
- Welcomme RL. 2001. *Inland Fisheries: Ecology and Management*. Fishing News Books.

I. Course Title : Coastal Aquaculture and Mariculture Farming Systems

II. Course Code : AQC 502

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge in establishing and managing different fish/shellfish farming systems in coastal zone and marine waters.

V. Theory

Unit I

Introduction: Overview of coastal aquaculture and open sea mariculture; Present trend and future prospects in India. Practices in tropical countries, production levels and adoption of technology. Major bottlenecks in the practices

Unit II

Different farming systems: Cage and pen culture – types, site selection, construction, specifications for different species; Raft and rack culture – Principles, site selection, design and construction; operations and troubles shooting, threats and environmental issues; Land based aquaculture. Principle, design, construction and operations, rules and legislations

Unit III

Aquaculture of finfishes: Distribution, biology, seed collection, nursery rearing, weaning on artificial feed, culture techniques, feeding strategies, constraints and

scope (Seabass, milkfish, mullets, pearlspot, sea breams, grouper, snapper, cobia, pompano).

Unit IV

Shrimp farming (*Penaeus monodon, P. indicus, P. semisulcatus, and Litopenaeusvannamei*): Systems of farming – extensive, semi- intensive, intensive and super intensive (Biofloc, RAS, etc.); site selection, design and construction of culture systems, pond preparation, stocking, feed and water quality management, disease prevention and treatment; use of probiotics and prebiotics: harvesting and handling; continuous stocking and harvesting, staggered harvest, management of differential growth; shrimp farming in undrainable ponds. Mud crab fattening, production of soft-shell crabs and Lobster culture.

Unit V

Culture practices for marine molluscs and echinoderms: Present status and future prospects in India, Species cultured (mussels, oysters, pearl oysters, clams, abalone, sea cucumber) distribution, biology, practices followed in India and other Asian countries, farming methods–different types and culture methods; Problems and prospects.

Unit VI

Seaweed farming: Major seaweed species of commercial importance; tissue culture of seaweeds, methods of culture; farming of agar, algin and carragenan yielding species; emerging trends in their farming inopen seas; Integration with other coastal and marine farming systems.

VI. Practical

Identification of commercially important cultivable finfish and shellfish species; Assessment of seed quality, rearing techniques; Feeds for nursery rearing, preparation and evaluation; pre-stocking factors in different systems, valuation and observation; Calculating carrying capacity of pond and stocking density; Cage construction, pen construction and identification of bottlenecks; Sampling process and species wise growth estimation; Construction of rafts and mollusc culture; Seaweed collection and identification; Farm feed production and feeding; Disease identification and management; Visits to cage sites and observation; Records keeping and data analysis; Modelling of different culture systems.

VII. Suggested Reading

- Appukuttan KK, Asokan PK, Mohamed KS, Subramaniam S and G Joseph GK. 2003. *Manual on Mussel Farming*. CMFRI Technical Bulletin 3.
- Bardach EJ, Rhyther JH and Mc Larney WO. 1972. *Aquaculture the Farming and Husbandry of Freshwater and Marine Organisms*. John Wiley and Sons.
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- Pillay TVR. 1990. *Aquaculture, Principles and Practices*. Fishing News Books.
- Pillay TVR and Kutty MN. 2005. *Aquaculture: Principles and Practices*. 2nd Ed. Blackwell.

- Sekar M, Ranjan R, Xavier B and Ghosh S. 2016. *Training manual on cage culture of marine finfish*. CMFRI Publ.
- Shepherd J and Bromage N. 1990. *Intensive Fish Farming*. B.S.P. Professional Books.
- Shepherd J and Bromage N. 1990. *Intensive Fish Farming*. B.S.P.Professional Books.
- Syda Rao G, Imelda-Joseph, Philipose KK and Suresh Kumar M, 2013. *Cage aquaculture in India*. CMFRI Publ.

I. Course Title : Hatchery Technology for Finfishes and Shellfishes

II. Course Code : AQC 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn research outlines and recent advances in seed productionand hatchery management of commercially important cultivable finfishes and shellfishes.

V. Theory

Unit I

Introduction: Current status; problems and prospects of seed of different shellfish species – freshwater and marine. Site selection and techniques of collection; identification and segregation of finfish and shellfish seed, handling, packing and transportation. Natural collection processes and their merits and demerits.

Unit II

Reproductive biology: Morphology and reproductive physiology; gonad anatomy; histology of gonad; Hormonal pathways and mode of control; Spermatogenesis and oogenesis; gametology (evaluation of milt and egg); Overview of current developments in reproductive biology of commercially important finfishes and shellfishes.

Unit III

Environmental and nutritional control of reproduction: Reproductive cycles, factors influencing reproduction (Photoperiod, change in water quality and quantity, temperature, lunar cycle, etc.), simulated environment and exogenous hormonal stimuli. Nutritional factors (types of feed - live and prepared feeds, nutritional quality, quantity, feeding management, feed utilisation, etc.) affecting maturation, spawning and nursery rearing.

Unit IV

Induced spawning: Brooder development, quality and its health management, transportation of brooders, hormonal and environmental stimulation, use of different natural, synthetic hormones and analogues and their application; GnRH and LINPE models, PIT tagging, Canulation and volitional spawning, Estimation of spawning efficiency, cryopreservation of gametes.

Unit V

Hatchery management: Indian major and minor carps, exotic carps, catfishes, tilapia, mahseer, murrels, Trout, Seabass, milkfish, mullets, grouper, snapper, breams, pompano, and cobia. Seed production of commercially important prawns (*Macrobrachiumrosenbergii*), shrimps (*Penaeus monodon, P. indicus, P. semisulcatus, and Litopenaeusvannamei*), crabs (*Scylla serrata, Portunuspelagicus*), spiny lobsters (*Panulirus*spp), mussels, edible oysters, pearl oyster and clams. Hatchery protocols, water quality management, larval rearing, estimations, troubleshooting in

hatcheries, record keeping, packing and transport of seed, anaesthetics in fish seed transport. Quarantine and Hatchery protocols and biosecurity principles; sanitary and phytosanitary (SPS) measures; Better Management Practices (BMPs); packaging and transport of seed. SPF brood stock development.

Unit VI

Seed quality: Hatchery protocols, water quality management, larval rearing, estimations, trouble shooting in hatcheries, record keeping, packing and transport of seed, anaesthetics in fish seed transport. Quarantine and Hatchery protocols and biosecurity principles; sanitary and phytosanitary (SPS) measures; Better Management Practices (BMPs); packaging and transport of seed. SPF brood stock development. Economics of seed production of different species

VI. Practical

Study of primary and secondary sexual characters; Brooder handling and morphological features recording; Gonadal development observation in carps and other cultivable finfishes; Histological observation of gonads and eggs; Estimation of GSI, Fecundity, Absolute fecundity, Egg parameters, Ovarian features; Collection and identification of cultivable finfish seed; Seed quality character identification; Observation and analysis of inducing agents; Induced breeding of fishes through various inducing agents; Evaluation of carp milt and egg; Cryopreservation of gametes; Preparation of brood and larval feed for different cultivable finfish; Packing and transportation of cultivable finfish seed; Visit to different finfish hatcheries.

VII. Suggested Reading

- Betsy, C.J. and Kumar, J.S.S., 2017. *Cryopreservation and Spermatology in Fishes*. Narendra Publishing House
- Chattopadhay NR. 2016. *Induced fish breeding: a practical guide for hatcheries*. Elsevier Academic Press.
- FAO. 1992. *Manual of Seed Production of Carps*. FAO Publ.
- Gupta SD, Mohapatra PC, Routray P, Sahoo SK, Verma DK, Sarangi N. 2008. *Textbook of breeding and management of carps*. Narendra Publ. House
- ICAR. 2006. *Handbook of Fisheries and Aquaculture*. ICAR.
- Jhingran VG. 1991. *Fish and Fisheries of India*. Hindustan Publ. Corp.
- Jhingran VG and Pullin RSV. 1985. *Hatchery Manual for the Common, Chinese and Indian Major Carps*. ICLARM, Philippines.
- Landau M. 1992. *Introduction to Aquaculture*. John Wiley and Sons.
- Mcvey JP. 1983. *Handbook of Mariculture*. CRC Press.
- Pillay TVR and Kutty MN. 2005. *Aquaculture- Principles and Practices*. Blackwell.
- Rath RK. 2000. *Freshwater Aquaculture*. Scientific Publ.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.

I. Course Title : Aquaculture Policy and Planning

II. Course Code : AQC 504

III. Credit Hours : 1+1

IV. Aim of the course

To gain in depth knowledge to develop aquaculture policies for the sustainable aquaculture practices.

V. Theory

Unit I

Sustainability issues: Environmental and Socio-economic issues; Exotic species introduction; escapement; contamination of indigenous gene pool; salinization of soil and water; environmental impact; over exploitation of wild stocks; mangrove deforestation. EIA, eco-system approach to aquaculture. Conflicts over water and land use; conflicts of interest between aqua farmers and fishermen, aquaculture andother enterprises; social issues; anti-dumping duties.

Unit II

Climate Change Impact: Weather elements of concern in aquaculture, Green house gases, global warming and their impact, Carbon sequestration in aquaculture, Microplastics in Aquaculture, measures and tools to reduce energy use and greenhouse gas emission in aquaculture.

Unit III

Strategies for sustainability: Sustainability concept; food security; biosecurity; organic farming; responsible aquaculture; rotational aquaculture; bioremediation; role of biotechnology, traceability. Energy conservation. Application of renewable energy in aquaculture- solar energy, wind, and tidal energy, Seed certification, Sustainable use of antibiotics, minimal water exchange system, natural productivity, preservation of natural resources.

Unit IV

Guiding principles for sustainable aquaculture: Coastal Aquaculture Guidelines Source Book, FAO Code of Conduct for Responsible Fisheries; Holmenskollen Guidelines for Sustainable Aquaculture. BMP, CRZ implications, CAA and it's role, ecolabelling, organic certification. PCB and State water bodies protection guidelines.

VI. Practical

Visit to conventional aquafarm to see the management of used water; Survey on environmental impact on nearby aquaculture farms; Applications of remote sensing and GIS (geographical information system); Economic evaluation of aquaculture practices. Case studieson environmental issues of different types of farms.

VII. Suggested Reading

- Bardach JE. 1997. *Sustainable Aquaculture*. John Willey and Sons.
- Bardach JE, Rhyther JH and Mc. Larney WO. 1972. *Aquaculture Farming and Husbandry of Freshwater and Marine Organisms*. John Wiley and Sons.
- Beets WC. 1990. *Raising and Sustaining Productivity of Small- Holder Farming Systems in the Tropics*. Agbe Publ.
- Edwards P, Little DC and Demaine H. (Eds.). 2002. *Rural Aquaculture*. CABI.
- FAO 2001. *Planning and Management for Sustainable Coastal Aquaculture Development*. FAO.
- Imai T. 1978. *Aquaculture in Shallow Seas. Progress in ShallowSea Culture*. Amerind Publ.
- James PM. 1983. *Handbook of Mariculture*. Vol. I. Crustacean Aquaculture. CRC Press.
- Leung P, Lee CS and O'Bryen JP. (Eds.). 2007. *Species and System Selection for Sustainable Aquaculture*. Blackwell Publ.
- Midlen and Redding TA. 1998. *Environmental Management for Aquaculture*. Chapman and Hall.

• Selvamani BR and Mahadevan RK. 2008. *Aquaculture, Trends and Issues*. Campus Books International. FAO, 2011. Code of conduct for responsible fisheries. FAO special edition.

I. Course Title : Fish Nutrition and Feed Technology

II. Course Code : AQC 505

III. Credit Hours : 2+1

IV. Aim of the course

To learn the nutritional requirements and feed equipment's of major cultivable to develop new and novel feeds for the commercial aquaculture

V. Theory

Unit I

Introduction: Need for studying the nutritional requirements of cultivable fishes, feed formulation, Methods to study the nutritional requirements, and its need.

Unit II

Feed ingredients and Feed preparation: Commonly used feed ingredients in aqua feeds, Novel feed ingredients, estimation of quality of feed ingredients, Qualities of feed ingredients that determine feed quality, Selection of ingredients, Formulation of feeds, Feed processing and making. Different feed preparation methods.

Unit III

Types of feeds: Floating, semi-floating, sinking and stable feeds for aquaculture, Feed making methods for different feeds, Nutrient leeching in feeds, feed quality determination and feed making, Evaluation of feeds, Simulated system evaluation, lab analysis.

Unit IV

Advanced feeds: High energy feeds, Alternative protein sources for feeds, maturation diets to enhance breeding efficiency, Larval feeds, bio availability in feeds, High FCE and economic benefits of feeding in the farming, Live feed enrichment, Bio-routing of nutrients, Chemo-therapeutants, Other growth promoting agents through live feeds. Evaluation of bio-accumulation and bio-utilisation.

Unit V

Feed processing technology: Common processes in feed manufacture; Grinding, Dosing, Homogenization; Extrusion cooking; Complimentary processes; Drying, crumbling, coating; Use of binders; Feed manufacture productions with high energy diets vacuum coating with lipid. Equipments used in feed manufacture; Pulverizer, grinder, mixer, pelletizer, crumbler, drier, Extruder/Expander, Vacuum coater, fat sprayer

Unit VI

Quality control in fish feed manufacturing: Quality control procedures, raw materials, finished products; Geometrical, and physical feature; Mechanical characteristics in air, Behavioural characteristics in water, Feed economics and evaluation criteria: FCR, AFCR, SGR, PRE, ERE, PER, NPU.

VI. Practical

Nutritional requirements determination for different species; Collection and analysis of different feed ingredients; Feed formulation with different feed ingredients;

Feed quality analysis; Evaluation process in farms and labs; Visit to feed mills and feed making process; Economic analysis of feeding and non feeding systems; Identification of different feed additives; Observation of novel feeds and their utilization

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme), 1980.*Fish Feed Technology*. ADCP/REP/80/11. FAO.
- Ali SA. 2018. *Nutritional feeding of fish and shrimps in India*. MJP Publ.
- Cyrino EP and Bureau D and Kapoor BG. 2008. *Feeding and Digestive Functions in Fishes*. Science Publ.
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture*. Vol. VI. World Aquaculture Society, Baton Roughe.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series.
- Elena M. 2003. *Nutrition, Physiology and Metabolism in Crustaceans*. Science Publishers.
- Ganguly S. 2014. *Potential and recommended feed additives for sustainable aquaculture, livestock and poultry farming practices*. Narerndra Publ.
- Guillame J, Kaushik S, Bergot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publ.
- Halver J and Hardy RW. 2002. *Fish Nutrition*. Academic Press.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fish feed Technology*.Vols. I, II Heenemann, Berlin.
- Hertrampf JW and Pascual FP. 2000. *Handbook on Ingredients for Aquaculture Feeds*. Kluwer.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell.
- Lavens P and Sorgeloos P. 1996. *Manual on the Production and Use of Live Food for Aquaculture*. FAO Fisheries Tech. Paper 361, FAO.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Chapman and Hall.
- Lovell T. 2014. *Nutrition and feeding of fish*. Springer Publ.
- Merrifield D and Ringo E. 2014. *Aquaculture Nutrition: gut health, probiotics and prebiotics*.
- Nates SF, 2016. Aquafeed formulation. Academic Press
- New MB. 1987. *Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture*. FAO – ADCP/REP/87/26.
- Strasbourg LK. 2013. *Fish feeding in integrated fish farming*. Random Exports.
- Wiley Blackwell. Ninawe AS and Khedkar GD. 2009. *Nutrition in aquaculture*. NarendraPubl.

I. Course Title : Soil and Water Quality Management Inaquaculture

II. Course Code : AQC 506

III. Credit Hours : 2+1

IV. Aim of the course

To learn effective soil and water quality management practices foraquaculture

V. Theory

Unit I

Soil and water interaction: Physical and chemical properties of soil and water, Productivity vs. nutrient quality and quantity of soil and water; Aquatic microorganisms and their role in carbon, Nitrogen, Phosphorus and sulphur cycles and impact on aquatic habitats andspecies.

Unit II

Soil and water quality monitoring: Soil and water quality standards; Equipment used for soil and water quality estimations, Automated systems for monitoring, Quality checks and management, aeration system for water quality management.

Unit III

Fertilizers and manures: Different kinds of fertilizers and manures, Fertilizer grade, source, rate and frequency of application, Biofertilizers, Use of treated sewage for pond fertilization, Ecological changes taking place after fertilizing, primary production, degradation of molecules in aquatic environment, Utilization of bioactive compounds by microorganisms.

Unit IV

Soil and water conditioners: Biological indicators, Chemical and physical method of conditioning, Prebiotics, Probiotics, Minerals, Micro-nutrients and additives.

Unit V

Development of suitable soil and water quality: Cat clay/pyrite soil, Seepage, water treatment, Water filtration devices, Aeration, Chlorination, Ozonization and UV radiation, Algal bloom control, Eutrophication, Aquatic weed management, Water quality management in hatcheries.

Unit VI

Waste water treatment practices: Waste discharge standards, Role of microorganisms in fish production, Fish health and fish safety; Microbial load and algal blooms.

VI. Practical

Preparation of water quality charts and maintenance; Equipment used in soil and water analysis; Soil sampling, determination of soil moisture and bulk density; pond filling, Analyses of mud acidity and soil texture; Measurements of temperature, pH, conductivity, salinity, transparency, turbidity and solids; Analyses of dissolved oxygen, alkalinity and hardness, phosphorus, nitrogen; Estimation of primary productivity and chlorophyll; Application of fertilizers and pond liming; Analysis of toxic elements, microbial techniques, Visit to effluent treatment plant.

VII. Suggested Reading

1. Adhikari S and Chatterjee DK. 2008. *Management of Tropical FreshwaterPonds*. Daya Publ. APHA, AWWA, WPCF. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, DC.
2. Boyd, C. E. and Tucker, C. S. 1992. *Water Quality and Pond Soil Analyses for Aquaculture*, Alabama Agricultural Experimental Station, Auburn University.
3. Boyd CE. 1979. *Water Quality in Warm Water Fish Ponds*. Auburn University.
4. ICAR. 2006. *Handbook of Fisheries and Aquaculture*. ICAR.
5. Mcvey JP. 1983. *Handbook of Mariculture*. CRC Press.
6. Parsons TR, Maita Y and Lalli CM. 1984. *A Manual of Chemical and Biological Methods for Seawater Analysis*. Pergamon Press.
7. Rajagopalsamy CBT and Ramadhas V. 2002. *Nutrient Dynamics inFreshwater Fish Culture System*. Daya Publ.
8. Sharma LL, Sharma SK, Saini VP and Sharma BK. (Eds.). 2008. *Management of Freshwater Ecosystems*. Agrotech Publ. Academy.

I. Course Title : Therapeutics and Health Management in Aquaculture

II. Course Code : AQC 507

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge on health management in aquaculture systems through diagnosis, treatment and preventing the disease outbreaks to protect aquaculture production.

V. Theory

Unit I

Diseases of fishes: Bacterial, Fungal, Viral diseases of fishes in farm ponds, Natural waters, and incidental outbreaks, Nutritional disorders and environmental diseases, situations for disease outbreaks, Natural immunity and disease control.

Unit II

Control of diseases in aquaculture systems: Control measures for fish diseases, Environmental and nutritional support methods for disease management, Immune modulation, Immunostimulation, Use of vaccines and other preventive methods, Control of diseases in various aquaculture systems, their limitations and benefits.

Unit III

Therapeutics: Concept of therapeutics in aquaculture, effectiveness of medication, Drugs in aquaculture, Herbal therapeutants, Use of and disuse chemicals in aquaculture, Legislation and jurisprudence in therapeutics for aquaculture organisms, Shrimp farming and control mechanism, Drug therapies for ornamental fishes, Biotraceability of antibiotics use in aquaculture.

Unit IV

Health management plans for hatcheries: Special features of hatcheries and health management of brooders, larvae, fry and young ones, Disease impacts on hatchery production, Disinfection protocol, Live feed crash due to diseases, Communicable diseases and their mechanism of spreading, Controlling outbreak of viral infections in all types of hatcheries, Economic benefits of investment in disease management.

Unit V

Modern treatment methods for fishes: Treatment methods currently in practice, isolation, Hospital tanks, Disinfection, Oral drug administration, immersion, Brooder treatment for immunity enhancement, mass treatment protocol, vaccination, advantagesand disadvantages.

Unit VI

Other health management aspects: Health improvement through feeds, Medicated feeds, Chemicals for treatment of external and internal diseases, Parasite treatment, health improvement after treatment, SPF, SPR and SPT seeds, their production protocols.

VI. Practical

Identification of disease conditions: Pathological features observation in cultivable fishes; Collection of diseased specimens and identification; Developing treatment protocols for fishes; Analysis of environmental situation favouring disease outbreaks;

Epidemic conditions in farms identification; Preparation of medicated feeds, validation and observation; Hospital tanks and management; Probiotics and prebiotics identification of their effects; Visit to hatcheries and farms to collect the specimens; Economics of different treatment methods.

VII. Suggested Reading

- Andrews C, Excell A and Carrington N. 1988. *The Manual of Fish Health*. Salamander Books.
- Brunton LL. (Ed). 2005. *Goodman and Gilman's The Pharmacological Basis of Therapeutics*. 11th Ed. McGraw-Hill.
- Felix S, Riji John K, Prince Jeyaseelan MJ and Sundararaj V. 2001. *Fish Disease Diagnosis and Health Management*. Fisheries College and Research, Institute, T. N. Veterinary and Animal SciencesUniversity. Thoothukkudi.
- Humphrey J, Arthur JR, Subasinghe RP and Phillips MJ. 2005. *Aquatic Animal Quarantine and Health Certification in Asia*. FAO Publ.
- Jorge E, Helmut S, Thomas W and Kapoor BG. 2008. *Fish Diseases*. Science Publ.
- Riviere JE and Papich MG. (Eds.). 2013. *Veterinary Pharmacology and Therapeutics* 9th ed. John Wiley and Sons.
- Sandhu HS and Rampal S. 2006. *Essentials of Veterinary Pharmacology and Therapeutics*. 1st Ed. Kalyani Publishers.
- Sindermann CJ. 1990. *Principal Diseases of Marine Fish and Shellfish*.Vols. I, II. 2nd Ed. Academic Press.
- Treves-Brown KM. 2013. *Applied Fish Pharmacology* (Vol. 3). Springer Science and Business Media.

I. Course Title : Larval Nutrition and Live Feed Production

II. Course Code : AQC 508

III. Credit Hours : 1+1

IV. Aim of the course

To learn the nutritional requirements of fish/shellfish larvae and techniques on mass culture and bio-enrichment of live food organisms.

V. Theory

Unit I

Larval nutrition: Nutritional requirements of finfish and shellfish larvae, Nutritional quality of commonly used live feed, Comparison of live feeds against the prepared feeds, Nutritional disorders in larvae, Larval feeds utilization and advantages.

Unit II

Formulation and preparation of artificial feeds: For larval rearing, Micro particulate diets, Particulate and microencapsulated diets, High energy feeds, energy sparing nutrients in larval feeds.

Unit III

Biology of live feeds: Important live feeds and their biological features, Identification of new live feeds, Live feed use in different forms, Advantages and disadvantages. Important microalgae, rotifers, artemia, infusoria, cladocerans, copepods, oligochaetes, nematode and insect larvae. Bio-enrichment of live feed, Biofilm/periphyton and its use, Culture of single cell proteins and their nutritional quality.

Unit IV

Live feeds research in India, Around the world, New techniques developed in live feed use. Quality determination and cost benefit analysis, Production methods for different micro feeds, lab analysis of quality.

VI. Practical

Collection, identification and isolation of live feed using various techniques, Preparation of various culture media, Preparation and maintenance of stock microalgal culture; Preparation of formulated feeds for rearing finfish and shellfish larvae; Mass culture of microalgae, cladocerans, copepods and rotifers; Hatching of artemia and enrichment; Culture of infusoria, earthworms and chironomidlarvae; Evaluation of different prepared feeds.

VII. Suggested Reading

- CIFE. 1993. *Training Manual on Culture of Live Food Organisms for AQUA Hatcheries*. Central Institute of Fisheries Education, Versova, Mumbai.
- Finn RN and Kapoor BG. 2008. *Fish Larval Physiology*. Science Publ.
- Gopinathan CP. 1993. *Handbook on Aqua Farming - Live Feed*. MPEDA Publication
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer.
- Joan Holt G. 2011. *Larval fish nutrition*. Wiley Blackwell Publ.
- Lee CS., O'Bryen, PJ, Marcus NH. 2005. Copepods in aquaculture. Blackwell Publishing.
- MPEDA. 1993. *Handbook on Aqua Farming - Live Feed. Micro Algal Culture*. MPEDA Publication.
- Muthu MS. 1983. *Culture of Live Feed Organisms*. Tech. Paper 14.Summer Institute in Hatchery Production of Prawns Seeds. CMFRI, Cochin.
- Ojha JS. 2005. *Aquaculture Nutrition and Biochemistry*. Daya Publ.
- Santhanam R, Ramnathan M and Venkataramanujum. 1997. *A Manual of Methods in Plankton*. Fisheries College and Research Institute, Tamil Nadu Veterinary and Animal Sciences University, Tuticorin.
- Sorgeloos P and Pandian KS. 1984. *Culture of Live Food Organisms with Special Reference to Artemia Culture*. CMFRI Spl. Publ. No. 15.
- Tonapi GT. 1980. *Freshwater Animals of India*. Oxford and IBH.

I. Course Title : Aquaculture Engineering

II. Course Code : AQC 509

III. Credit Hours : 1+1

IV. Aim of the course

To learn basic aspects of different aquaculture farm designing for effective management and optimum yield.

V. Theory

Unit I

Site selection: Criteria for site selection, Correction factors, Survey methods, Earth work calculations and cost estimation; water resources and their suitability, Suitability of soil from stability and productivity point of view; Land conversion effects and Environmental Impact Assessment (EIA).

Unit II

Estimation in farm construction: Area and volume calculations for an aquafarm

and water bodies, surveying and leveling (chain, compass and plain table survey, dumpy level and the odolite).

Unit III

Design, layout planning and construction of different types of production systems: Types of ponds, shape, size and orientation, Design of embankments, Ponds and tanks, Water distribution, canals and exchange structures (inlets, outlets, sluice gates, and monks); Design of feeder channels and drainage systems. Pens, cages (fixed, floating, semi-submerged and tray cages) raceways, Flow-through systems and re-circulatory aquaculture systems (RAS), aquaponics, Feed dispensers, Demand feeders and effluent treatment systems (ETS), Automation in aquaculture.

Unit IV

Design and construction of hatcheries: (carp, freshwater prawn, shrimp and trout). Selection of aquaculture equipment and implement: Selection criteria and maintenance of water pumps, Water filtration systems, Principles of aeration, Aerators, Oxygen budgeting, Aeration grid, Automatic and demand feeders, Soil and water samplers. Aquifers, soil permeability, Hydraulic conductivity, Water budgeting, Water harvesting, Multiple uses of water, Economic impactof modernization in aquafarms

VI. Practical

Estimation in construction, Model development, Visit to aqua farms and hatcheries, Survey - contour survey and mapping, chain and compass survey, Dumpy leveling, Evaluation of performance of seepage control measures, Layout planning and design of hatcheries (carp, freshwater prawn, shrimp and trout) and farms including their costing and evaluation, Estimation of pump capacity, Estimation of construction cost of ponds, Hatchery shed, Aeration devices and Evaluation of their capacity.

VII. Suggested Reading

- Creed R. 2017. *Aquaculture and Fish Farming*. Syrawood Publ.
- Bose AN. 1991. *Coastal Aquaculture Engineering*. Oxford and IBH Publ.
- Ivar LO. 2007. *Aquaculture Engineering*. Daya Publ. House.
- Lekang OI. 2013. *Aquaculture Engineering*. Wiley-Blackwell Publ.
- Pillay TVR and Kutty MN. 2005. *Aquaculture- Principles and Practices*. Blackwell.
- Thomas L. 1995. *Fundamentals of Aquacultural Engineering*. Chapman and Hall.
- Wheaton FW. 1977. *Aquacultural Engineering*. John Wiley and Sons.

I. Course title : Open Water Aquaculture

II. Course code : AQC 510

III. Credit Hours : 1+1

IV. Aim of the course

To learn about the open water aquaculture for production enhancement

V. Theory

Unit I

Introduction: Overview of global scenario of aquaculture in open waters, open water resources in India, Present status, Utilization, Prospects of production augmentation, Utilization of open water bodiesfor aquaculture to enhance production

Unit II

Different culture systems: Cages, pens and enclosures in open waters, Seed stocking, quality and quantity, Cages for sea, estuaries, reservoirs, lakes and canals, Pen culture, Selection of site for sea farming, Different designs of open sea farming structures-construction of cages-bioengineering problems and solutions, Species selection for open water aquaculture, Rearing of fingerlings, advanced fingerlings and table size fish in open water bodies.

Unit III

Practices: Ranching in open waters, species quality and quantity, Natural feed enhancement, Supplementary feeding in cages, Stock assessment, Harvesting and conflicts with irrigation, Drinking water and hydroelectric projects on open water farming.

Unit IV

Environmental impact of Open water Aquaculture: Salinity intrusion, Effluent, discharge, Eutrophication, Chemical residues including antibiotics and hormones, Destruction of natural habitat including paddy field and mangroves, Social issues and conflicts with other users on resources

VI. Practical

Different types of cage materials, fabrication of cages and pens and their installation. Determination of stocking density in cages and pens, Feeding in cages and pens, Stock assessment in cages and pens; Environmental impact of cages and pens, Visit to cages and pen sites.

VII. Suggested Reading

- Beveridge MCM. (Ed.). 2004. *Cage Aquaculture*, 3rdEdition. Blackwell Publishing.
- Beveridge M. 2008. *Cage Aquaculture*. Oxford Publ.
- Burnell G, Allan G. 2009. *New Technologies in Aquaculture*. 1st Edition. Woodhead Publishing House.
- Chiu Liao I, Kwei Lin C. 2000. *Cage aquaculture in Asia: Proceedings of the First International Symposium on Cage Aquaculture in Asia*, AFS and WAS Publ.
- FAO. 2018. *The State of World Fisheries and Aquaculture -Meeting the Sustainable development goals*. Rome.
- NFDB. 2018. *Guidelines for Sea Cage Farming in India.*
- Syda Rao G, Imelda-Joseph, Philipose KK and Suresh Kumar M, 2013. *Cage Aquaculture in India*. CMFRI Publ.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Commercial Ornamental Fish Breeding and Culture

II. Course Code : AQC 511

III. Credit Hours : 1+1

IV. Aim of the course

To gain knowledge on advanced ornamental fish production technologies and aquatic ornamental plant propagation.

V. Theory

Unit I

Introduction: Global status of ornamental fish trade, present status and prospects

of ornamental fish farming and trade in India, Indian ornamental fish diversity and its status, Prospects of production of new strains / varieties, Ornamental fish breeding techniques towards strain development.

Unit II

Design and construction: Self-maintained aquarium, species compatibility, High value species, Aquarium maintenance and care, Common aquarium plants and their identification, Gadgets used in freshwater and marine aquarium, aerators, Filters (UV, trickling and biofiltration), Protein skimmers, Ozonizer, thermostatic heater, Chiller, Lighting, Water conditioners, etc.

Unit III

Captive Breeding techniques: Mass production of commercially important freshwater and marine ornamental fishes, Nursery and grow out culture of commercially important ornamental fish species in Raceways, RAS etc., Hybrids development, Feed and feeding, Color enhancement through pigmented feed, Novel feeds, Common diseases, and control, Water quality management.

Unit IV

Transportation and Trading of Ornamental Fishes: Medicines and chemicals used in the ornamental fish industry, Anaesthetics, packing, transportation and marketing strategies. Culture unit for entrepreneurship development, Socio-economic upliftment through backyard ornamental fish farming, Micro-traders in ornamental fish marketing.

VI. Practical

Identification of common ornamental fishes; Plants and gadgets used in aquariums; Breeding of commercially important ornamental fishes, Visit to ornamental fish units, Aquarium fabrication, Setting and maintenance, Application and use of medicines/chemicals.

VII. Suggested Reading

- Ahilan, B., Felix, N., Santhanam, R., 2008. *Textbook of Aquariculture*. Daya Publishing House, Delhi.
- Axelrod HR and Vorderwinkler W. 1978. *Encyclopaedia of Tropical Fishes*.TFH Publ.
- Axelrod HR and Sweenen ME. 1992. *The Fascination of Breeding Aquarium Fishes*. TFH Publ.
- Axelrod HR. 1967. *Breeding Aquarium Fishes*. TFH Publ.
- Mills D. 1981. *Aquarium Fishes*. Kingfisher Books.
- Sanford G and Crow R. 1991. *The Manual of Tank Busters*. Salamander Books.
- Saxena A. (Ed.). 2003. *Aquarium Management*. Daya Publ.
- Spotte S. 1979. *Fish and Invertebrate Culture*. John Wiley and Sons.
- Thabrow De WV. 1981. *Popular Aquarium Plants*. Thornbill Press.

I. Course Title : Computer Application In Aquaculture Dataprocessing

II. Course Code : AQC 512

III. Credit Hours : 0+1

IV. Aim of the course

To understand the scope on the computer application in the aquaculture process flow and systems

V. Practical

Computer application basics; Different common software installation and application; Identification of farm based software; Installation and application; Application of SPSS, SAS, SYSTAT and STATISTICA for analysis and presentation of fisheries data; Basic concepts of database management systems: Introduction to MS-ACCESS, ORACLE (RDBMS); Exercise on analysis of data using MS-EXCEL, SPSS, SAS, FISAT, SYSTAT and STATISTICA; Creation of Database using MS-ACCESS, ORACLE, Linear modelling of Feed formulation software installation and use.

VI. Suggested Reading

- Cody RP and Smith JF. 1997. *Applied Statistics and SAS Programming Language*. Elsevier.
- Economics of vertical integration in hybrid striped bass aquaculture, in *Aquaculture: Models andEconomics* (Ed.) U. Hatch and H. Kinnucan, Boulder: Westview Press, pp. 91-105.
- FAO. 2018. *The State of World Fisheries and Aquaculture -Meeting the sustainable development goals*. Rome.
- Griffin, W.L., Hanson JS, Brick RW and Johns MA. 1981. Bioeconomic modelling with stochastic elements in shrimp culture. *J. World Maric. Soc.* 12: 94-103.
- Griffin, W.L., Jensen LA and Adams C.M. 1983. A generalized budget simulation model for aquaculture. TAMU-SG-83-202, Texas A and M University, 131 pp.
- Haakanson, L. and Wallin M. 1991. Use of ecometric analysis to establish load diagrams for nutrients in coastal areas, in *Marine Aquaculture and the Environment* (Ed.) T. Maekinen, pp. 9-23.
- Johnson, F.C. 1974. Hatch—a model for fish hatchery analysis.U.S. National Bureau of Standards, Washington, D.C. Report NBSIR 74-521, 51 pp.
- Landou S and Everitt BS. 2004. *A Handbook of Statistical Analyses Using SPSS*. Chapman and Hall/CRC.
- Lester, L.J., Perkins S and Wong BT. 1987. *Microcomputer use in aquaculture genetics*.
- Lee, P.G. 1993. *Computer Automation for Recirculating Aquaculture Systems*, in *Techniques for Modern Aquaculture* (Ed.) J. K. Wang, St. Joseph, Minnesota: American Society of Agricultural Engineers, pp. 61-70.
- Paulraj R. 1997. *Aquaculture Feed: Handbook on Aquafarming*. MPEDA Publ.

I. Course title : Inland Saline Aquaculture

II. Course code : AQC 513

III. Credit Hours : 1+1

IV. Aim of the course

To understand the scope for expanding aquaculture in inland saline waters for effective use

V. Theory

Unit I

Introduction: Inland saline waters, surface and ground water, Quality parameters of inland saline water in India, Global and national status of inland saline soils and underground saline water, Causes and process of salinization, geo-morphological changes, Problems of salinization, Potential for aquaculture.

Unit II

Soil and water characteristics: Comparison with coastal waters, Ionic amendment, water conditioning, Technological and engineering interventions for water quality improvement, Nutrient sparing and chelation in inland saline water.

Unit III

Potential candidate species: Sea bass, pearl spot, milk fish, mullet, shrimps, freshwater prawn, tilapia, cobia, pompano and selective carps for culture, Constraints and solutions, Alternate species with breeding possibilities, Metabolic interactions and growth promotion in altered water systems, Different farming systems.

Unit IV

Socio-economic Importance of Inland Saline Aquaculture: Nutritional intervention in inland shrimp farming; Economics of various finfish and shellfish culture in inland saline arenas; Integrated inland saline aquaculture systems; Recommendations for an action plan.

VI. Practical

Inland saline soil and water sample collection, analysis and ionic amendments, Visit to inland saline water farms, Case studies of inland saline farms, Evaluation of different systems with regard to species cultured, Trials with different species in known inland saline water bodies.

VII. Suggested Reading

- Boyd CE. 2000. *Water Quality: an Introduction*. Kluwer Academic.
- Burnell G and Allan G. 2009. *New Technologies in Aquaculture, Improving Production Efficiency, Quality and Environment Management*. Woodhead Publ.
- CIFE 2014. *Training Manual on Inland Saline Water Aquaculture Management Practices*.
- Garg SK and Arasu ART. 2003. *Proceedings of 3rd Interaction workshop, Fish Production using Brackishwater in Arid Ecosystem*.
- Pillay TVR and Kutty MN. 2005. *Aquaculture - Principles and Practices*. Blackwell.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Multilevel Integrated Aquaculture Systems

II. Course Code : AQC 514

III. Credit Hours : 1+1

IV. Aim of the course

To gain knowledge on advanced integration practices along with aquaculture for enhancing aquaculture production.

V. Theory

Unit I

Integrated fish farming: Global status, integration with agricultural (paddy), horticultural crops (vegetable and fruits) and livestock (cattle, poultry, ducks, pigs and other terrestrial animals). Effective recycling of wastes, nutrient budgeting in different integrated farming systems. Production levels and economics.

Unit II

Bioprocessed manures in integration: Vermicompost, farmyard manure/ compost, biogas slurry, etc. Advantages of biomanures, Control of microbial interactions, Fermentation of manures.

Unit III

Concepts: Integrated multitrophic aquaculture systems and design of an IMTA unit, Aqua tourism. Aquaponics: concept, Principles, types and operation, Multilateral interaction and reserve management.

Unit IV

Bio-resource flow in integrated aquaculture system: Discharge of nutrient wastes from integrated aquafarms; environmental effects, and potential for integrated multi-trophic aquaculture, An economic analysis of different integrated culture systems.

VI. Practical

Preparation of vermicompost; Analysis of nutrient value of different manures; Design of various integrated farming models; Different models of aquaponics; Nutrient analysis and management in aquaponics; Visit to integrated farms; Economics of different integrated systems with case studies.

VII. Suggested Reading

- Ahilan, B., Ravaneshwaran, K., Kumaravel, P., 2011. *Integrated Aquaculture*. Daya Publishing House.
- Little D, Edwards P. 2003. *Integrated Livestock-fish Farming Systems*. FAO Publ.
- Mathias JA, Charles AT and Baotong H. 1994. *Integrated Fish Farming*. CRCPress
- Pandey N and Davendra SM. 2008. *Integrated Fish Farming*. Daya Publ. House
- Sherman RL, Arancon NQ and Edwards CA. 2010. *Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management*. CRC Press.
- Soto D. 2009. *Integrated Mariculture a Global Review*. FAO Publ.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Cold Water Aquaculture and Recreational Fisheries

II. Course Code : AQC 515

III. Credit Hours : 1+1

IV. Aim of the course

To learn about the breeding and culture of different cold water fishes and their importance as sport fisheries or sport fish

V. Theory

Unit I

Introduction: Status of cold water fisheries in World with special reference to India, Biology, breeding and culture of trouts (*Oncorhynchus mykiss, Salmo truttafario, Schizothoraichthys esocinus, S. longipinnis, S. niger, Schizothorax richadsonii*), Mahseer (*Tor putitora, Tor tor, Tor khudree*), Common carp (*Cypinuscarpio cummuinis, Cyprinuscarpio specularis*). Specific environmental parameters pertaining to cold water fish culture and metabolic interaction, Feeds suitable for cold water aquaculture.

Unit II

Culture of coldwater fishes: Construction and management of coldwater fish farms, Effect of exotic fish introduction on indigenous fish fauna, Polyculture of exotic carps in mid hill region based on three Chinese carps, post-harvest and harvest issues in trouts with regards to cold water species, Special factors for consideration in cold water fish seed production and nursery rearing.

Unit III

Introduction to sport fisheries: Sports fishes and their life history, Equipments for sports fishing, fishing methods, area suitable for sports fishing, etc. Management

and conservation of sports fisheries through aquaculture, Sport fisheries and tourism, recreational aquaculture.

Unit IV

Issues and Desired Interventions: Potential and Innovative Strategies for the Development of Cold water Aquaculture in India- problems encountered in fisheries development of rivers supporting cold water fisheries.

VI. Practical

Identification of cold water fish species; Primary and secondary sexual characters in coldwater fishes; Different breeding methods for coldwater fishes; Identification of larval stages of trout and mahseer; Preparation of hatchery layout for coldwater fishes; Studies on different types of sports fishing equipment; Visit to cold water fish hatchery.

VII. Suggested Reading

- Boghen, A.D., 1989. Cold-water aquaculture in Atlantic Canada. Institut Canadien de recherche sur le developpement regional, Atlantic Coast, Canada
- ICAR. 2006. *Handbook of Fisheries and Aquaculture*.
- Jhingran VG and Sehgal KL. 1978. *Cold Water Fisheries of India*. J.Inland. Fish. Soc. India. Sp. Publ.
- Jhingran VG. 1991. *Fish and Fisheries of India*. 3rd Ed. Hindustan Publ.
- Mahanta, P.C., Sarma, D., 2010. *Coldwater Fisheries Management*. ICAR
- Singh, H.R. and Lakra, W.S., 2008. *Coldwater Aquaculture and Fisheries*. Narendra Publishing House.
- Singh AK, Sarma D, Akhtar, MS and Baruah D. 2017. Souvenir – National seminar on stratagies, innovations and sustainable management for enhancing coldwater fisheries and aquaculture. ICAR-DCFR, Bhimtal.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ.

I. Course Title : Recirculating Aquaculture Systems (RAS)

II. Course Code : AQC 516

III. Credit Hours : 1+1

IV. Aim of the course

To gain complete knowledge about the recirculating aquaculture systems and its recent developments

V. Theory

Unit I

Introduction: Evolution of intensive culture technologies, Need for intensification in aquaculture, Land and water constraints, Conflicts between enterprises for water use, Need for RAS, Current status and prospects of RAS in world with special reference to Asian countries.

Unit II

System engineering: Basic needs for the construction of RAS, Design of RAS, water re-use methods, Water budgeting, culture tanks, shape and size, Special features, waste solids removal, Cornell dual-drain system, Settling basins and tanks- design, Fabrication and construction, Water collection and sludge removal

Unit III

Filters: Mechanical filters, Biofilters- trickling towers, Floating bead filters, Fluidized sand beds, Down flow micro-bead biofilter, Moving bed bioreactors; aerators.

Unit IV

Management of RAS: Waste management, feeding management. Animal health management in RAS. Economic viability of RAS for various commercially important finfishes. Challenges in uplifting RAS practices.

VI. Practical

Species for RAS; Calculating stocking density of fishes in RAS; Determining the controlling flow rate; Calculating required design flow rate for DO; Calculating tank sizes; Feeding management in RAS; Waste water management in RAS; Visit to RAS units

VII. Suggested Reading

- Burnell G, Allan G. 2009. *New Technologies in Aquaculture*. 1st Edition. Woodhead Publishing House.
- Bregnballe J. 2015. *A Guide to Recirculation Aquaculture*. FAO Publ.
- Christenson K. 2014. *Aquaponics: Aquaculture – An Introduction to Aquaculture for Small farmers*.
- Davion A. 2018. *Recirculating Aquaculture Systems: a Guide to Farm Design and Operations*.
- Hendry lau. 2015. *Aqauculture Production system*
- Hughston M. 2015. *Hydroponics: Hydroponic Gardening And Growing Vegetables Without Soil*.
- Kaul SN, Juwarkar AS *et al*. 2002. *Utilization of Wastewater in Agriculture and Aquaculture*. Scientific Publishers.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley- Blackwell.
- Timmons MB, Guerdat, T, Vinci, BJ. 2019. *Recirculating Aquaculture*. Ithaca Publishing Comp.
- Yoram, A., 2015. *Biofloc Technology: a Practical Guidebook*. WAS Publ.

Course Title with Credit Load
Ph.D. in Aquaculture

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
AQC 601	Hi-tech Aquaculture Production Systems	2+1
AQC 602	Seed Production and Hatchery Management	2+1
AQC 603	Aquaculture Ecosystem Management and Climate Change	2+1
AQC 604	Fish and Shellfish Physiology and Endocrinology	2+1
	Minor Courses (From the subjects closely related to a students major subject)	**6 Credits**
AQC 605	Feed Management in Aquaculture	1+1
AQC 606	Applied Biotechnology in Aquaculture	1+1
AQC 607	Automation in Aquaculture Systems	1+1
AQC 608	Aquaculture Medicine	1+1
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	**5 Credits**
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
AQC 691	Doctoral Seminar-I	0+1
AQC 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 Credits**
AQC 699	Doctoral Research (Semester II)	0+5
AQC 699	Doctoral Research (Semester III)	0+15
AQC 699	Doctoral Research (Semester IV)	0+15
AQC 699	Doctoral Research (Semester V)	0+20
AQC 699	Doctoral Research (Semester VI)	0+20
	Total Ph.D Program Credit Hours	100 Credits

Course Contents
Ph.D. in Aquaculture

I. Course Title : Hi-tech Aquaculture Production Systems

II. Course Code : AQC 601

III. Credit Hours : 2+1

IV. Aim of the course

To learn the advanced aquaculture production system research for different species globally

V. Theory

Unit I

Introduction: An overview of global aquaculture production, demand- consumption scenario and emerging trends, Present status, Constraints and future prospects in India and the world, Aquaculture practices indifferent parts of the world, Enhancing carrying capacity in culture systems.

Unit II

Biofloc technology: Principles of biofloc, Different carbon sources, Design of aeration system and biofloc reactor, Carrying capacity, C: N ratio, harvesting of biofloc, Biofloc quality and quantity, Biofloc as feed ingredient, Stocking of fish and shellfish species. Bioremediation in wastewater aquaculture.

Unit III

Minimal water exchange aquaculture systems: Principles of closed system farming, RAS, Components, design of mechanical and biological filters for the water reuse system, Sludge removal, disposal of wastes and control of pollution to the environment, Design of RAS, biofiltration and nitrifiers, Suitable cultivable species for indoor culture systems, polyhouses.

Unit IV

Aquaponics: Principles, Components and design of different aquaponics systems, Components in aquaponics, ratio of fish and plants, Water quality and system maintenance, Resource utilization, Nutrient recycling and zero discharge of nutrients.

Unit V

Running water systems: Flow-through system, Raceways (IPR), IMTA, Partitioned Aquaculture Systems (PAS), Aquamimicry systems.

Unit VI

Other farming methods: Cluster farming, Organic farming, Satellite farming, co-operative farming and conservation aquaculture, Network of production and marketing aspects, Economics of super intensive farming systems, Advantages and disadvantages.

VI. Practical

Design, fabrication and performance evaluation of biofloc systems; Different equipment in closed grow-out system; Aerators, Biofilters, RAS, Raceways, IMTA, PAS and aquaponics systems; Plankton and microbial analysis of biofloc. Studies on different C: N ratio; Nutrient analysis in aquaponics; Visit to hatcheries with super-intensive models. Identification and understanding the network of the systems; Market analysis for the produces; Analysis of economic advantages, case studies

VII. Suggested Reading

- Avnimelech Y. 2015. *Biofloc Technology- a Practical Guidebook*. 3rd edition. World Aquaculture Society
- Chakrabarti NM. 2014. *Biology, Culture and Production of Indian Major Carps*.
- Felix S. 2008. *Biosecured Aquaculture- Principle and Prototype*. Agrobios (India)
- Soderberg RW. 1995. *Flowing Water Fish Culture*. Lewis Publishers.
- Tidwell JH. (Ed.). 2012. *Aquaculture Production Systems*. Wiley-Blackwell.

I. Course Title : Seed Production and Hatchery management

II. Course Code : AQC 602

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge in the latest research in seed production methods for finfishes and shellfishes along with hatchery management technology.

V. Theory

Unit I

Reproductive biology: High value cultivable fishes, Crustaceans and molluscs. Reproductive behaviour of fishes, Sex determination, Anatomy and morphology of reproductive organs, Gametology and factors influencing the gamete quality.

Unit II

Broodstock management: Factors affecting the maturation and spawning of cultivable finfishes and shellfishes, Nutritional and environmental requirement for brood stock and their manipulation for early maturation, Criteria for the selection of brood stock, selective breeding strategies, Tagging, Transportation of broodstock, Natural and synthetic anaesthetics for transport, Vaccines and therapeutics for health management of brood stock, Brood stockquality determination and hormonal dynamics.

Unit III

Induced Spawning: Inducing agents, Factors behind the development of inducing agents, Analogues development, Comparative evaluation of commercially available inducing agents, Artificial insemination in crustaceans and molluscs; cryopreservation of gametes and embryos in finfishes and shellfishes, Artificial fertilization protocols.

Unit IV

Larval Nutrition: nutritional requirement of larvae and post larvae, live food culture, nutritional enrichment of live food organisms, different live feed products like powdered algae, algal paste, micronized algae, vitamin fortified algal products, formulation of artificial diets.

Unit V

Hatchery management: Water quality management in hatcheries; physico-chemical and biological approaches; Strategies to control diseases in hatcheries, Diagnosis, quarantine procedure, Prebiotics, Probiotics use in hatcheries, Seed quality testing methods and seed certification, Use of immunostimulants and immune modulators in hatcheries, SPF and SPR, Effluent treatment in hatcheries, Seed transportation methods.

Unit VI

Seed production and hatchery technology: Advances in seed production of commercially important finfishes and shellfishes, Artificial propagation of seaweeds (tissue culture), Recent technologies for enhancing survival and growth in nurseries, Nursery technology for different finfishes and shellfishes, Legal issues in seed quality and marketing.

VI. Practical

Determination of brood stock quality; Quantitative and qualitative determination of fish gametes like sperm motility, viability, counts; Cryopreservation of fish and shellfish gametes; Artificial fertilization in fishes; Project preparation for constructing hatchery (freshwater fish, marine fish, shrimp, molluscs); Broodstock quarantine in hatcheries; Live feed culture; Methods to identify quality of seeds (stress test, microscopic examination); Water quality management in hatcheries; Disease identification and treatment in hatcheries; Visit to hatcheries.

VII. Suggested Reading

- Allan, G. and Burnell, G. 2013. *Advances in Aquaculture Hatchery Technology*. Woodhead Publishing Limited.
- Betsy, C.J. and Kumar, J.S.S. 2017. *Cryopreservation and Spermatology in Fishes*. Narendra Publishing House.
- Betsy, C.J. and Kumar, J.S.S., 2017. *Biotechnological Applications in Fish Seed Production*. Narendra Publishing House.
- Diwan, A.D., 2018. *Biotechnology of penaeid shrimps*. Narendra Publ.
- FAO. 1992. *Manual of Seed Production of Carps*. FAO Publ.
- Elsa Cabrita, Vanesa Robles, Paz Herraez, 2015. *Methods inReproductive Aquaculture*.
- Gjedrem, T. and Baranski, M., 2009. *Selective Breeding in Aquaculture: an Introduction*. Springer.
- Gjedrem, T. (Ed.)., 2005. *Selection and Breeding Programs in Aquaculture*. Springer.
- Gupta SD, Mohapatra PC, Routray P, Sahoo SK, Verma DK, Sarangi N. 2008. *Textbook of Breeding and Management of Carps*. Narendra Publ. House
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer.
- ICAR. 2006. *Hand Book of Fisheries and Aquaculture*. ICAR.
- Jhingran VG and Pullin RSV. 1985. *Hatchery Manual for the Common, Chinese and Indian Major Carps*. ICLARM, Philippines.
- Muthu MS. 1983. *Culture of Live Feed Organisms*. Tech. Paper 14.Summer Institute in Hatchery Production of Prawns Seeds. CMFRI, Cochin.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ.

I. Course Title : Aquaculture Ecosystem Management and Climate Change

II. Course Code : AQC 603

III. Credit Hours : 2+1

IV. Aim of the course

To learn the impact of aquaculture on ecosystem management and climate change effects.

V. Theory

Unit I

Aquaculture and ecosystem relationship: Ecosystems and productivity, Biotic interaction within ecosystems and ecological homeostasis, Climate; Weather elements of concern in aquaculture, Greenhouse gases, Global warming and their impact.

Unit II

Impact of environment on aquaculture: Raw water source, Physical and chemical characteristics, Contaminants and pollutants (algae, pathogens, heavy metals, pesticides) and their effect on productivity.

Unit III

Impact of aquaculture on environment: Waste water discharge, Its quality and quantity, Impacts of effluents on ecosystems, Chemical degradation of soil and water.

Unit IV

Environment monitoring: Problems and preventive measures of antibiotic and drug residues, Salinization of soil and water, Eutrophication, Environment impact assessment and environmental audit.

Unit V

Sensor based monitoring: Biosensors in aquatic environment, Toxicity assessment, eco-labeling and traceability, Environment management.

Unit VI

Environment threats: Introduction of exotics and escape of farmed fish, Pathogens in aquatic environment, Safety of aquaculture products, Role of microbes in aquatic environment, Assessment of probiotic impact in aquaculture.

VI. Practical

Waste water analysis, Toxicity assessment studies; Eco-labelling and traceability, Isolation, nutrients budgeting, Quantification and administration of solid and liquid doses, Physical and chemical characteristics of soil, Design and construction of effluent treatmentplant.Carbon credit/ budgeting.

VII. Suggested Reading

- Black KD. 2001. *Environmental Impacts of Aquaculture*. CRC Press.
- Holmer M, Black K, Duarte CM, Marba N and Karakassis I. (Eds.). 2008. *Aquaculture in the Ecosystem*. Daya Publ. House.
- Midlen, A. and Redding, T., 1998. *Environmental Management for Aquaculture*. Chapman and Hall.
- Mischke, C.C., 2014. *Aquaculture Pond Fertilization - Impacts of Nutrients Input on Production*.

- Mustafa, S. and Shapawi, R. (Eds.), 2015. *Aquaculture Ecosystems- Adaptability and Sustainability*. Wiley Blackwell.
- Phillips BF, Ramirez, M.P. (Eds.), 2018. *Climate Change Impacts on Fisheries and Aquaculture- a Global Analysis*. Vol. I. Wiley Blackwell.
- Rajagopalsamy CBT and Ramadhas V. 2002. *Nutrient Dynamics in Freshwater Fish Culture System*. Daya Publ.
- Saha, R.K., 2013. *Soil and Water Quality Management for Sustainable Aquaculture*.
- Sharma LL, Sharma SK, Saini VP and Sharma BK. (Eds.). 2008.*Management of Freshwater Ecosystems*. Agrotech Publ. Academy.

I. Course Title : Fish and Shellfish Physiology and Endocrinology

II. Course Code : AQC 604

III. Credit Hours : 2+1

IV. Aim of the course

To gain knowledge on finfish and shellfish endocrinology and physiological aspects.

V. Theory

Unit I

Endocrine system: Endocrine glands in fishes, Hormones and their kinetics, Structure and function of neuro-endocrine system in finfish and shellfish, Hormonal control of physiology.

Unit II

Hormones: Chemical nature of hormones, synthesis, storage, Release and control of hormones, Homeostasis, Endocrine control of growth and metabolism in fishes, Exogenous hormone administration, Implication, Impact on the general health and wellbeing of fishes.

Unit III

Influence of hormones: Eco-physiology, Adaptive mechanisms - reversible and irreversible changes, Physiology of migration and behaviour.

Unit IV

Neurophysiology: Neurosecretory system in fishes, Crustaceans and molluscs, Neurotransmitters, Physiology of ecdysis.

Unit V

Reproductive physiology: Endocrine control of maturation, spermatogenesis, oogenesis, spawning vitellogenesis.

Unit VI

Respiratory physiology: Gas exchange concept, Excretion and osmoregulation.

VI. Practical

Dissection of finfish and shellfish to study endocrine glands, Hormone assay – ELISA, Histological techniques to study reproductive and endocrine glands, Identification of moult stages, Application of respirometer and osmometer.

VII. Suggested Reading

- Babin PJ, Lubzens E. 2007. *The fish oocyte: from basic studies to biotechnological applications*. Springer Publ.
- Bernier NJ, Van Der Kraak G, Farrrell AP, Brauner CJ. 2014. *Fish neuroendocrinology*.

Fish physiology series Vol. 2, Elsevier Publ.
- Diwan AD. 2018. *Biotechnology of penaeid shrimps*. Narendra Publ.
- Farrell AP 2011. *Encyclopedia of fish physiology* Vol. I-III. Academic Press.
- Hara TJ and Zielinski BS. 2014. *Sensory systems neuroscience*. Fish physiology series Vol. 25, Elsevier Publ.
- Hoar WS and Randall DJ. 2014. *Fish Physiology* Vol. The Endocrine System. Academic Press
- Hoar WS, Randall DJ and Donaldson EM. 2014. *Fish Physiology* Vol. 9 A Reproduction: Endocrine Tissues and Hormones. Academic Press
- Hoar WS. 2014. Fish Physiology Vol. 9B. Academic Press
- Hoar WS and Randall DJ. 2014. *Fish Physiology* Vol. 4 The Nervous System, Circulation and Respiration. Academic Press
- Modayil MJ and Diwan AD. 2007. *Physiology of marine white shrimp Fenneropenaeusindicus*.
- Norris DO and Lopez KH. 2011. *Hormones and Reproduction of Vertebrates*. Vol. I Fishes. Academic Press.
- Perry SF, Tufts BL. 2014. *Fish respiration, Fish physiology* series, Vol. 17. Elsevier Publ.
- Reinecke M, Giacomo S, Kapoor BG. 2006. *Fish Endocrinology*. CRC Press.
- Samantaray K. 2015. *Physiology of finfish and shellfish*. New India Publ. Agency
- Shashikala KB, Sahoo AK. 2018. *Histology of Indian Major Carps* - A Colour Atlas.
- Sherwood NM and Hew CL. 2014. *Fish Physiology* Vol. 13. Molecular Endocrinology of fish. Academic Press

I. Course Title : Feed Management in Aquaculture

II. Course Code : AQC 605

III. Credit Hours : 1+1

IV. Aim of the course

To learn the latest research in the lines of understanding the influence of environment on nutrient utilization

V. Theory

Unit I

Nutrient dynamics: Influence of nutrient cycles on web/chain, Influence of detrital food web on nutrient distribution, Nutrient loading through feed and fertilizer, Natural feed augmentation for increasing fish production, Different food chains in aquatic ecosystem, Feeding behavior and feeding niche, Effect of environmental parameters on appetite of fish.

Unit II

Eco-friendly feed: Use of exogenous phytase and acidifiers, high energy diets, methods of enhancing feed digestibility, biofloc and probiotics influences.

Unit III

Nutritional pathology: Deficiency and imbalance diseases: essential amino acids, essential n-3 and n-6 fatty acids deficiencies, Micronutrients: fat-soluble vitamins, water-soluble vitamins; Macro- elements, trace-elements and mineral toxicity, Influence of stress on feed intake, Digestion and absorption, Stress indicator and nutritional strategies for mitigate stress.

Unit IV

Feed Management: Impact of feed and nutrition on environment, Nutrients affecting the water quality, Nutritional strategies to reduce the nutrient flow in

aquaculture system, Contribution of feed waste to organic load of aquaculture production systems, Role of additives in reducing environmental pollution.

VI. Practical

Practical Study of influence of thermal stress, Hypoxia, Salinity and pH, Stress enzyme. (LDH, catalase, SOD, glutathione peroxidase), Stress hormone (Cortisols) and sex steroid hormone.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed Technology. ADCP/REP/80/11. F.A.O., Rome.
- De Silva, S. S. and Anderson, T. A. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver, J. E. 1989. *Fish Nutrition*, Academic Press, San Diego, California.
- Halver, J. E and Tiews, K. T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver, J. E. and Hardy, R. W. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher, B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell, R. T. 1998. *Nutrition and Feeding of Fishes*. KluwerAcademic Publishers.

I. Course Title : Applied Biotechnology in Aquaculture

II. Course Code : AQC 606

III. Credit Hours : 1+1

IV. Aim of the course

To learn about applied biotechnology aspects in aquaculture.

V. Theory

Unit I

Introduction: Scope of biotechnology in fisheries and aquaculture research. Vaccination in fishes- DNA vaccines, sub Unit Vaccines and Biofilm Vaccines.

Unit II

Feed biotechnology: Probiotics, single cell proteins, Neutraceuticals, Gnotobiotics. Recombinant proteins of commercial importance: enzymes, hormones, bioactive compounds, therapeutic proteins. Anti- microbial Peptides and their applications.

Unit III

Environmental Biotechnology: Bioremediation, biosensors, biofouling, treatment of waste water, Applications of biotechnological tools: Transgenic technology, Recombinant DNA, Monoclonal antibodies, Cell lines and stem cell culture, DNA markers and MAS, Biotechnological instrumentation in Aquaculture.

Unit IV

Constraints and Limitations: Biochemical and Molecular Markers; Commercial applications of Fish Biotechnology; Government regulation of Transgenic fish and Biotechnology products.

VI. Practical

Cell culture and cell lines; Development of hybridoma and production of monoclonal antibodies; Preparation of chromosomes from embryos and young fish Ploidy

determination by RBC measurement and chromosome numbers; DNA markers; Gene transfer experiments; Northern blotting and southern blotting for integration and expression of transgenes.

VII. Suggested Reading

- Betsy CJ and Kumar JSS. 2017. *Biotechnological applications in fish seed production*. Narendra Publishing House.
- Diwan AD. 2018. *Biotechnology of penaeid shrimps*. Narendra Publ.
- Felix S and Ninawe AS. 2014. *Aquariculture Biotechnology*. Daya Publishing House.
- Fletcher GL, Rise ML. 2012. *Aquaculture Biotechnology*. Wiley Blackwell.
- Gautam NC. 2007. *Comprehensive Biotechnology*- Vol. 4 Aquaculture Biotechnology. Shree Publishers and Distributors
- Greglutz C. 2001. *Practical genetics for aquaculture*. Wiley Blackwell Publ.
- LakraWS, Abidi, SAH, Mukherjee, SC, Ayyappan S. 2014. *Fisheries biotechnology*.
- Montet D and Ray RC. 2009. *Aquaculture Microbiology and Biotechnology*. Vol. 1. Science Publishers.
- PreethiKartan, 2017.*Aquaculture Biotechnology*
- Richard Reece, 2017. *Analysis of genes and genomes*.
- Se-Kwon Kim, 2017. *Springer handbook of marine biotechnology*.
- Sunita R. 2015. *Fish Biotechnology*. Random Publications.

I. Course Title : Automation in Aquaculture Systems

II. Course Code : AQC 607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the possible automation in aquaculture systems for efficient management and enhanced income

V. Theory

Unit I

Introduction: Automation principles and procedures, Economic benefits of automation, Comparison of automation in agriculture and allied enterprises, History of automation in aquaculture, Scope for automation and need for automation in aquaculture, Evolution of machines and mechanisation in aquaculture, Advantages and disadvantages of automation, Current status and prospects of automation in World and India.

Unit II

Artificial Intelligence: Definition and application of AI in aquaculture, operating systems, system architecture, modules, AI software and its characteristics; AI in aquaculture, advantages of AI

Unit III

Robotics in aquaculture: Scope for Robotics in aquaculture, ROV, AUV, Drones, ASV, Automation for water quality management and health management in aquaculture, Novel automated systems in the world, technologies in aquaculture.

Unit IV

Software's used in Automation: Use of data acquisition systems in aquaculture. Biological models related to automatic control in aquaculture; Artificial intelligence

software focuses on niche markets, A plug-and-play machine vision application for aquaculture.

VI. Practical

Automated systems description and application; Preparation of automation plans for individual systems; Robotics systems and application modules preparation; Drones and their utilization; Energy monitoring systems design and use; Trial automation in any one system.

VII. Suggested Reading

- Balchen, J.G. (Ed), 1986. *Automation and Data Processing in Aquaculture: Proceedings of the IFAC Symposium*, Trondheim, Norway, 18-21 August 1986 (Ifac Symposia Series) 1st Edition
- https://www.ntnu.edu/documents/919518/18708867/Giancarlo+Marafioti+NTNU+kybernetikk+ (uten+film).pdf
- https://www.eolss.net/Sample-Chapters/C18/E6-43-35-05.pdf
- https://www.sciencedirect.com/science/article/pii/014486099400 002I
- https://pdfs.semanticscholar.org/ae37/7b22085fbb6b975855f5f3 426c2357294be9.pdf
- http://ijsrcseit.com/paper/CSEIT172254.pdf
- Unbehauen, H.D., 2009. *Control Systems, Robotics And Automation*–Volume XIX: Industrial Applications of Control Systems-II. EOLSS Publications.

I. Course Title : Aquaculture Medicine

II. Course Code : AQC 608

III. Credit Hours : 1+1

IV. Aim of the course

To understand the pharmacokinetics of aquaculture drugs and chemicals

V. Theory

Unit I

Anaesthetics: Anaesthetics and methods of anaesthetizing fish and shellfish.

Unit II

Amendments in Aquaculture: Different chemicals and drugs used in aquaculture and dosages, Use of probiotics and immunostimulants in aquaculture

Unit III

Drug Mechanism: Action of different drugs in finfish and shellfish.Bioaccumulation and toxicity

Unit IV

Antibiotics: Antibiotics – use and misuse including development of antibiotic resistant bacteria and their impact on environment and human health

VI. Practical

Antibiotic sensitivity test, Estimation of dose, Estimation of antibiotic residues, Detection of gut colonization by probiotic bacteria

VII. Suggested Reading

- Andrews C, Excell A and Carrington N. 1988. *The Manual of Fish Health*. Salamander Books.
- Brunton LL. (Ed). 2005. *Goodman and Gilman's. The Pharmacological Basis of Therapeutics.* 11th Ed. McGraw-Hill.

- Riviere JE and Papich MG. (Eds.). 2013. Veterinary pharmacology and therapeutics 9th ed. John Wiley and Sons.
- Sandhu HS and Rampal S. 2006. *Essentials of Veterinary Pharmacology and Therapeutics*. 1st Ed. Kalyani Publishers.
- Treves-Brown KM. 2013. *Applied Fish Pharmacology* (Vol. 3). Springer Science and Business Media.

List of Suggested Journals

- *Aquaculture*
- *Aquacultural Engineering*
- *Aquaculture International*
- *Aquaculture Nutrition*
- *Aquaculture Research*
- *Reviews in Aquaculture*
- *Aquaculture Economics and Management*
- *Journal of the World Aquaculture Society*
- *Journal of Fish Diseases*
- *Fisheries Science*
- *Fisheries Research*
- *Fish and Fisheries*
- *Fish and Shellfish Immunology*
- *Fisheries Management and Ecology*
- *FEMS Microbiology Ecology*
- *FEMS Microbiology Letters*
- *Current Science*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *British Journal of Environment and Climate Change*
- *Biotechnology Letters*
- *Asian Fisheries Science*
- *Asian Journal of Animal Sciences*
- *Aquatic Sciences*
- *Aquatic Toxicology*
- *African Journal of Aquatic Science*
- *Turkish Journal of Fisheries and Aquatic Sciences*
- *Indian Journal of Animal Nutrition*
- *Journal of Fish Physiology and Biochemistry*
- *Journal of Applied Icthyology*
- *Journal of Aquaculture in Tropics*
- *Journal of Aquatic Living Resources*
- *Journal of Biotechnology*
- *Journal of Fish Physiology and Biochemistry*
- *Annual Review of Nutrition*
- *Annual Review of Physiology*
- *Journal of Plankton Research*
- *Water Research*
- *World Journal of Microbiology and Biotechnology*
- *Ecotoxicology and Environmental Safety*
- *Environment and Ecology*
- *Environmental Pollution*
- *Environmental Science*
- *Environmental Studies*
- *Environmental Technology*
- *Environmental Toxicology*
- *Indian Journal of Agricultural Statistics*
- *Indian Journal of Cytology and Genetics*

- *Indian Journal of Genetics and Plant Breeding*
- *Indian Journal of Statistics*
- *Journal of Animal Breed and Genetics*
- *Journal of Animal Science*
- *Journal of Applied Statistics*
- *Indian Journal of Fisheries*
- *Indian Journal of Experimental Biology*
- *Indian Journal of Entomology*
- *Indian Journal of Animal Research*
- *Indian Journal of Animal Sciences*
- *Journal of Statistical Software*
- *Journal of Statistics Education*
- *Indian Journal of Agricultural Economics*
- *Indian Journal of Agricultural Marketing*
- *Indian Journal of Pharmacology*
- *International Journal for Parasitology*
- *Journal of Applied Microbiology*
- *Journal of Aquatic Animal Health*

List of suggested e-Resources

- https://www.icar.org.in/
- http://www.fao.org/home/en/
- https://www.worldfishcenter.org/
- http://epubs.icar.org.in/ejournal/
- https://lib.icar.gov.in/full_text_ebooks.html
- https://lib.icar.gov.in/Open_Access_Journal.html
- https://www.aquaculturealliance.org/
- https://www.sciencedirect.com/
- http://www.ciba.res.in/
- http://www.cmfri.org.in/
- http://www.cife.edu.in/
- http://cifa.nic.in/
- http://www.nbfgr.res.in/ http://www.dcfr.res.in/
- http://www.cift.res.in/
- http://www.tnjfu.ac.in/
- https://www.was.org/
- https://www.asianfisheriessociety.org/
- https://www.aquaeas.eu/
- https://www.curtin.edu.au/
- https://www.tp.edu.sg/
- https://www.arizona.edu/
- https://mpeda.gov.in/MPEDA/
- http://dof.gov.in/
- http://www.caa.gov.in/
- http://www.fao.org/fishery/statistics/en
- http://kufos.ac.in/
- http://www.auburn.edu/
- https://www.stir.ac.uk/
- https://www.ugent.be/en

Suggested Broad Areas for Master's and Doctoral Research

- Recirculating aquaculture systems (RAS)
- Development of genetically improved broodstock
- Cryopreservation of gametes and embryos
- Development of vaccines for larvae

- Renewable energy in aquaculture
- Replacement of fish meal ingredient in shrimp and fish feed
- Development of novel feed ingredients
- Ontogeny of digestive system in fish larvae
- Cell lines and stem cell culture
- Inland saline aquaculture
- Dessert Aquaculture
- Arid land aquaculture
- Defense mechanisms and immunity
- Cage and pen culture of marine finfishes
- Study of nutrient dynamics in ponds
- Nutraceuticals for aquaculture feed
- Impact of climate change in aquaculture
- Statistical tools in Aquaculture
- Microbiomes in host environment interactions
- Status of seafood consumption and promotion
- Climate resilient aquaculture
- Carrying capacity and environmental impact in aquaculture
- Development of high resistant materials in the fabrication of cages
- Designing the cost effective probes for the water management
- Automation in aquaculture
- Development or restructuring of the aquaculture systems
- Integration of ANNAMOX nitrogen removal
- Nitrogen removal using Heterotrophic bacteria
- Algal culture and its impact in aquaculture systems
- Development of innovative and advanced filters and sludge units
- Open Ocean Aquaculture
- Aquaponics
- Open water IMTA and land-based IMTA
- Breeding and seed production of new candidate species
- Natural history of the cultured animal throughout its life stages.
- Biology of the cultured animal in terms of an aquaculture perspective
- The management of microbiome in the gut of the fish
- Novel and rapid diagnostic methods for the emerging diseases of commercial importance in Aquaculture
- Hi-Tech Aquaculture systems
- Quality control in feed and feed supplements
- Nutritional requirement of commercially important fishes
- Precision farming in Aquaculture
- Development of Phytogenic compounds to combat the diseases
- Electron-beam irradiation for the major deactivation of anti-nutritional factors.
- Supplementation of Exogenous enzymes to remove anti-nutritional factors
- Supplementation of nutraceuticals in mitigating multiple stressors
- The stress management strategies of super intensive culture
- The Nutrigenomic studies involving transcriptomics, proteomics and metabolomics
- Evaluating flesh quality using different feed supplements.
- Altering the dietary protein/energy ratio to increase the product shelf life.
- Integration of proteomic approaches with genomics and transcriptomis is the need of the hour.
- Bioinformatic capabilities to integrate omics technologies with aquaculture.
- Germplasm study and the analysis of the genetic diversities
- Larval fish nutrition
- Impact of aquaculture amendments
- Organic aquaculture
- Impact of Algal driven aquaculture

- Soil and water quality management
- Functional feed ingredient supplements in aquaculture
- Physiology of the major organs in finfishes and shellfishes
- Gene expression on growth stimulating factors in fishes
- Induce breeding and sex reversal
- Bioremediation and waste management
- Importance of fermentation and fermented products in aquaculture
- Micro and trace minerals requirements for the commercial candidate species
- Development of phyto sanitary measures and Standard operating procedures
- Disease surveillance, forecasting and development of field level diagnostic kits.
- Pigment enhancement studies in Ornamental aquaculture
- Hybridization of cultivable species
- Participatory aquaculture development models
- Control of cyanobacteria in aquaculture systems
- Bio-enrichment of live feed
- Microscopic studies on the microbial community
- Pharmacodynamics of drugs in fish, drug delivery systems, excretion of drugs, residual assays, herbal compounds as therapeutic drugs
- Characterization of parasites infecting fish and shellfish
- Host-parasite relation of various parasites and their biology
- Therapeutic approaches for control of infections
- Histopathological investigations of specific disease conditions
- Economic analysis of aquaculture practices
- Development of tissue specific cell expression systems
- Genetically engineered microorganisms for recombinant protein production
- Design of viral vectors for efficient gene delivery
- Digestibility due to plant to animal ingredient ratio
- Enhancement of digestibility of plant feed ingredients

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fisheries Resource Management

Preamble
(Fisheries Resource Management)

Fisheries is one of the important and fast growing sector in the country which is 1.28% of the national GVA and 7.28% of the Agricultural GVA. It provides livelihood to more than 25 million fishers and fish farmers.

With a coastal length of over 8, 000 km, an EEZ of around 2.02 million sq. km and with vast freshwater resources, fisheries play a vital role. It generates employment for a large coastal and other population, raises nutritional standards, increases food supply and earns foreign exchange. The marine fish landings stood around 3.56 million tonnes (CMFRI, 2019). Due to increasing the demand for the fisheries, fishing vessels are increased drastically to capture these protein rich resources. Unlike mineral resources, fisheries resources are self-renewable if it is properly managed.

During recent years, production from capture fisheries has been stagnating. Unregulated access to these fisheries resulted in significant overcapacity, especially of medium and small trawlers that compete over dwindling fishery resources with mostly impoverished small-scale fishers. The fishery resources are affected due to overexploitation in shore waters, bycatch, habitat alteration and anthropogenic actives. While it is difficult, if not impossible, to regenerate and improve open water fisheries, even small improvements in average yield would significantly enhance national fish production, because of the large extent of open water resources. Hence, it is necessary to recognize appropriate conservation and management measures to improve and sustain production. These resources should be sustainably managed and protected for the following reasons.

- Sustain, protect and increase national seafood supply
- Maintain and improve subsistence fishing
- Protect ecosystem health and sustainability
- Create jobs, support related economic and social benefits, and sustain community resilience

In the absence of a database on standing stocks, catch statistics, gear selectivity, fish behaviour, etc. of both inland and marine stocks, and oceanographic parameters, it would not be possible to come up with any management solutions for conservation of depleting stocks and increased exploitation of underexploited stocks.

Strenuous efforts are needed at central and state levels to upgrade the country's capacity to manage its natural fisheries resources. In this regard, the fisheries resource management discipline will provide the basis for the conservation and management of fisheries resources and it stems from the biological characteristics. According to the FAO definition fisheries resource management is the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives.

To undertake these tasks, it is essential to understand the fisheries resource through proper education in the field of fisheries resources and its management. The following

reasons substantiate the education and research in fisheries resource management.

- To study the biodiversity and biology of threatened and commercially important finfish and shellfishes
- To provide an insight into the various coastal and inland resources, multi user issues and anthropogenic effects on the resources and to devise resource management plans and protect the coastal and inland resources.
- To know the present level of exploitation of marine resources through stock assessment and biodiversity studies and to impart knowledge on conservation measures
- To advance the research on the reproductive endocrinology of threatened and commercially important finfish and shell fishes
- To judiciously exploit fishery resources
- To establish management measures to prevent overfishing, allocate fishing quotas to different fishing groups, implement gear restrictions, and protect sensitive habitats.
- To comply national and international treaties, act and rules
- To meet the sustainable development goals 2, 3, 4, 12, 13 and 14

Accordingly, the syllabus for Fisheries Resource Management is evolved as a multi-disciplinary PG program of study that provides exposure to all dimensions of modern fisheries resource management. This will empower the graduates to take management decisions for sustainable exploitation of national or regional fisheries and achieve the Sustainable development goals.

The following new courses were introduced at Master's level:

1. *FRM 501 Sustainable Fisheries Management	2+1
2. *FRM 503 Climate Change and Fisheries Resource	2+1
3. *FRM 505 Trophodynamics in Aquatic Systems	2+1
4. *FRM 506 Reproductive Biology of Finfish and Shellfish	2+1
5. FRM 509 Bio Systematics of Aquatic Fauna	1+2
6. FRM 512 Advanced Fish Anatomy and Physiology	2+1
7. FRM 513 Fish Histology and Histochemistry	1+1
8. FRM 514 Field techniques in Fisheries Resource Management	0+2

The following courses were suitably revised to study the biodiversity and stock.

1. *FRM 502 Fish Biodiversity and Conservation Biology	2+1
2. *FRM 504 Fish Stock Assessment	2+1
3. *FRM 507 Developmental Biology of Finfish and Shellfish	1+1
4. *FRM 508 Modern Techniques in Fisheries Biology	2+1

The following courses were removed.

1. FRM 505 Fisheries Regulations	2+1
2. FRM 506 Remote Sensing and GIS for Fisheries Management	1+1
3. FRM 50 Integrated Coastal Zone Management	2+1
4. FRM 508 Aquatic Floral Resources	2+1
5. FRM 511 Fishing and Allied Technologies	2+1

At Ph.D. level the following new courses were introduced:

- FRM 603 Functional Physiology of Fishes (2+1)
- FRM 604 GIS Use in Fisheries Resources (2+1)
- FRM 605 Fisheries Legislations, Governance and Treaties (1+1)

The following two courses were suitably revised. Software based course is introduced to derive exploitation status of the fish stock.

- FRM 601 Fisheries Resource Conservation and Restoration Biology (2+1)
- FRM 606 Software Applications in Fish Stock Assessment (1+1)

The following three courses were removed as the subjects overlap with related disciplines:

- FRM 602 Applications of Fisheries Models in Stock Assessment (2+1)
- FRM 605 Data Collection and Estimation of Exploited Fisheries Resources (0+2)
- FRM 606 Fisheries Environmental Assessment (2+1)

Course Title with Credit Load
M.F.Sc. in Fisheries Resource Management

Course Code	Course Title	Credit Hours
	Major courses	
FRM 501	Sustainable Fisheries Management	2+1
FRM 502	Fish Biodiversity and Conservation Biology	2+1
FRM 503	Climate Change and Fisheries Resource	2+1
FRM 504	Fish Stock Assessment	2+1
FRM 505	Trophodynamics in Aquatic Systems	2+1
FRM 506	Reproductive Biology of Finfish and Shellfish	2+1
FRM 507	Developmental Biology of Finfish and Shellfish	1+1
	Minor courses (From the subjects closely related to a student's major subject)	**8 Credits**
FRM 508	Modern Techniques in Fisheries Biology	2+1
FRM 509	Bio Systematics of Aquatic Fauna	1+2
FRM 510	Inland Fisheries Resources Management	2+1
FRM 511	Marine Fisheries Resources Management	2+1
FRM 512	Advanced Fish Anatomy and Physiology	2+1
FRM 513	Fish Histology and Histochemistry	1+1
FRM 514	Field techniques in Fisheries Resource Management	0+2
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common courses (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its Management in Agriculture 4. Basic Concepts in Laboratory Techniques 5. Agricultural Research, Research Ethics and Rural Development Programmes	**5 Credits**
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	**1 Credit**
FRM 591	Masters' Seminar	0+1
	Masters' Thesis Research	**30 Credits**
FRM 599	Masters' Research (Semester III)	0+15
FRM 599	Masters' Research (Semester IV)	0+15
	Total M.F.Sc Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fishereis Resource Management

I. Course Title : Sustainable Fisheries Management
II. Course Code : FRM 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the major inland and marine fisheries resources of the world and India. To discuss the major sustainability issues in the inland and marine fisheries sectors. To understand the ways and means to resolve the issues for sustainable fisheries resource management.

V. Theory

Unit I

Inland fisheries: Major inland fisheries resource of the world-India-Overview-State of the fisheries- Fishing gears-and crafts- Catch composition

Unit II

Marine fisheries: Major marine fisheries resources of the world and india-Overview- State of the fisheries -Fishing gears -Catch composition-pelagic, Demersal, Oceanic, Deep sea

Unit III

Sustainability issues in fisheries: Ghost fishing- Overexploitation, Overcapacity, pollution, Habitat degradation/ biodiversity loss, Damming of rivers, Interlinking of rivers , Environmental flows; Fishing conflicts-Exotics; Trans-boundary issues, IUU fishing, Interlinking of rivers-Climate change, By catch and discards.

Unit IV

Sustainable fishing: Components of sustainability, Indicators and goals of sustainability, Eco-friendly fishing, Ecosystem Based Fisheries Management-resilient fishery system

Unit V

Principle of fisheries management-Management approaches: By catch reduction- Rebuilding fishery, Rebuilding stock, Co-management- right based fishing-input control (fishing efforts, mesh regulations, fishing ban, licensing, capital investments, etc)-output control (catch quotas, minimum legal size, etc)- - Fishery reserve-technical measures, Spawning aggregates; trade agreement- Market-based instruments; Access right- Catch sharing-balanced fishing-Subsidy-certification and traceability-Sustainable management approach in lake, Reservoir and bheels.

Unit VI

Responsible fishing practices Precautionary management -Fisheries Co-management: Right based fishing- Catch sharing access right- Balanced fishing.-Technical Guidelines of CCRF for responsible fishing; National and International

treaties (National policy on marine fisheries-2017; National policy on inland fisheries-2019; MFRA's; UNCLOS; UNFSA; IOTC)

VI. Practical

Capture fisheries observation at lakes, reservoirs, river stretches, and marine landing centres, Species landings analysis, Interaction with managers Co-operative societies and stakeholders Fleet capacity assessment, Visit to fishery reserves to understand management, Field survey and observation of fisheries issues, Development of management plan.

VII. Suggested Reading

- Bal DV and Rao KV. 1990. *Marine Fishes of India*. 1st Revised Ed. Tata McGraw Hill.
- Blaber JM. 1997. *Fish and Fisheries in Tropical Estuaries* Chapman and Hall.
- Chandra P. 2007. *Fishery Conservation, Management and Development*. SBS Publ. Dholakia AD. 2004.
- E. Eric Knudsen, Donald McDonald, 1999. *Sustainable Fisheries Management: Pacific Salmon*. 1st Edition. CRC Press p. 752 .
- FAO. Technical Papers on Freshwater Fisheries.
- Greene, C. M. and and G.R. Pess. 2009. *Multi-species modeling for salmon: alternatives, challenges, and opportunities*. 429-454 in E.E. Knudsen and J.H. Michael Jr., editor. Pacific salmon environmental and life history models: advancing science for sustainable salmon in the future. American Fisheries Society, Symposium 71, Bethesda, Maryland.
- Hilborn, R. C. and C. J. Walters. 1992. *Quantitative fisheries stock assessment*, ed. Chapman and Hall. New York, New York
- Jhingran VG and Pathak V. 1987. *Ecology and Management of Bheels in Assam: A case study of DhirBheel*. In: Workshop on Development of Bheel Fisheries in Assam, held at Assam Agricultural University, Guwahati from 21st to 22nd April.
- Jhingran VG. 1991. *Fish and Fisheries of India*. 3rd Ed. Hindustan Publ.
- Moyle PB and Joseph JC Jr. 2000. *Fishes – An Introduction to Ichthyology*. 4th Ed. Prentice Hall.
- Murawski SA, Matlock GC. *Ecosystem science capabilityies required to support* NOAA's mission in the year 2020. US Dept. Comm. NOAA Tech. Memo. NMFS-F/SPO-74. 2006.
- Peter BM and Joseph JC. Jr. 2000. Fishes- An Introduction to Ichthyology. 4th Ed. Prentice Hall.
- Samuel CT. 1968. *Marine Fisheries in India*. Narendra Publ. House.
- Sugunan VV. 1997. *Reservoir Fisheries of India*. Daya Publ. House
- Yadav BN. 1997. *Fish and Fisheries*. 2 nd Ed.Daya Publ. House.

I. Course Title : Fish Biodiversity and Conservation Biology

II. Course Code : FRM 502

III. Credit Hours : 2+1

IV. Aim of the course

To appreciate the biodiversity of various major aquatic fauna and flora, To understand the major threats to this aquatic biodiversity, To develop management strategies for the conservation of aquatic biodiversity

V. Theory

Unit I

Fish diversity: Fresh water fish diversity- Marine fish diversity-Quantification and importance of biological diversity- abundance- distribution.

Unit II

Species concept for conservation related decisions: Unique species- umbrella species-flagship species, Keystone species, state fish concept, -Endangered species-extinction-recovery-CITES- NBA- Migratory stock- Essential Habitat-EBSA.

Unit III

Biodiversity conservation methods: IUCN criteria - Red List, Marine Protected Areas, Sanctuaries and Biosphere reserves, Establishment of National marine parks, in situ and ex situ conservation, Participatory approach- Conservation value index – criteria – Medicinal and biological, IBI –stock resilience-recovery. Wildlife protection act, Biodiversity Act, International treaties and conventions (CITES, CMS, RAMSAR Convention).

Unit IV

Impacts of anthropogenic intervention on fisheries biodiversity: Exotic species, Damming of rivers, Construction of shore protection walls, Micro hydral power stations, Oil rigs.

Unit V

Aquatic biodiversity: Threats-Over exploitation, habitat reclamation, pollution, habitation, planning and management, tools for conservation, participatory approach -Impact of climate change on the ecosystem biodiversity, health and productivity

Unit VI

Conservation biology of biodiversity: Concept of hotspots- Ecological integrity: Minimum population sizes, Inbreeding depression, Genetic tolerance of extreme conditions, Restoration of populations at risk of extinction, Conservation – management of invasive species- Economic valuation of biodiversity and ecosystems

VI. Practical

Identification of scheduled aquatic organisms and exotic species, Predators of endangered animals, Visit to various aquatic ecosystem for recording the biodiversity, Conservation strategies (case studies), Calculation of trophic levels, Biodiversity indices-IBI, Conservation value Index, Presentation of field study.

VII. Suggested Reading

- Brian G. 1992. *Global Biodiversity - Status of the Earth's Living Resources*. Chapman and Hall.
- Denton TE. 1973. *Fish Chromosome Methodology*. Charles Thomas Publ.
- Elliott A. Norse (Ed.) 1993. *Global Marine Biological Diversity*. Inland press, Washington, D.C.383p. 4. Gunderson DR. 1993. *Surveys of Fisheries Resources*. John Wiley and Sons. New York. 248 p.
- Khanna DR, Chopra AK and Prasad G. 2005. *Aquatic Biodiversity in India*. Daya Publ. House.
- Kumar U and Asija M. J. 2000. *Biodiversity Principles and Conservation*. Agrobios.
- Lakra WS, Abidi R, Singh AK, Sood N, Rathore G and Swaminathan TR. 2000. Fish *Introductions and Quarantine: Indian Perspective*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Lambshead PJD, Paterson GLJ and Gage JD. 1997. *Biodiversity Professional*. Version 2. National History Museum and the Scottish Association of Marine Science.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*. Taylor and Francis.
- Mahanta PC and Tyagi LK. 2003. *Participatory Approach for Fish Biodiversity Conservation in North East India*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.

- Ponniah AG and Gopalakrishnan A. (Eds.). 2000. *Endemic Fish Diversity of Western Ghats*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Zoological Survey of India. 2007. *National Symposium on Conservation and Valuation of Marine Biodiversity*.

I. Course Title : Climate Change and Fisheries Resource

II. Course Code : FRM 503

III. Credit Hours : 2+1

IV. Aim of the course

To become familiar with causes and effects of climate change, To understand the models and methods available for estimating climate change effects, To develop strategies for the mitigation of climate change effects for the management of fisheries resources.

V. Theory

Unit I

Introduction to climate science: Climate and biosphere, Climatic forcing factors, history of earth's climate, Climate change: The physical basis in marine and freshwater systems; Anthropogenic activities, greenhouse gases; Role of oceans; Diagnosing climate change-Scenarios.

Unit II

Climate change threats to fisheries resource: Temperature, Freshwater precipitation and sea level rise- Climate-induced degradation and loss of critical fish habitats. –Resilience - Tolerance limit-Temperature, pH and Salinity- Global warming and ocean acidification on fish early life stages.

Unit III

Climate change: Interaction between biodiversity - Effect on aquatic population –critical habitats-marine -freshwater-estuarine-high seas- endemic resources-Indicators of climate change - Climate change and invasive species.

Unit IV

Impact of Climate change on fish: On fish biology, Reproduction and life stages, Distribution and abundance- Migration patterns-fish physiology- Disease prevalence, Adaptation strategies of fishes towards climate change.

Unit V

Models on climate change and capture fisheries: Trophic dynamics model-Methods for estimating effects of climate change on fishery resources-Long term monitoring- Survey on effects of climate change on fisheries resources -Developing vulnerability index.

Unit VI

Policies and strategies on climate change: Impact of climate change on livelihood, Mitigation (emission reduction, life cycle assessment, carbon sequestration, improved governance) and adaptation strategies (resilience, vulnerability and risk assessment, institutional mechanisms) to climate change-Policy on climate change - IPCC, UNFCCC - Harvesting strategies - fishing right-Fishery resource management- key indicator species monitoring.

VI. Practical

Fish production trend analysis- India- global, Thermal effect on fish biology and reproduction, Climate change effect on fish early life stages- Fish physiology. Biodiversity- Threshold limits-temperature-pH and Salinity, Generation of fish distributional map. Group discussion on climate change, impact and mitigation strategies, Presentation of case studies.

VII. Suggested Reading

- AmielleDeWan, Natalie Dubois, Kathleen Theoharides, Judith Boshoven, 2010. *Understanding the impacts of climate change on fish and wildlife in North Carolina-* A review of climate change science, impacts, and planning options. for sensitive species and habitats. Defenders of Wildlife Washington D.C accessed through http://www.defenders.org 209 p.
- ACIA. 2004. *Impacts of a Warming Arctic.* Arctic Climate Impact Assessment (ACIA). Cambridge University Press, Cambridge, UK. 139 p.
- Crance JH. 1987. *Guidelines for using the Delphi technique to develop habitat suitability index curves. Biological Report* 82 (10.134), U.S. Fish and Wildlife Service, Washington,
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- Sinclair M. 1988. *Marine Populations: an Essay on Population Regulation and Speciation*. University ofWashington Press, Seattle
- Tasker M. (Ed.). 2008. The effects of climate change on the distribution and abundance of marine species in the OSPAR maritime area. *ICES Cooperative Research Report*, 293. 45p.
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- Vivekanandan E. 2011. *Climate Change and Indian Marine Fisheries*. CMFRI Special Publication No. 105, CMFRI, Kochi.
- Janardhanan Sundaresan, KM Santosh, Andrea Deri, Rob Roggema and Ramesh Singh., eds.2013. *Geospatial Technologies and Climate Change*. 299p.
- Waggoner PE (ed) *Climate change and U.S. water resources*. John Wiley and Sons, New York,
- Weisberg S. 2005. *Applied linear regression*. 3rd edition. John Wiley and Sons, Inc., Hoboken, NJ.

I. Course Title : Fish Stock Assessment
II. Course Code : FRM 504
III. Credit Hours : 2+1

IV. Aim of the course

- To understand the stock concept and principles of fisheries management
- To understand the application of various models and their applications in fisheries management. To get an idea of the interaction of fish population in the ecosystem.

V. Theory

Unit I

Concept of stock and fish stock assessment: Distribution and types of stock - unit stock-mixed stock- straddling stock; Characterization of stock (life history traits, truss network, environmental signals, otolith shape; genetic analyses, applied marks); Principle and general procedure of fish stock assessment; Features of tropical and temperate fish stocks; Role of fish stock assessment in fisheries management.

Unit II

Sampling and measurements for fish stock assessment: Data requirement; Methods of sampling commercial catch, Sampling design and fish measurements; Assessment of fishery under data poor conditions; Survey methods for inland fisheries.

Unit III

Concept of growth and mortality: Principles of growth; Growth parameters-estimation of growth parameters employing hard parts and size frequency, Separation of cohorts, Mortality -Decay curve; types of mortality; Estimation of total, natural and fishing mortality rates.

Unit IV

Recruitment and gear selectivity: Timing and size of recruitment; Factors influencing recruitment; Principle and estimation of gear selectivity – trawl net and gill net selectivity; Eumetric fishing; Stock recruitment relationship– Cushing-Rickers- Beverton and Holt models.

Unit V

Fish stock assessment models: Analytical models: Cohort dynamics and life history; Virtual population analysis; Prediction models (Thompson and Bell model; Yield per recruit model and Relative Yield per Recruit model); Prey-predatory model; Surplus production models / Holistic models: Schaefer's model, Fox model, Swept area method, Stochastic model, Estimation of technical reference point MSY and other yield base reference point; economic and social reference points, Bio-economic modelling, Economic models - MEY, Swept area method - Box model-Bayesian Stochastic models, Multispecies models.

Unit VI

Trophic models: Ecosystem based models– Principles, Applications; Productivity models; Ecopath with Ecosim.

VI. Practical

Cohort analysis; Characterization of fish stock, 11-measurements; Truss network

analysis, Otolith shape estimation of growth and mortality parameters (hard parts/ length based/age based), Gear selectivity, Stock recruitment relationship; Analytical models – VPA, Thompson and Bell model, Beverton's Yield per recruit and Relative yield per recruit model, Holistic models - Schaefer and Fox models; Swept area method, MSY, Use of FiSAT, LFDA, CEDA, YIELD. Presentation of case studies on use of ecosystem models.

VII. Suggested Reading

- Beverton RJH and Holt SJ. 1957. On the dynamics of exploited fish population. *Fish. Invest. Ser. II*, Vol. 19: 533p. Min. of Agriculture and Fisheries, London.
- Callucci VG, Saila SB, Gustafson DJ and Rothschild BJ. 1996. *Stock Assessment. Quantitative methods and applications for small scale fisheries*. Lewis publishers. Boca Raton, P. 527.
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- Gulland JA. 1977. *Fish population dynamics*. Johnwiley and sons. Chichester. P. 422.
- Gulland JA. 1992. *A review of length based approaches to assessing fish stocks*. FAO technical paper. 323. p.100.
- Hilborn R and CJ Walters. 1992. *Quantitative Fisheries Stock Assessment – Choice, Dynamics and Uncertainty*. Pub. Chapman and Hall. 570p.
- King M. 1995. *Fisheries Biology, Assessment and Management*. Pub. Fishing News Books. 341p.
- Manual FAO. *Fisheries Technical paper* No: 301. FAO Rome. p407.
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- Pauly D. 1980. *Selection of simple methods for the assessment of tropical fish stocks*. FAO Fish. Circ., (729): 54p.
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- Ricker WE. 1971. *Methods for the Assessment of Fish Production in Freshwaters*. Blackwell, Oxford and IBH.
- Sparre P and Venema SC. 1998. *Introduction to Tropical Fish Stock Assessment*. Part 1 Manual. FAO. Fisheries Tech.Paper No.301, Rome
- Vivekanandan E. 2005. *Stock assessment of tropical marine fishes*. Indian Council of Agricultural Research, New Delhi.

I. Course Title : Trophodynamics in Aquatic Systems

II. Course Code : FRM 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the various methods of gut content analysis and various feeding indices To understand the relationship within a community, energy flow To develop linkages between biota and environment

V. Theory

Unit I

Food and feeding adaptations: Food and feeding habits of different types of finfish and shellfishes -Morphological and anatomical adaptation for feeding; Feeding behaviour-Ontogenic changes in food and feeding.

Unit II

Digestion : Food digestion - Energetics- Food partitioning- Larval feed- Gut development.

Unit III

Food web: Food web - food web in nearshore reef, Seagrass and unvegetated ecosystems - Biomarkers - Stable isotopes and fatty acids markers

UNIT IV

Prey predator interaction : Prey density - Predator density—Prey predatory interaction forage theory—Species succession - Food availability - Fishing effect on prey and predator

Unit V

Trophodynamics: Concept of trophodynamics-Methods in food and feeding analysis-Diet analysis -Diet breath- Diet overlapping indices- Energy flow and trophic indices and modelling- Calculation of trophic level.

Unit VI

Application of information on trophodynamics in fisheries management: Trophodynamic indicators- Ecopath with Ecosim model, SEAPODYM model.

VI. Practical

Morphological and anatomical adaptations in finfishes and shellfishes with different feeding habits. Analysis of gut contents, Gastro somatic Index, Use of indices in feeding, digestion and food consumption rates of fishes, Calculation of trophic levels- Mean trophic level, Comparison of mean trophic level between gears-season-space, Analysis of diet breath and diet overlap, Case studies using available data sets.

VII. Suggested Reading

- Aquaculture. ADCP/REP/87/26.F.A.O., Rome
- Baton Roughe LA, De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Bone Q.N.B. Marshall and JHS Blaxter. 1995. *Biology of Fishes* (2nd edition) Black ie Academic and professional, New york. 332 p.
- Boyd CE. 2015. *Water quality: an introduction*. Springer.
- Carl E Bond. 1979. *Biology of Fishes (2nd edition).* Saunders college publishing Harcount Brace college publishers, New york. 750 p.
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutritional: Advances in Aquaculture* Vol. 6. World Aquaculture Society,
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
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- Kaushik SJ. 1998. *Nutritional bioenergetics and estimation of waste production in non-salmonids*. Aquat living resour 11(4): 211-217
- Khanna SS. 1993. *An introduction to fishes*. Central Book of Depo, Allahabad, 530 p.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
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- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and crustaceans*. National Academy Press, Washington.
- Venkataramanujam K and N Ramanathan. 1994. *Preparation and Preservation of Compound Feeds for Shrimp and Fish* Manual of Finfish Biology. Oxford and IBH publishing Co. pvt. Ltd 1108.

I. Course title : Reproductive Biology of Finfish and Shellfish

II. Course code : FRM 506

III. Credit Hours : 2+1

IV. Aim of the course

To familiarise with the reproductive system and physiology of reproduction of teleost, elasmobranch, shrimps and molluscs

V. Theory

Unit I

Fish reproduction: Types – Gonads - Sexual differentiation, Reproductive biology: Gonado Somatic Index, Fecundity, Length at first maturity-breeding migration-Environmental influence of breeding cycle.

Unit II

Male reproductive system of finfish and shellfish: Endocrinology-spermatogenesis-sperm morphology.

Unit III

Female reproductive system of finfish and shellfish: Endocrinology- Oogenesis-Ovulation- Atresia- Vitellogenesis.

Unit IV

Physiological control of reproduction in finfish: Fish reproduction –Fish-hormone- Hormone Dynamics- Maturation and spawning, Hormones in spermatogenesis, oogenesis, Yolk formation, Mechanism of sex reversal; Pheromone. hormone based induced reproduction.

Unit V

Physiological control of reproduction in crustaceans (shrimp, crab and lobsters): Maturation and spawning, spermatogenesis, Oogenesis, Yolk formation, Mechanism of sex reversal- Eye stalk ablation.

Unit VI

Physiological control of reproduction in molluscs: Maturation and spawning, Spermatogenesis, oogenesis, Yolk formation, Mechanism of sex reversal – sex Control; Early Embryonic Development Maturity cycle and hormone

VI. Practical

Sexual dimorphism, Study of reproductive organs in finfish and shellfish by dissection, Maturity stage observation, Length at maturity estimation- intra-ovarian periodicity, Dissection of reproductive glands; fish sperm quality analysis – morphology, quantification and motility; Egg quality analysis – morphology, fecundity estimation; Histological techniques- study gonadal maturity stages; Identification of moult stages

VII. Suggested Reading

- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea. Biology Reviews*. Agarwal NK. 2008. Fish Reproduction. APH Publ.
- Adiyodi K.G, *Reproductive Biology of Invertebrates*: Vol-X P.B Prog in Developmental Endocrinology, Narendra Publishing House Publishers and Distributors
- Agarwal, N.K. 1996. *Fish reproduction* APH publishing corporation, New Delhi. 155p.
- Barrington, E.J.W.1981. *Invertebrate structure and Function* (2nd Edition). The English

Language Book society and Nelson, Great Britain. 765p.
- Bell TA and Lightner TA. 1988. *A Handbook of Normal Penaeid Shrimp Histology*. World Aquaculture Society.
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- Ghosh R. 2007. *Fish Genetics and Endocrinology*. Swastik Publ. and Distr.
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- Khanna, S.S.1993. *An introduction to fishes.* Central Book of Depo, Allahabad, 530 p.
- Malcolm Jobling 1995. *Environmental Biology of Fishes*, Chapman and Hall London. 455 p.
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- Maria RJ, Augustine A and Kapoor BG. 2008. *Fish Reproduction. Science*. Publ.
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- Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
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- Thomas, P.C. Rath, S.C. and Mahapatra, K.D. 2017. *Breeding and Seed Production of Finfish and Shellfish*. DayaPublsihing house. 402 pp.
- Venkataramanujam, K. and N. Ramanathan 1994. *Manual of Finfish Biology*. Oxford and IBH publishing Co. pvt. Ltd 1108.

I. Course Title : Developmental Biology of Finfish and Shellfish

II. Course Code : FRM 507

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on the collection and identification of eggs and larvae of commercially important finfish and shellfish To understand developmental biology of aquatic organisms.

V. Theory

Unit I

Fish eggs and larvae: Morphology and identification of eggs and larvae of commercially important finfishes, crustaceans, molluscs and echinoderms-morphometry.

Unit II

Methods in Fish eggs and larval study: Quantitative sampling of fish eggs and larvae; Spatial and temporal distribution, Dispersion of eggs and larvae, Effect of environmental parameters on eggs and larvae.

Unit III

Eggs and larval dynamics: Reproductive cycle in fish- Spawning – Environmental cues- Recruitment assessment-Natural food of commercially important finfish and shellfish larvae from egg to adult.

Unit: IV

Larval development: Developmental biology of fish- Shellfish-sea urchin- Stages of development- Cell fate and commitment, Embryonic induction, Differentiation— Organogenesis- Morphogenetic movements,

VI. Practical

Identification of eggs and larvae commercially important species of crustacean and molluscan, Morphometry of eggs and larvae of finfishes, identification keys, Quantitative sampling- finfish and shellfish larvae; Food and feeding habits of larval stages of finfish and shellfishes.

VII. Suggested Reading

1. Barrington EJW. 1981. *Invertebrate Structure and Function*. 2nd Ed. The English Language Book Society and Nelson.
2. Diwan AP and Dhakad NK. 2004. *Embryology of Fishes*. Recent Advances in Embryology Series-1. Anmol Publ.
3. Ede DA. 1978. *An Introduction to Developmental Biology*. Blackie.
4. Hoar WS and Randall J. (Ed.). 1988. *Fish Physiology*. Vol XI. The Physiology of Developing Fish. Part B. Viviparity and Post hatching Juveniles. Academic Press.
5. Jobling M. 1995. *Environmental Biology of Fishes*. Chapman and Hall.
6. Khan SA, Raffi SM and Lyla PS. 2003. *Larvae of Decapod Crustaceans*. Centre of Advanced Study in Marine Biology, Parangipettai, TamilNadu.
7. Silas EG. 1983. *Development of Penaeid Prawns*. CMFRI Bull. No. 28.8.Werner A. Muller, 1996. Developmental Biology, Springer. 328p.

I. Course Title : Modern Techniques in Fisheries Biology

II. Course Code : FRM 508

III. Credit Hours : 2+1

IV. Aim of the course

To be aware of the modern / including molecular techniques that can be applied in fisheries biology

V. Theory

Unit I

Introduction: Advances in molecular technology – DNA extraction and PCR-quality and size of DNA- Sequencing-RNA extraction

Unit II

Electrophoresis: Principles – Types of electrophoresis- Identification of fish using agarose gel electrophoresis- SDS-Page- Staining protein gels- Digital electrophoresis analysis- Other electrophoresis techniques.

Unit III

PCR: Principle; PCR as a rapid detection method- Quantitative real-time PCR-Multiplex PCR- Nested PCR -Developments in molecular genetic techniques in fisheries.

Unit IV

Molecular genetic techniques in fisheries: Metagenomics and meta-transcriptomics- molecular techniques in population studies.

Unit V

Molecular methods in taxonomy: Cytological and Molecular Systematics and DNA Barcoding-barcode analysis.

Unit VI

Fish genetic markers and their applications in fisheries: Use of microarrays and RT-PCR- D-loop polymorphism analysis -Single Nucleotide Polymorphism - Restriction Length polymorphism analysis.

VI. Practical

Molecular laboratory safety issues- Extraction of DNA/ RNA, Barcode generation and analysis, Phylogenetic tree construction using barcode, Allozyme variation, Protein assay -2D gel electrophoresis.

VII. Suggested Reading

- Brown TA. (Ed.). 2002. *Essential Molecular Biology*. Vols. I, II. 2nd Ed. Oxford University Press.
- Carvalho Gary R. Molecular Genetics in Fisheries
- Cocolin, L Rajkovic, A., Rantsiou, K., .Uyttendaele M. 2011. The challenge of mergingfood safety diagnostics needs with Real-time PCR platforms. *Trends in Food Science and Technology*. 1-9
- Cooksey K. 1997. *Molecular Approaches to the Study of the Oceans*. Chapman and Hall.
- *Environmental Microbiology*. 2014 Eds Pepper, I.L., Gerba, C.P., Gentry, T.J Elsevier Academic Press ISBN-13: 978-0123946263
- FAO. 2000. *DNA Based Molecular Diagnostic Techniques*.
- Harvey Lodish and Arnold Berk, Chris A. Kaiser, and Monty Krieger; 2008. *Molecular Cell Biology* Ed. 6th; W H Freeman and Company; New York;
- Kocher TD and Carol AS. (Ed.). 1997. *Molecular Systematics of Fishes*. Academic Press.
- Le Gal Y and Halvorson HO. 1998. New Development in Marine Biotechnology. Plenum Press.
- Mayer E. 1977. *Principle of Systematic Zoology*. Tata McGraw Hill.
- Ponniah AG and George J. 1998. *Fish Chromosome Atlas*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Sambrook, J., Fritsch, E.F., Maniatis. *Molecular Cloning, A laboratory Manual*. Third edition. 2001. Cold SpringHarbor Laboratory, USA
- Whitmore DH. 1990. *Electrophoretic and Isoelectric Focusing Techniques in Fisheries Management*. CRC Press.
- Wilson, K. and Walker, J. (eds.). *Practical Biochemistry – Principles and Techniques:* Cambridge University Press, UK.

I. Course Title : Bio Systematics of Aquatic Fauna

II. Course Code : FRM 509

III. Credit Hours : 1+2

IV. Aim of the course

To acquire in-depth knowledge on the basics and recent developments in systematics and taxonomy of aquatic fauna

V. Theory

Unit I

Principles of taxonomy: Systematics, Taxonomy and Classification; Importance of taxonomy, Describing and naming of a new species, International Code of

Zoological Nomenclature, and its amendments and rules of Binomial Nomenclature; Zoo Bank and its policies, Morphology, Morphometric, Meristic, Osteology and Soft anatomical characters.

Unit II

Classification of Commercially important finfish: Classification of modern fishes up to order and family levels - Elasmobranchii (Cartilaginous fishes) and Actinopterygii (bony fishes).

Unit III

Classification of Commercially important shellfish: Classification of commercially important invertebrate up to family level: Arthropoda (Prawns, Shrimps, Lobsters and Crabs); Mollusca (Gastropods, Bivalves, Cephalopods and Scaphopods); Echinodermata (Sea Cucumbers), Preparations of dichotomous key.

Unit IV

Methods in taxonomy: Phylogeny and Zoo geography, Modern tools of taxonomy: Cytotaxonomy, Basics of biochemical taxonomy (Electrophoretic studies of muscle myogen, eye-lens protein, enzyme pattern and serology), PCR based methods and DNA finger printing, mitogene in fish identification. Identification of fish through auto-image processing.

VI. Practical

Collections and preparation of field data; Preservation techniques of specimens: Morphology, Graphical representation and statistical analysis of meristic, Morphometric, Osteological and soft anatomical characters; Key Pattern – Dichotomous key – Type of keys –Dichotomous, Bracket, Indented, Branching, Pictorial and computer keys; Protocols followed for describing of a new species, Use of distribution maps; curation and sorting protocols, Visit to freshwater, brackishwater and marine waters (markets; landing centres) of the locality and inventorying of commercially important fishes, Mollusca, Crustacea, Echinodermata (diagnostic characters of the orders, families and species), Modern taxonomical tools. Cytotaxonomy: Karyotyping – preparation and identification of chromosomes, Electrophoresis studies (muscle myogen, eye-lens protein, enzyme pattern and serology), Molecular markers–PCR, RAPD, RFLP, Microsatellites, mini satellites and Mitochondrial DNA and their application in fish phylogenetic studies; Barcoding

VII. Suggested Reading

- Apte D. 1998. *The book of Indian Shells*. Oxford University Press. Calcutta, Chennai, Delhi, Mumbai. p 115.
- Barman RP and SS Mishra. 2012. *Nemipteridae, Polynemidae, Mullidae* (Separate compilation for each family).
- Barman RP, SS Mishra, S Kar, P Mukherjee and SC Saren. 2012. *Marine and estuarine fishes of Maharashtra*. Zool. Surv. India, Fauna of Maharashtra, state fauna series, 20 (part 1): 369-480, 2012.
- Cooksey K. 1997. *Molecular Approaches to the Study of the Oceans*. Chapman and Hall, London. ICZN: International code for Zoological Nomenclature Publ: International Commission 1999.
- Day F. 1878. *The Fishes of India*. Published by William Dawson and sons Ltd.
- FAO. 2000. *DNA based molecular diagnostic techniques.*
- Fischer W and Biachi G. 1984. *FAO-identification sheets for fishery purposes*. Vol I-VI pages variable.

- Hamilton F. 1822. *Fishes of the River Ganges and its branches*. Publ. Edinberg
- Holden MJ and Raitt FS. 1974. *Manual of Fisheries Science*, Part II - Methods of Resource, Investigation and their Application. FAO Fish Technical Paper 115 Review Page 1-224.
- Jayaram KC. 2010. *The freshwater fishes of the Indian Region* II edition. Narendra Publishing house New Delhi.
- Jayaraman KC. 2002. *Fundamentals of Fish Taxonomy*. Publ.
- Lagler, Karl F, John E Bardach, Robert R, Miller and Dora R, May Passino. 1977. *Ichthyology* II edition. John Weily and Sons.
- Le Gal Y and Halvorson HO. 1998. *New Development in Marine Biotechnology*, Plenum. Marine species identification portal for crustaceans (crabs and prawns etc).
- Mayr E. 1977. *Principles of Systematic Zoology*. Tata Mc Graw Hill Publishing Co. Ltd. New Delhi, p. 428.
- Michael M Cox and David L Nelson. 2010. *Leninger Principles of Biochemistry*, Fifth Edition. W.H. Freeman and company, New York.
- Moyle PB and JR Cech. 1996. *Fishes – An Introduction to Ichthyology*. Prentice Hall Inc. N. Jersey, 594p.
- Munro ISR. 2000. *The Marine and Freshwater Fishes of Ceylon*. Narendra Publishing house, New Delhi. 351 p.
- Nelson JS. 2006. *Fishes of the World*, IVth edition, John Weily and sons.
- Ponniah AG and George John. 1998. *Fish Chromosome Atlas*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow publication.
- Poutiers JE. 1998. Bivalves; Gastropods. In: K. E. Carpenter, V H. Niem (eds.), FAO species identification guide for fisheries purposes. The living marine Resources of the Western Central Pacific. Volume I. Seaweeds, corals, bivalves And gastropods. Pp.123-686.FAO, Rome, ISBN 92-5-104051-6.
- Raje SG, S Sivakami, G Mohanraj, PP Manojkumar, A Raju and KK Joshi. 2007. *An atlas of the elasmobranch fishery resources of India*. CMFRI special Publication no.95.
- Subramanuam TV, KR Karandikar and NN Murthy. 1949. *Marine Pelecypods of Bombay* Part I. J. Bombay University. Vol 17. 50-81.
- Subramanuam TV, KR Karandikar and NN Murthy. 1951. *Marine Gastropods of Bombay* Part I. J. Bombay University. Vol 3. 21-34.
- Subramanuam TV, KR Karandikar and NN Murthy. 1952. *Marine Gastropods of Bombay* Part II. J. Bombay University. Vol 21. 26-73.
- Talwar PK and Jhingran AG. 1991. *Inland fishes of India and adjacent countries*, Delhi Oxford and IBH Publishing Co.Pvt. Ltd. 1158 p. Vol. I and II
- Talwar PK and Kacker RK. 1984. *Commercial Sea Fishes of India*. Published by ZSI, Kolkata. 997 p.
- Thomas D, Kocher and Carol A Stepien (Ed.). 1997. *Molecular Systematics of Fishes*. Academic Press. New York. 314p.
- Whitmore DH. 1990. *Electrophoretic and Isoelectric focusing techniques in fisheries management*. 350pp.

I. Course title : Inland Fisheries Resources Management

II. Course code : FRM 510

III. Credit Hours : 2+1

IV. Aim of the course

To understand the present exploitation and future potential of inland Fisheries. To learn the methodologies for assessments of Inland Fisheries Resources

V. Theory

Unit I

Freshwater fisheries resources India-world: Ponds, Lakes, Bheels, Tanks,

Estuaries, Brackish water lagoons, Wetlands, Biosphere reserves and mangroves and derelict water bodies their problems and management aspects, Assessment of carrying capacity of different inland water bodies; Water budgeting, Community participation in fishery resource management.

Unit II

Bheel fisheries resources of India: Open and closed bheels, Productivity conditions, Capture scenario, Prospects of culture based systems.

Unit III

Riverine fisheries resources in India: Present trend of dwindling fisheries resources, Direct and Indirect effects of human intervention in rivers, habitat modification and improvement (rehabilitation of channels and flood plains), Protection and restoration of fish movements (different types of fish passes and enhancement of fish migration), Management and repair of riverine vegetation, Stock enhancement strategies like introduction of new species, Pre- and post-stocking management, Potential risk of stocking.

Unit IV

Cold water fisheries of India: Present trends, Problems due to habitat destruction, Management aspects, Prospects of sports fisheries in India.

Unit V

Reservoir Fisheriesin India: Classification of reservoirs, Present productivity levels, Management practices.

Unit VI

Estuarine fisheries in India: Classification of estuaries- Present productivity level potential; Problem – Management practices.

VI. Practical

Freshwater fish identification, Tagging – different types of tags, Visit to nearest freshwater body; catching methods – catch data analysis on major freshwater resources- Bheels- Estuaries - Reservoirs – lakes, Biodiversity indices – Gear selectivity.

VII. Suggested Reading

- Blaber JM. 1997. *Fish and Fisheries in Tropical Estuaries* Chapman and Hall.
- FAO. Technical Papers on Freshwater Fisheries.
- Jhingran VG and Pathak V. 1987. *Ecology and Management of Bheels in Assam*: A case study of DhirBheel. In: Workshop on Development of Bheel Fisheries in Assam, held at Assam Agricultural University, Guwahati from 21st to 22nd April.
- Jhingran VG and Sehgal KL. 1978. *Cold Water Fisheries of India. J. Inland. Fish. Soc. India*. Sp. Publ.
- Jhingran VG. 1991. *Fish and Fisheries of India*. 3rd Ed. Hindustan Publ.
- Sugunan VV. 1997. *Reservoir Fisheries of India*. Daya Publ. House.

I. Course Title : Marine Fisheries Resources Management

II. Course Code : FRM 511

III. Credit Hours : 2+1

IV. Aim of the course

To know the present level of exploitation of marine resources and to impart

knowledge on conservation measures. To learn the recent methodologies of sustainable exploitation of renewable resources.

V. Theory

Unit I

Status of marine fisheries: Major fishing nations of the world, Major fishing regions, present trend of marine capture fisheries.

Unit II

Marine fish resources: Important finfish and shellfish resources in demersal and pelagic systems; Conservation strategies.

Unit III

Fishery management: Mud bank fishery- wadge bank fishery-Commonly used tools for input and output regulations, Principles of management of fisheries resources, Objectives of management, Issues and challenges of managing multi-gear fisheries.

Unit IV

Sustainability: Principles, Socio-economic, Ecological, Biological and Legal issues-Fisheries co-management - Case studies of fisheries conflicts between sectors, states and nations, Conflict management.

Unit V

Fisheries and fishing methods in open waters: Inshore fisheries (up to 50 m depth), Offshore fisheries (50-200 m depth) -High sea fisheries.

Unit VI

Conservation aspects: Marine Biodiversity of selected areas including coral reef conservation, Biodiversity principles, Categorization of species into endangered; Indeterminate and extinct varieties- Managing the highly exploited fishery resources.

VI. Practical

Marine fishery resources – visit to nearest marine landing centres, Length frequency analysis – catching method, Catch data analysis on marine fishery resources of India. Closed season studies – gear selectivity.

VII. Suggested Reading

- Bal DV and Rao KV. 1990. *Marine Fishes of India.* 1st Revised Ed. Tata McGraw Hill.
- Chandra P. 2007. *Fishery Conservation, Management and Development* .
- *Fisheries and Aquatic Resources of India*. Daya Publ. House.
- FAO. *Technical Papers on Marine Fisheries.*
- Kurian CV and Sebastian VO. 1986. *Prawns and Prawn Fisheries of India*. Hindustan Publ. Corp.
- Peter BM and Joseph JC. Jr. 2000. *Fishes- An Introduction to Ichthyology*. 4th Ed. Prentice Hall.
- Samuel CT. 1968. *Marine Fisheries in India.* Narendra Publ. House.
- Shanbhogue SL. 2000. *Marine Fisheries of India.* ICAR.
- Yadav BN. 1997. *Fish and Fisheries*. 2 nd Ed. Daya Publ. House.

I. Course Title : Advanced Fish Anatomy And Physiology

II. Course Code : FRM 512

III. Credit Hours : 2+1

IV. Aim of the course

To impart an in depth knowledge on anatomy and physiological regulations in fishes for better fisheries resource management

V. Theory

Unit I

Principles of Fish anatomy: Study of internal anatomy of important groups of finfish and shellfish, Body form, swimming mechanisms and buoyancy regulation-bioenergetics, strategies for buoyancy regulation- Fish behaviour and regulatory mechanism- alarm reaction-transduction mechanism, Sense organs and their functions. Hearing mechanism and specialization. Physiology of photoreceptors and pineal organ.

Unit II

Anatomy and physiology of digestive system: Digestive organ and their mechanism, Functions, Feed ingestion and feeding mechanism - Feeding mechanisms and their control, Effect of starvation.

Unit III

Anatomy and physiology of excretory system: Excretory organs in fish and shellfish and their functions, Mechanism of excretion of nitrogenous waste, Osmoregulation in freshwater fishes, Marine fishes, Elasmobranches, Crustaceans and molluscs.

Unit IV

Muscle physiology: Striated and smooth muscle, Adaptations of muscles for various activities, Neuronal control of muscle contraction, Electric organs, Stenohaline and Euryhaline animals and their tolerance capacity.

Unit V

Endocrine and exoocrine glands: Hormones and their role in appetite, Osmoregulation, Calcium metabolism, Cardiovascular regulation and behaviour, hormone receptors, Endocrine disruption, Mechanism of hormone synthesis, Release, transport and action, Hormone receptors and their characteristics, Neuroendocrine regulation of gametogenesis, Maturation and ovulation processes.

Unit VI

Adaptations to Stress: Basic concept of environmental stress, Acclimatization, Avoidance and tolerance, Stress and Hormones.

VI. Practical

Dissection of different shellfishes and finfishes to understand their internal organs. Influence of temperature and salinity on metabolism, Display of visceral organs; dissection of fish bones and skeleton, Oxygen consumption in relation to body size/ stress/anesthesia, Chronic and acute responses to environmental changes (temperature and salinity) on metabolism, Collection and analysis of body fluids, blood sampling; gamete collection, Oxygen consumption in relation to body size/

stress/anesthesia, Haematology, Acute and chronic stress markers (estimation of glucose, cortisol, total protein, AST, ALT, LDH), Analysis of digestive enzyme activities. Measuring osmoregulatory parameters. measuring reproductive hormones; Audio visual recording of behaviour in simulated experiment.

VII. Suggested Reading

- Alan GH. 1995. *Water Pollution and Fish Physiology*. CRC Press.
- Chavin W. (Ed.). 1973. *Responses of Fish to Environmental Changes*. Charles C Thomas Publ
- Conn EE and Stumpf PK. 1987. *Outline of Biochemistry*. Wiley.
- Diwan, 2007. *Physiology of Marine White Shrimp: Fenneropenaeusindicus*. Delhi Narendra Publishing House: "x, 245p." ISBN: 81-85-375-93-3
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRC Press.
- Evans. 2014. *Physiology of fishes*. Boca Raton CRC Press 2014 Edition: 4th: "xiv, 453p" ISBN: 978-1-4398-8030-2
- Hoar WS and Randall DJ.1988. *Fish Physiology*. Academic Press.
- Jobling M. 1995. *Environmental Biology of Fishes*. Springer.
- Johnston, 2014. *Fish physiology* (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014: "v, 318p" ISBN: 978-93-5107-130-3
- Nielsen , 1983. *Animal Physiology: Adaption and Environment* New York Cambridge University Press Edition: 3rd: "xii, 619p"
- Northcutt RG and Davis RE. 1983. *Fish Neurobiology*. University of Michigan Press
- Pickering AD. 1981. *Stress and Fish*. Academic Press.
- Rankin JC and Jensen FB. 1996. *Fish Ecophysiology*. Chapman and Hall.
- Reinecke, 2006. *Fish Endocrinology*, Vol. 1": Enfield "Science Publishers, Inc.: "xx, 440p" ISBN: 9781578083183
- Reinecke , 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc.: "xx, 441-871pp" ISBN: 978-1-57808-415-9
- Rocha, 2008. *Fish reproduction*. Enfield "Science Publishers, Inc. xiii, 629p" ISBN: 978-1-57808-331-2
- Samantaray, 2015. *Physiology of Finfish and Shellfish*.: New Delhi New India Publishing Agency 2015: "xviii, 230p" ISBN: 978-93-83305-68-1
- Scharrer E. 1963. *Neuroendocrinology*. Columbia University Press.
- Smith, Lynwood S." 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- Val , 2006. *Physiology of Tropical Fishes*. California Elsevier Academic Press: "xiv, 634p"; 23cm ISBN: 0-12-350445-7
- William O. Reece, Eric W. Rowe, 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7, Wiley-Blackwell p. 576.

I. Course title : Fish Histology and Histochemistry

II. Course code : FRM 513

III. Credit Hours : 1+1

IV. Aim of the course

To know the present level of exploitation of marine resources and to impart knowledge on conservation measures. To learn the recent methodologies of sustainable exploitation of renewable resources.

V. Theory

Unit I

Fundamentals of histology: Epithelial, Connective, Muscular, Nervous and other

specialized tissues.- Tools in histology: Principles, design and functioning of microtomes, Automated microtomes, Ultra microtome, Cryostat, Problems and troubleshooting.

Unit II

Techniques in histology: Sample preparation, Obtaining tissue samples, Handling reagents, Fixatives (types of fixatives and effect on tissue), Processing of fixed samples, dehydration (procedure and significance), Embedding, Block making, Staining (staining methods histochemical and immunohistologial methods), dyes and Dye binding reactive groups, Mordants and mordanting, Temporary and permanent preparations, Whole mount preparation

Unit III

Fundamentals of histochemical techniques: Principle and practice, Detection of glycogen, Neutral and acid mucopolysaccharides, Detection of basic proteins, Detection of specific and nonspecific lipids, detection of nonspecific esterases, Detection of acid /alkaline phosphatase.

Unit IV

Systemic Histology: Study of Microscopic structure of the organs of digestive, Respiratory, Urinary, Reproductive, Nervous and cardiovascular systems, Sense organs, endocrines and Lymphoid organs of fish and shellfish.

VI. Practical

Histology slide preparation- studying the general architecture of various tissues- staining- vital staining- histochemistry, Enzyme detection: acid phosphatase, Alkaline phosphatase, Esterases, Nucleic acid staining: Methyl green, Pyronine, Feulgen stain. Study of different types of tissue with help of permanent slides, Effect of fixatives, fixation of tissues, Block preparation and sectioning, Mucolpolysaccharide staining, AB pH 1.5, 2.5. Proteins and lipid staining, Microscopic examination and identification of tissues.

VII. Suggested Reading

- Doaa M, Mokhtar. 2018. *Fish Histology: From Cells to Organs*. 1st Edition Apple Academic Press p. 264.
- Franck Genten, Eddy Terwinghe, André Danguy 2009. *Atlas of Fish Histology*, 1st EditionReference – 224 Pages – 440 Color Illustrations, ISBN 9781578085446
- *Histology:* Roland lesson and Thomas Leesan WB Saunders company Co., Canada
- *Histochemistry* Vol. I II III A G E pearse Churchill Livingstone NY
- Jonathan AC, Roques, Omaimah Maghrabi. 2019. *Fish Histology*.p. 326.
- Sonia Mumford; Jerry Heidel; Charlie Smith; John Morrison; Beth MacConnell; Vicki Blazer. *Fish Histology and Histopathology Contributing*.
- *Text book of Histology* Roland lesson DL. WB Saunders Company, Tokyo.

I. Course Title : Field Techniques In Fisheries Resource Management

II. Course Code : FRM 514

III. Credit Hours : 0+2

IV. Aim of the course

To learn field skills in fishery biology and resources management

V. Practical

Planning a fish survey- survey protocol, Fishery dependant sampling- Netting and

trapping: Seine nets; Trawl nets; Hand nets, throw nets and push nets; Gill nets and trammel nets (Set nets); Traps- hook and line, Assessing CPUE, Fishery independent sampling Snorkelling- SCUBA survey – line transect- manta survey-Tagging, Underwater Visual Census; Hydro–Acoustics-Electrofishing, Egg and larval collection-abundance estimation.

VI. Suggested Reading

- Anderson RO. 1976. *Management of small warm water Impoundments*. Fisheries (Bethesda, Maryland) 1(6): 5-7, 26-28.
- Anderson RO. 1980. Proportional stock density (PSD) and relative weight (Wr): interpretive Indices for fish populations and communities. 27-33 in S. Gloss and B. Shupp, editors. *Practical Fisheries management: more with less in the 1980's*. Workshop proceedings, New York Chapter, American Fisheries Society, Ithaca, New York, USA.
- Dartnall AJ and Jones M. 1986. *A manual of survey methods for living resources in coastal areas*. Australian Institute of Marine Science, Townsville, Australia. 167pp.
- English S, Wilkinson C and Baker V. 1994. *Survey manual for tropical marine resources*. ASEAN Australian Marine Science Project: Living Coastal Resources, Townsville. 368pp.
- Gabelhouse DW Jr. 1984. A length-categorization system to assess fish stocks. North *American Journal of Fisheries Management* 4: 273-285.
- Richmond MD. 1997. *A guide to the seashores of eastern Africa and the Western Indian Ocean islands*. Sida-SAREC, Sweden. 448pp
- Veron JEN. 1986. *Corals of Australia and the Indo- Pacific, Townsville*. Australian Institute of Marine Science. 644pp.
- Wege GJ and RO Anderson. 1978. *Relative Weight (Wr): a new Index of condition for largemouth bass*. 79-91 in GD Novinger and J.G. Dillard, editors. New approaches to the management of small impoundments. Special Publication 5, North Central Division, American Fisheries Society, Bethesda, Maryland, USA

Course Title with Credit Load
Ph.D. in Fisheries Resource Management

Course Code	Course Title	Course Hours
	Major courses	**12 Credits**
FRM 601	Fisheries Resource Conservation and Restoration Biology	2+1
FRM 602	Assessment of Aquatic Biodiversity and Ecosystem	2+1
FRM 603	Functional Physiology of Fishes	2+1
FRM 604	GIS Use in Fisheries Resources	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a student's major subject)	
FRM 605	Fisheries Legislations, Governance and Treaties	**1**+1
FRM 606	Software Applications in Fish Stock Assessment	1+**1**
FRM 607	Coral Reef Management	1+1
	Supporting courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminars	**2 Credits**
FRM 691	Doctoral Seminar-I	0+1
FRM 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 Credits**
FRM 699	Doctoral Research (II semester)	0+15
FRM 699	Doctoral Research (III semester)	0+15
FRM 699	Doctoral Research (IV semester)	0+15
FRM 699	Doctoral Research (V semester)	0+15
FRM 699	Doctoral Research (VI semester)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fisheries Resource Management

I. Course Title : Fisheries Resource Conservation and Restoration Biology

II. Course Code : FRM 601

III. Credit Hours : 2+1

IV. Aim of the course

To understand the protection needs of fisheries resources and aquatic system and restore them to sustain the fisheries resources

V. Theory

Unit I

Functions and importance of Aquatic habitats: Mangrove, Corals, Seagrass beds, and dunes, Turtle nesting grounds, horseshoe crab habitat; Role and functions of aquatic habitat; Human activities and pollution sources; Effects of Conservation Practices on Aquatic Habitats and Fauna.

Unit II

Aquatic habitat conservation: Freshwater habitat and Marine water habitat; Erosion and sediment control-transplantation-stocking-population stabilisation.

Unit III

Restoration and Management: Restoration of freshwater and marine water; Storm water management; Restoration challenges of aquatic habitats, Spawning/ feeding ground protection, Fish refugee-ex-situ conservation.

Unit IV

Marine parks: Formation guidelines- Ecosystem stability- Population viability-effect-coral restoration- Seagrass meadow formation-artificial reef-Heritage sites-Protection of spawning aggregates-.ranching- Relocation-critical stock/ Critical viability stock-Bio-augmentation.

Unit V

Land development guidelines for protection of aquatic habitats: Beach creation and beach maintenance –Aquatic habitat protection and restoration programs, Projects and policies; Governance and regulation

Unit VI

Ecosystem Valuations: Carbon sink- carbon Budgeting –Economic and financial aspects; Economic value of aquatic habitat.

VI. Practical

Visit to natural aquatic habitats like ponds, lakes, rivers, streams, springs, estuaries, bays, and various types of wetlands. Visit to Marine national parks- Eco-sensitive zones. Sampling methods; Isolation, identification and enumeration of aquatic

organisms from diverse aquatic habitats; Suggest management plan for aquatic habitat protection- permit application form. Valuation of ecosystems – awareness on fisheries resource conservation. Visit to reservoir and assess the threats and developing plan for stock rebuilding. Seagrass, Mangrove restoration. Reservoir stock/ ranching

VII. Suggested Reading

- Arthur. 2008. *Integrated monitoring protocol for seagrass ecosystems: a field manual* Description: New Delhi The United Nations: 43p
- Ben-Yami M. 1989. *How to make and set FADs: fish aggregating devices*
- Dawson CL and Hellenthal RA. 1986. *A Computerized System for the Evaluation of Aquatic Habitats Based on Environmental Requirements and Pollution Tolerance* Associations of Resident Organisms. EPA/600/S3-86/019. Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon.
- Larkum. 2007. *Seagrass: biology, ecology and conservation*. Dordrecht Springer: xvi, 691p" ISBN: 978-1-4020-2942
- Leber 2004. *Stock enhancement and sea ranching: developments, pitfalls and opportunities*. Blackwell Publishing Inc., (Malden) 2nd.Description: xii, 562p. 1-4051-1119-4.
- Lim 1998. *Carrying capacity assessment of PulauPayar Marine Park*, Malaysia. Chennai BOBP 1998: 129 Books
- McClanahan. 2000. *Coral reefs of the Indian ocean: their ecology and conservation*. Oxford Oxford University Press: "xxiii, 525p" ISBN: 0-19-512596-7
- Nath S. (Ed.). 2008. *Recent Advances in Fish Ecology Limnology and Eco Conservation*. Vol. VII. Narendra Publ. House
- Ramachandra, 2005. *Aquatic ecosystems: conservation, restoration and management*. Description: New Delhi: Capital Publishing Company: "xiii, 348p"; 25cm ISBN: 81-85589-38-0
- Ramasubramanian, 2004. *Mangroves forest restoration in Andhra Pradesh,* India Description: Chennai MS Swaminathan Research Foundation: 26p Books
- Rogers Caroline S. 1994. *Coral reef monitoring manual for the Caribbean and western atlantic* Food and Agricultural Organization of the United Nations, Rome.
- Thorpe JE, Gall GAE, Lannan JE and Nash CE. (Eds.). 1995. *Conservation of Fish and Shellfish Resources*, Managing Diversity.
- Young TP. 2000. *Restoration Ecology and Conservation Biology*. Biological Conservation.

I. Course Title : Assessment of Aquatic Biodiversity And Ecosystem

II. Course Code : FRM 602

III. Credit Hours : 2+1

IV. Aim of the course

To enrich the knowledge on aquatic biodiversity, assessment of healthiness using indices, threats and conservation needs.

V. Theory

Unit I

Introduction to Aquatic Biodiversity assessments: Measurement, Methods for sampling and analysis, Scales and indices of biodiversity assessment – Biodiversity monitoring- Biotic integrity index-fish- Benthos-Plankton.

Unit II

Biodiversity assessment in ecosystems: (Inland and Marine Resources) Rivers, lakes, estuaries intertidal (mangrove and coral reefs) and gulf and island ecosystem.

Unit III

Threats to biodiversity: Over exploitation, Land reclamation, Exotic species – pollution, habitation, Climate change, Conversion of agricultural land and aquacultural farms (case studies pertaining to sensitive marine/estuarine/freshwater hot spots).

Unit IV

Impacts of anthropogenic intervention on aquatic biodiversity: Damming of rivers, Linking of rivers, Construction of sea walls, Micro hydel power stations, oil rigs, Biodiversity loss, extinction risk and endangered species management.

Unit V

Conservation and Restoration: Declaration of mangrove sanctuaries and mangrove afforestation, Marine protected areas, Riverine ecosystem and diversity management Plan, Introduction of exotic species and their implications, Bio-monitoring, Genetic diversity and conservation.

Unit VI

Ecosystem Conservation Acts: Legal and institutional acts, Regimes of biodiversity: International and national conventions, Biodiversity Acts- Biodiversity Boards/Authority, Benefit sharing mechanism- IUCN criteria – Red List, Wildlife protection act, International treaties, ETP species.

VI. Practical

Preparation of records and inventories of biodiversity of any three critically important ecosystems based on secondary data and field visits. Comparison of biodiversity indices; assessment of biotic integrity index. Compilation of all important International and National laws and conventions related to biodiversity. Collection and identification of flora and fauna from biodiversity hotspot. Identification of scheduled aquatic fauna. Data sheet preparation on IUCN criteria. Assess threats to aquatic biodiversity. Development of conservation plans. Analysis of earlier biodiversity study reports.

VII. Suggested Reading

- Brian G. 1992. *Global Biodiversity – Status of the Earth's Living Resources*. Chapman and Hall.
- Denton TE. 1973. *Fish Chromosome Methodology*. Charles Thomas Publ.
- Elliott A. Norse (Ed.) 1993. *Global marine Biological Diversity*. Inland press, Washington, D.C.383p.
- Gunderson DR. 1993. *Surveys of Fisheries Resources*. John Wiley and Sons. New York. 248 p.
- Khanna DR, Chopra AK and Prasad G. 2005. *Aquatic Biodiversity in India*. Daya Publ. House.
- Kumar U and Asija MJ. 2000. *Biodiversity Principles and Conservation*. Agrobios.
- Lakra WS, Abidi R, Singh AK, Sood N, Rathore G and Swaminathan TR. 2000. *Fish Introductions and Quarantine: Indian Perspective*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Lambshead PJD, Paterson GLJ and Gage JD. 1997. *Biodiversity Professional*. Version 2. National History Museum and the Scottish Association of Marine Science.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*. Taylor and Francis.
- Mahanta PC and Tyagi LK. 2003. *Participatory Approach for Fish Biodiversity Conservation in North East India*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Mahanta PC and Tyagi LK. 2003. *Participatory Approach for Fish Biodiversity Conservation*

in North East India. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Menon AGK. 2004. *Threatened Fishes of India and their Conservation*. Fisheries Survey of India.
- Michael RR. 1997. *Fisheries Conservation and Management*. Prentice Hall.
- Ponniah AG and Gopalakrishnan A. (Eds.). 2000. *Endemic Fish Diversity of Western Ghats*. National Bureau of Fish Genetic Resources (NBFGR), Lucknow.
- Pascoe S. 2005. *Bycatch Management and the Economics of Discarding*. Daya Publ. House.
- Thorpe JE, Talbot C and Miles MS. (Ed.) 1995. *Conservation of Fish and Shell Fish Resource; Managing Diversity*. Academic Press.
- WCMC. 1992. *Global Biodiversity: Status of the Earth's Living Resources*. Chapman and Hall.
- Zoological Survey of India. 2007. *National Symposium on Conservation and Valuation of Marine Biodiversity*.

I. Course Title : Functional Physiology of Fishes

II. Course Code : FRM 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand advanced concepts in physiology of finfish and shell fishes

V. Theory

Unit I

Growth and metabolism: BMR- SDA- Bioenergetics-energy requirement of fish-energy budgeting-digestion-liver function-starvation effect.

Unit II

Sense organs and their functions: Hearing mechanism and specialization, Vision and mechanosensation – photoreceptors; Olfaction. Vision

Unit III

Neurophysiology: Nerve gap junction, Potential, Nerve Pulse, Passage, Circadian rhythm.

Unit IV

Endocrinology physiology: Migration physiology, Endocrine glands, Hormone, Endocrine disruptor- Osmoregulation; Excretion, Blood parameters and hormones, Regulation of electrolytes and ions.

Unit V

Reproductive physiology: Reproductive behaviour – hormones, embryonic development – Pheromones and other signals, Ecomorphology; strategies for buoyancy regulation.

Unit VI

Stress physiology: Stress resistance, Stress tolerance- General Adaptive Syndrome-Immune system – Responses to temperature, Hypoxia and anoxia

VI. Practical

Fish anesthetisation. Analysis of blood composition –blood volume measurement. Histological analysis of gills. Energy requirement studies. Estimation of gross energy and digestible energy of feed. Measuring osmoregulatory parameters. Measuring of cortisol –water regulation. Measuring reproductive hormones. Electro-olfactograms.

Chronic and acute responses to environmental changes. Stress study- symptoms. Observe embryonic development.

VII. Suggested Reading

- Alan GH. 1995. *Water Pollution and Fish Physiology*. CRC Press.
- Conn EE and Stumpf PK. 1987. *Outline of Biochemistry*. Wiley.
- Diwan, 2007. *Physiology of marine white shrimp: Fenneropenaeus indicus.* Delhi Narendra Publishing House: "x, 245p." ISBN: 81-85-375-93-3
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes.* CRC Press.
- Evans, 2014. *Physiology of Fishes*. Boca Raton CRC Press 2014 Edition: 4th : "xiv, 453p" ISBN: 978-1-4398-8030-2
- Hoar WS and Randall DJ.1988. *Fish Physiology*. Academic Press.
- Johnston, 2014. *Fish Physiology* (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014 : "v, 318p" ISBN: 978-93-5107-130-3
- Nielsen , 1983. *Animal Physiology: adaption and environment* New York Cambridge University Press Edition: 3rd : "xii, 619p"
- Northcutt RG and Davis RE. 1983. *Fish Neurobiology*. University of Michigan Press
- Reinecke, 2006. *Fish Endocrinology*, Vol. 1": Enfield "Science Publishers, Inc. : "xx, 440p" ISBN: 9781578083183
- Reinecke , 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc. : "xx, 441-871pp" ISBN: 978-1-57808-415-9
- Samantaray, 2015. *Physiology of Finfish and Shellfish.:* New Delhi New India Publishing Agency 2015 : "xviii, 230p" ISBN: 978-93-83305-68-1
- Scharrer E. 1963. *Neuroendocrinology*. Columbia University Press.
- Smith Lynwood S. 1999. *Introduction to fish physiology*. Narendra Publishing House
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- Val. 2006. *Physiology of tropical fishes.* California Elsevier Academic Press : "xiv, 634p"; 23cm ISBN: 0-12-350445-7
- Rocha 2008. *Fish reproduction.* Enfield "Science Publishers, Inc. Xiii, 629p" ISBN: 978-1-57808-331-2
- William O. Reece, Eric W. Rowe, 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7 , Wiley-Blackwell p. 576.

I. Course Title : GIS use in Fisheries Resources

II. Course Code : FRM 604

III. Credit Hours : 2+1

IV. Aim of the course

To apply the knowledge in GIS for assessment and management of fisheries sector.

V. Theory

Unit I

GIS in Fisheries: Applications of Geographical Information Systems (GIS) based on spatial decisions in fisheries resources.

Unit II

GIS applications in MPA: Application of GIS to evaluate efficiency of Marine Protected Areas (MPA) in India.

Unit III

GIS in shrimp aquaculture: Applications of GIS for sustainable management of shrimp culture in India.

Unit IV

Fish modelling: Modelling of essential fish habitats based on remote sensing, spatial analysis and GIS.

Unit V

Geographical Information Systems: Their past, present and future use in global marine fisheries.

Unit VI

GIS applications in Mangroves: Application of GIS in the management of mangrove forests and Marine Protected Area.

VI. Practical

Applications of GIS software in fisheries resource management. Mapping of fisheries resources using GIS. Exercises in Arc GIS/ Open sources software.

VII. Suggested Reading

- Boca Raton. 2014. *GIS: fundamentals Wise Description*: CRC Press Edition: 2nd: "xv, 322p" ISBN: 978-1-4398-8695-3
- Carocci. 2009. *Geographic information systems to support the ecosystem approach to fisheries: status, opportunities and challenges* FAO Fisheries and Aquaculture Technical Paper; No. 532. Description: Rome Food and Agriculture Organization of the UN: "xv, 101p" ISBN: 978-92-5-106433-7
- COPEMED**.** 2001b. *GIS in fisheries management, Training manual, Higher national diploma in fisheries science for the Mediterranean countries*. Rome, Italy, Department of fisheries and aquaculture (Malta), University of Plymouth (UK) and COPEMED (FAO). 135 pp. Description: New York Routledge: xvi, 471p ISBN: 978-0-415-82906-
- FAO. 2003. *Geographic Information Systems in fisheries management and planning. Technical manual*, by G. De Graaf, F.J.B. Marttin, J. Aguilar-Manjarrez and J. Jenness. FAO Fisheries Technical Paper No. 449. Rome. 162p.
- FAO. 1996. *Geographical information systems. Applications to marine fisheries*, by G.J. Meaden and Do Chi. FAO Fisheries Technical Paper No. 356. Rome. 335 pp. (available at: http://www.fao.org/DOCREP/003/W0615E/W0615E00.HTM).
- FAO. 1997a. *A strategic assessment of the potential for freshwater farming in Latin America*, by J.M. Kapetsky and S.S. Nath. FAO COPESCAL Technical Paper No. 10. Rome. 128 pp. (available at: http://www.fao.org/DOCREP/005/W5268E/W5268E00.HTM).
- Faiz Sami. 2013. *Geographical information systems and spatial optimization*. Boca Raton CRC Press: xxii, 154p ISBN: 978-1-4665-7747-3
- Jeff Thurston Thomas K Poiker and J Patrick Moore. 2000. *Integrated Geospatial Technology – A Guide to GPS, GIS and Data Logging*. John Wiley and Sons.
- Kraak MJ and Ferjan O. 2003. *Cartography, Visualization of Spatial Data*. Prentice Hall.
- Meaden GJ and Kaptesky JM. 1991. *Geographical Information Systems and Remote Sensing in Inland Fisheries and Aquaculture*. FAO Fisheries Tech. Paper No. 318, Rome.
- Pandey. 2014. *Geographic information system*. New Delhi The Energy and Resources Institute 2014: "xvii, 151p" ISBN: 978-81-7993-537-8
- Patel AN and Singh S. 1992. *Remote Sensing – Principles and Applications*. Scientific Publ.
- Sahu. 2008. *Textbook of remote sensing and geographical information system*. New Delhi Atlantic Publishers and Distributors 2008: x; 499
- Schuurman. 2003. *GIS; a short introduction.: Malden "Blackwell Publishing Inc.*, xiii; 169 ISBN: 0-631-23532-9
- Valavanis VD**.** 2002. *Geographic Information Systems in Oceanography and Fisheries*. London, Taylor and Francis. 209 pp. Morain, Stanley A.1999. *GIS solutions in natural resource management*.

- Valavanis VD. 2002. *GIS System in Oceanography and Fisheries*. Taylor and Francis.
- Zhu Xuan. 2016. *GIS for environmental applications: a practical approach*.

I. Course Title : Fisheries Legislations, Governance and Treaties

II. Course Code : FRM 605

III. Credit Hours : 1+1

IV. Aim of the course

To familiarise various legislation, agreement under international law which govern responsible utilisation of fisheries resources

V. Theory

Unit I

Overview of legislation: Critical review of fisheries regulatory and developmental setup in centre and states (spheres of responsibility and division of power); Need for fisheries management; Regulatory, Legal and enforcement regimes. Developmental planning for fisheries; Plan allocation, Programs and performance of fisheries sector; Regional disparities and balanced development; Political economy of fisheries development political ecology.

Unit II

National policies and regulations: Objectives, Salient features and amendments: Indian Fisheries Act, Biodiversity Act, The Environmental (Protection) Act; Policy and regulatory environment in marine fisheries and mariculture Sector (National Policy on Marine Fisheries, MFRA, Deep sea fishing policy, Guidelines for deep sea vessels, Policy on Mariculture, seed certification), Inland Fisheries and Aquaculture Sector (National Policy on Inland Fisheries and Aquaculture), Wet lands, Heritage sites, Hot spots; Brackishwater Aquaculture Sector (CAA), Processing Sector (MPEDA Act; HACCP/ ISO Standards / Food safety/ Quality Safety Management Systems). Fish Marketing and Trade policies, institutionalization of stakeholder participation and Developing policy framework for fisheries.

Unit III

International policy and regulatory scenario in fisheries sector: FAO's CCCRF; IUU; MCS; UN's Law of the Sea and other conventions; treaties; SAARC, NACA, CBD, CITES, MARPOL, IWC, EU's Common Fisheries Policy, RAMSAR-SDG- RFMOs; Fisheries policy and regulation of selected countries in Asian American and Australian regions, Eco-labeling and Certification.

Unit IV

Governance: Need for fisheries governance and institutional framework, Formal and traditional, Fisheries Law, Rights based fisheries, Improve fisheries governance, Multi-stakeholder processes in governance, Case studies in self-governance in the fisheries sector.

VI. Practical

Review of the existing fisheries policies: suggest and draft ideal inland and marine fishery legislations for India. Fisheries regulatory, legal and enforcement regimes-responsibilities of the centre and states of India. Preparation of management plans for specific fisheries. Visit to appropriate Government organizations/research, institutions/NGOs and preparation of working report. Impact survey on regulations-

group discussion on fisheries regulations. Comparison of policies and acts with neighbouring countries. Comparison of Fisheries Regulation Acts of different states.

VII. Suggested Reading

- Anon. 1998. *Maritime Law of India in the International Context*. Bhadarkar Publ.
- Brahtz JFP. 1972. *Coastal Zone Management*. U.N. International Economic and Social Affairs, New York.
- Burke William T. 1992. *Fisheries regulations under extended jurisdiction and international law*: "Food and Agricultural Organization of the United Nations.
- Christy Lawrence C. 1980. *Fisheries legislation in Somalia*. "Food and Agricultural Organization of the United Nations," 1980
- Churchill RR and Lowe AV. 1988. *Law of the Sea*. Manchester University Press.
- Dixit 2013. *Regulating oceanic fishing: international laws and treaties*. Delhi Swastik Publications: "viii, 264p" ISBN: 978-93-81991-04-6
- Gray 2005. *Participation in Fisheries Governance*. Dordrecht Springer: xxv; 363 ISBN: 978-1-4020-3777-1
- Henkin L, Pugh RC and Smit H. 1993. *International Law: Cases and Materials*. West Publ. Co.
- Kumar. U. *Biodiversity Principles and Conservation*, Narendra Publishing House Publishers and Distributors.
- Pandey. 2014. *Fisheries governance and legislation in India*. Delhi Narendra Publishing House 2014: "xviii, 182p" ISBN: 978-93-82471-85-1
- Ponniah AG and A Gopalakrishnan (Eds.). 2000. *Endemic Fish Diversity of Western Ghats* NBFGR, Lucknow 347 p.
- Raval 2013. *Combating Marine Pollution: International Laws and Regulations*. New Delhi Cyber Tech Publications 2013: "viii, 264p"; 21x13cm ISBN: 978-93-5053-150-1
- Sinha RK. (Ed.). 1996. *Marine Resources and Applicable Laws* (World Environmental Series – 009). Commonwealth Publ.
- Verghese CP. 1989. *Fishing Regulation in India's Territorial Waters*. World Fishing.

I. Course Title : Software Applications in Fish Stock Assessment

II. Course Code : FRM 606

III. Credit Hours : 1+1

IV. Aim of the course

To familiarise various software available for stock assessment and use for taking decision to optimally exploit the stock.

V. Theory

Unit I

Introduction to sampling and data collection: Collection of fishery data, Field procedure, Abundance estimation, Transect Study, Sampling-survey, Fish landing centre, Exploratory survey, Fishery independent survey, Non-extractive abundance sampling, Catch effort assessment.

Unit II

Models: single species, Biomass dynamics, Cohort analysis, YPR, Depletion model; Multispecies – Descriptive multispecies, Dynamic multispecies, Aggregate system and Dynamic system models.

Unit III

Softwares: Software for fish stock assessment-open source. Computer based softwares, FiSAT/CEDA/LEDA/LFDA

Unit IV

R program: basics- Application of R program in fisheries.

VI. Practical

Collection of fishery data at landing centres from different gears separately. Details of craft and gear of landing centres and recording of data in the entry forms. Collection of length frequency data for various groups of finfish and shellfish. Estimation of age and growth based on length frequency data. Growth, mortality, population and stock parameters employing computer based softwares, FiSAT/ CEDA/LEDA/LFDA, YIELD and PAR Fish Length structured VPA, Thompson and Bell yield stock prediction for single and multi-fleet version. RAPFISH. Types of simulation model: yield-per-recruit and dynamic logistic model. Multispecies model-Multispecies Virtual population dynamcis. Beverton and Holt yield-per-recruit model; biomass-per-recruit. Relative yield-per-recruit model and yield isopleth. ECOPATH With ECOSIM. Introduction to R program in fisheries. R-programme in stock assessment.

VII. Suggested Reading

- Christensen V, CJ Walters and D Pauly. 2005. *Ecopath with Ecosim: a User's Guide*. Fisheries Centre, University of British Columbia, Vancouver. November 2005 edition, 154 p. (available online at www.ecopath.org)
- FAO. 2995. FISAT II - FAO-ICLARM Stock Assessment Tools II: User's Guide (Computerized Information Series: Fisheries) Paperback – Import, 15 Dec 2005
- Gayanilo FC, Jr. Soriano M, Pauly D. 1988. *A draft guide to the complete ELEFAN*. ICLARM Softw. (2): 65p.
- Keller G. 2001. *Applied Statistics with Microsoft Excel*. Duxbury.
- Paul Med ley. 2003. *Participatory Fisheries Stock Assessment Software*.p.71.
- Sparre, P. 1987. *Computer Programs for Fish Stock Assessment: Length-based Fish Stock*. p.218.

I. Course Title : Coral Reef Management

II. Course Code : FRM 607

III. Credit Hours : 1+1

IV. Aim of the course

To enhance the knowledge on coral reefs, their importance, conservation and restoration management:

V. Theory

Unit I

Introduction: Type of coral reefs and their distribution. Origin of coral reefs – coral reefs of the world, Ecology of coral reefs, factors influencing growth, Productivity of coral reefs, Plants and animals associates of living reef corals and fringing reefs.

Unit II

Reef types: Types of corals - Soft coral, Hard corals, Biology of corals (Nutrition, production, larval dispersal and settlement), Coral resource, Field assessment.

Unit III

Bioactive substances: Bioactive substances of soft and hard corals, Extraction, Analysis, identification, Classification of biactive compounds.

Unit IV

Coral reef management: Economic importance of coral reefs, Ecological role, Threats, Sedimentation in coral reef environment, Restoration.

VI. Practical

Collection and identification of soft and hard corals, Survey of corals and mapping, identification of associated organisms, preparation of checklist and associated organisms of Indian coast- Predatory animals of corals, Extraction of bioactive substances from soft and hard corals. Observations of destructive methods of corals and coral reef fishes. Coral restoration-valuation.

VII. Suggested Reading

- Bakus GJ. 1994. *Coral reef ecosystem*. Oxford and IBH publish co. pvt. Ltd. P. 232.
- Biswas KP. 2008. *Corals of tropical oceans*, Daya publishing House, Delhi. 228 p.
- Caroline S, Rogers *et al*. 1999. *Coral reef monitoring manual for the Caribbean and western Atlantic*. National Park service, Virgin Islands National Park.
- Eugene Rosenberg and Yoss Loya (Eds.). 2004. *Coral Health and disease*. Springer, Bartin -488p.
- Frank Talbot and Clive Wilkinson. 2001. *Coral reefs, management and seagrasses*. A source book for managers. Australian Institute of Marine suck Australia, 193p.
- Frederic M, Bayer Manfred Gracshotf, Jakob Verseveldt. 1983. *Illustrated trilingual glossary of morphological and anatomical terms applied to octocorallia*, E.J., Brill, Dr W. Backhuys Leiden 75 p.
- James PSBR. 1986. *Recent advances in marine biology*. (Dr Johnes 70th Birthday commemoration volume. Today and tomorrow printers and publishers. P. 591.
- McClanahan. 2000. *Coral reefs of the Indian ocean: their ecology and conservation.* Oxford Oxford University Press: "xxiii, 525p" ISBN: 0-19-512596-7
- Peter Sale. Ed. 2006. *CORAL REEF FISHES: Dynamics and Diversity in a Complex Ecosystem*, Pb Academic Press
- Pillai CGS. *Coral reefs of India*
- Polunin NVC and CM Roberts. 1996. *Reef fisheries.* Chapman and Hall, London. P.477.
- Rogers Caroline S. 1994. *Coral reef monitoring manual for the Caribbean and western Atlantic.*

VIII. List of Suggested Journals

- *Advances in Marine Biology*
- *African Journal of Marine Science*
- *American Journal of Physiology - Endocrinology and Metabolism*
- *Annual Review of Cell and Developmental Biology*
- *Applied Entomology and Zoology*
- *Aquaculture*
- *Biodiversity and Conservation*
- *BioTechniques*
- *Bulletin of Marine Science*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *Canadian Journal of Remote Sensing*
- *Canadian Journal of Zoology*
- *Climate Change*
- *Climate Change and Environmental Sustainability*
- *Conservation*
- *Conservation Biology*
- *Conservation Letters*
- *Coral Reefs*

- *Developmental Biology*
- *Ecological Management and Restoration*
- *Environment and Ecology*
- *Environmental Biology of Fishes*
- *Environmental Conservation*
- *Environmental Modeling and Software*
- *Fish and Fisheries*
- *Fish and Shellfish Immunology*
- *Fish Physiology and Biochemistry*
- *Fisheries and Fisheries*
- *Fisheries management and ecology*
- *Fisheries Research*
- *Fisheries technology*
- *Flora and Fauna*
- *General and Comparative Endocrinology*
- *Histology and Histopathology*
- *Histopathology*
- *ICES Journal of Marine Science*
- *Ichthyological Exploration of Freshwaters*
- *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*
- *IEEE Transactions on Geoscience and Remote Sensing*
- *Indian Journal of Fisheries*
- *Indian Journal of Geo-Marine Sciences*
- *International Journal of Remote Sensing*
- *International Journal of Sustainable Development and World Ecology*
- *Japanese Journal of Applied Entomology and Zoology*
- *Journal fisheries biology*
- *Journal for Nature Conservation*
- *Journal of Animal Ecology*
- *Journal of Animal Physiology and Animal Nutrition*
- *Journal of Applied Ecology*
- *Journal of Applied Physiology*
- *Journal of Biodiversity*
- *Journal of Biology*
- *Journal of Coastal Conservation*
- *Journal of Coastal Research*
- *Journal of Comparative Neurology*
- *Journal of Ecology, Ecosystems and Ecophysiology*
- *Journal of Ecophysiology and Occupational Health*
- *Journal of Environment and Bio-sciences*
- *Journal of Environmental Biology*
- *Journal of Experimental Marine Biology and Ecology*
- *Journal of Fish and Shellfish Immunology*
- *Journal of Fish Behaviour*
- *Journal of Fish Biology*
- *Journal of Fish Diseases*
- *Journal of Fish Physiology and Biochemistry*
- *Journal of the Indian Society of Remote Sensing*
- *Journal of the Marine Biological Association of India*
- *Journal of Zoology*
- *Marine Biology*
- *Molecular Ecological Notes*
- *Molecular Marine Biology and Biotechnology*
- *New Zealand Journal of Marine and Freshwater Research*
- *North American Journal of Fisheries Management*

- *North American of Journal of Aquaculture*
- *Oceanography and Marine Biology*
- *Remote Sensing*
- *Restoration Ecology*
- *Reviews in Fish Biology and Fisheries*
- *Seaweed Research and Utilisation*
- *Sustainability*
- *Weed Biology and Management*
- *Weed Research*
- *Weed science*

List of Suggested e-Resources

- http://www.iucnffsg.org/
- http://www.ncseonline. org/WHPRP/cms.cfm?id=2524, April 20 2009
- http://tafcc.forestry.oregonstate.edu/.
- http://www.csiro.au/news/Climate-Change-Hits-Fish.html
- http://www.fao.org/fishery/topic/16072/en
- http://www.stat.uiowa.edu/~rlenth/Power.
- https://bhuvan.nrsc.gov.in/bhuvan_links.php
- https://cran.r-project.org/web/packages/TropFishR/TropFishR.pdf
- https://earth.esa.int/web/guest/missions/3rd-party-missions/current-missions/oceansat-2
- https://earthexplorer.usgs.gov/
- https://ecopath.org/
- https://gisgeography.com/gvsig-software/
- https://github.com/tokami/TropFishR
- https://i0.wp.com/geoawesomeness.com/wp-content/uploads/2017/06/GLOVIS.jpg?ssl=1
- https://mrag.co.uk/sites/default/files/fmspdocs/R7947/R7947_Guide.pdf
- https://nctc.fws.gov/resources/course-resources/fish-histology/Fish_Histology_Manual_v4.pdf
- https://neo.sci.gsfc.nasa.gov/
- https://palaeo-electronica.org/2001_1/past/issue1_01.htm
- https://www.cites.org
- https://www.esri.com/
- https://www.iucn.org/resources/conservation-tools/iucn-red-list-threatened-species
- https://www.iucnredlist.org/
- https://www.worldwildlife.org/
- www.barcodinglife.org
- www.bhuvan.org.
- www.cites.org
- www.cmfri.org.in/
- www.fao.org
- www.fishbase.org.
- www.icun.org
- www.indiaenvironmentportal.org.in
- www.devbio.com
- http://people.ucalgary.ca/~browder/virtualembryo/dev_biol.html

Suggested Broad Areas for Master's and Doctoral Research

- Mapping of fisheries resources in different freshwater, brackish water and marine water bodies
- Impact of intensive-aquaculture activities on biodiversity of coastal ecosystems
- Fish stock assessment in different freshwater bodies using FiSAT
- Analysis of productivity in different freshwater bodies
- Assessment of bycatch from trawl, bottom set gillnet and other gears
- Sea ranching and effect of ranching in the marine ecosystem

- Biology and assessment of deepsea fishery resources
- Estimation of biodiversity and abundance of endangered species of sponges, corals, gastropods, bivalves, sea cucumbers, fishes, sea snakes, turtles, birds and marine mammals
- Effect of conservation measures in the restoration of depleting fish stocks
- Development of proper guidelines for commercial deep sea fishing
- Impact of Coastal Regulation Zone on the stock replenishment
- Monitoring, Control and Surveillance (MCS) systems for inland and marine capture fisheries
- Collection of satellite information on various aquatic resources and ground truthing Interpretation of satellite pictures for resource management
- Use of remote sensing for Potential Fish Zone
- Estimation of flora and faunal diversity of mangroves and coral reefs.
- Estimation of fleets and catches at landing sites for effective fisheries management
- Neurohormones controlling the reproduction of commercial crustacean Species
- Identification of commercially important species of finfish and shellfish eggs and larvae, spat.
- Forecasting the fishery potential through the study of abundance of finfish and shellfish eggs and larval in the marine ecosystem.
- Studies on migratory pattern of fishes
- Food and feeding habits of larval stages of shell and finfishes.
- Catalogue preparation of commercially important fishes (FW, BW and Marine)
- Studies on biodiversity estimates for coastal resources, fresh water bodies.
- Upgradation of food and feeding habit of commercially important fishes and shellfishes using latest techniques
- Microsatellite based identification of commercial fishes
- Karyotaxonomy of commercially important fishes and shellfishes
- Ecopath modelling for minor reservoir, small waterbody
- Conservation biology and marine pollution
- Coral reef reproduction, assessment, monitoring and management
- Assessment of Coral reef associated fauna and flora biodiversity
- Remote sensing and geospatial analysis of coral reef ecosystem.
- Spawning grounds characterisation
- Estimation of MSY in various marine ecosystems
- Stock assessment and biology of Indigenous and endemic fisheries resources
- Multispecies fish stock assessment
- Fish stock assessment in various freshwater, brackishwater and marine ecosystems using FiSAT
- Mapping of coral resources and conservation strategies
- Mapping of seaweed resources
- Up gradation and Molecular characterization of various seaweed species available in the marine ecosystem
- Spawning biomass estimation
- Estimation of Taxonomic distinctness for major finfish and shellfish resources using molecular tools

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Aquatic Environment Management

Preamble

(Aquatic Environnent Management)

The objective of this course is to develop specialised human resources equipped with the latest knowledge related to changes in Aquatic Environment Management strategy in light of changing ecological condition, climatic variability and their impact on fish and fisheries.

The course provides advance skills and exposure in the wide range of topics necessary for the aquatic environment management at the post-graduate and doctoral levels.

Emphasis is given both on developing expertise in the techniques, understanding future environmental challenges and different gametes of aquatic environmental management including coastal zone management.

The new and innovative courses included for M.F.Sc. are Climate Change: Impact and Management, Inland Aquatic Resource Management and Utilization and Management of Aquatic Algal Resources and for Ph.D. Water Issues Challenges and governance and Aquatic Plant Resource and its Management. Practical credits have been enhanced and more emphasis is given towards field exposure and case studies based learning. These courses may help in understanding the policy issues related to Aquatic Environment Management.

Course Title with Credit Load
M.F.Sc. in Aquatic Environnent Management

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
AEM 501	Inland Aquatic Resource Management	2+1
AEM 502	Chemical Interactions in Aquatic Environment	2+1
AEM 503	Analytical Techniques in Environnemental Sciences	1+2
AEM 504	Climate Change: Impact and Management	1+0
AEM 505	Aquatic Pollution and Management	2+1
AEM 506	Eco-toxicology	1+1
AEM 507	Coastal Ecology and Coastal management	2+1
AEM 508	Aquatic Microbiology	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
AEM 509	Aquatic Environment and Biodiversity	1+1
AEM 510	Plankton Ecology and Trophic Dynamics	1+1
AEM 511	Environmental Biotechnology	1+1
AEM 512	Fisheries Oceanography	1+1
AEM 513	Utilization and Management of Aquatic Algal Resources	2+1
AEM 514	Restoration Ecology	1+1
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 Credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
AEM 591	Master's Seminar I	0+1
	Masters' Thesis Research	**30 Credits**
AEM 599	Master's Research (Semester III)	0+15
AEM 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Aquatic Environnent Management

I. Course Title : Inland Aquatic Resource Management
II. Course Code : AEM 501
III. Credit Hours : 2+1
IV. Aim of the course

- To educate the students on ecology of wetlands and its importance
- Manipulation and mapping of wetlands for sustainable management of these ecosystems.

V. Theory

Unit I

Types of inland aquatic resources: Concept of watershed; Lacustrine, Riverine, Wetlands, Floodplains, Swamps and Ponds, Habitat characteristics, Flora and Fauna, Economic importance; Relationship between productivity (primary and secondary) and fish yield.

Unit II

Wetlands: Trophic classifications, Functions, Degradation of wetlands (causes consequences; Constructed wetlands; Restoration, Conservation and management of wetlands, Ecological services and livelihood from wetland.

Unit III

Ecological engineering: Concept, Application and restoration; Resource enhancement; Biomanipulation - Top-down and bottom-up methods; Integrated Environment Management (IEM) Programme, Ramsar convention.

Unit IV

River continuum concept and new paradigm shift, River linking; Mapping of aquatic resources using remote sensing and GIS.

Unit V

Water budget and Environmental flow, Its significance in water conservation and ecology, Environmental Economics and auditing, Ecosystem approach to resource management.

Unit VI

Wasted and degraded resources, Coastal and inland saline areas, Adaptations of organisms, restoration/remediation strategies, Prospects of gainful use of available technologies.

VI. Practical

Collection, preservation and analysis of flora and fauna (plankton, macrophytes and benthos) of wetland/degraded aquatic ecosystem. Calculation of shoreline development index and morphometry. Calculation of Morpho-edaphic index. Field visits to selected lakes/wetlands/degraded/restored ecosystem.

VII. Suggested Reading

- Andy D Ward, Stanley W Trimble, Suzette R Burckhard, John G Lyon. 2015. *Environmental Hydrology*, CRC press.
- Dodds WK. 2002. *Freshwater Ecology: Concepts and Environmental Applications*. Academic Press, New York.
- Jan Vymazal. 2010. *Water and Nutrient management in Natural and constructed wetlands*, Springer.
- Mitsch WJ and Jorgensen SE. 2003. *Ecological Engineering and Ecosystem Restoration*. 2nd revised edition, John Wiley and Sons, New York, 424 pp.
- Mitsch WJ. 2009. *Wetland Ecosystems*. John Wiley and Sons. 295 pp.
- Nath S. (Ed). 2008. *Recent Advances in Fish Ecology Limnology and Eco Conservation* Vol 7. Narendra Publishing House, New Delhi.

I. Course Title : Chemical Interactions in the Aquatic Environment

II. Course Code : AEM 502

III. Credit Hours : 2+1

IV. Aim of the course

- To acquaint the students with basic principle of chemistry with special reference to soil chemistry
- To study physical, chemical, biological and geological interactions in the aquatic environment.
- To study the nutrient dynamics and fate of contaminates in the aquatic environment.

V. Theory

Unit I

Basic principles: Chemical kinetics, Chemical equilibrium and Redox chemistry, Solubility concept, Dissolution kinetics.

Unit II

Sediment properties: Weathering of rocks; Soil formation, Soil profile, Mineral weathering; transformation, weathering products, Structure of oxide and silicate minerals, Sources of charge, adsorption on to clay minerals of major cations and anions, Double layer, Ion exchange - concept and source of cation exchange capacity (CEC), Sediment texture.

Unit III

Nutrient dynamics: Nutrient holding capacity of sediments and fixation, Processes controlling elemental cycling.

Unit IV

Transport of nutrients: Availability of Nutrients and productivity inaquatic ecosystem

Unit V

Processes in the degradation and conversion of organic matter, Humus and biogeochemical substances.

Unit VI

Fate of Contaminants: Degradable and non-degradable contaminants, Speciation

and transport of contaminants, Bio-availability; Bio-accumulation and Biomagnification.

VI. Practical

Sample collection techniques

Determination of physicochemical parameters of sediment – pH, electrical conductivity, redox potential, soil texture, bulk density, particle density, porosity, total and organic carbon, total and available nitrogen, phosphorus, potassium and micronutrients; C: N: P ratio, CEC

VII. Suggested Reading

- Claude E Boyd. 1995. *Bottom Soils, Sediment, and Pond Aquaculture*, Chapman and Hill
- Essington ME. 2003. *Soil and Water Chemistry: An Integrated Approach*, CRC Press.
- Evangelou VP. 1998. *Environmental Soil and Water Chemistry: Principle and Application*, Wiley-Interscience.
- Lindsay WL. 1979. *Chemical Equilibria in Soils*. John Wiley and Sons, New York.
- Stumm W and Morgan JJ. 1996. *Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters*. John Wiley and Sons, New York.
- Tan KH. 1998. *Principles of Soil Chemistry*. CRC Press Inc., Boca Raton
- TD Biswas and SK Mukharjee. 2000. *Textbook of Soil Science*. Tata McGrow-Hill Publishing Company Limited, ND.

I. Course Title : Analytical Techniques in Environmental Sciences

II. Course Code : AEM 503

III. Credit Hours : 1+2

IV. Aim of the course

- To teach the student advance analytical techniques employed in environmental studies
- To acquaint the student to the advanced instrumentation employed in environmental studies

V. Theory

Unit I

Qualitative and quantitative analytical techniques including Gravimetric and volumetric analyses used in environmental science, Sampling techniques and procedures, Factors affecting the choice of analytical techniques, Interferences and their minimization, Laboratory safety measures.

Unit II

Photometric techniques: Theory, instrumentation and application of spectrophotometry and spectroscopy, AAS, FT-IR, ICP-MS, XRD, XPS, Biosensor, Microscopic Techniques etc. Theory and applications of electrophoresis, Principles and uses of ultra-centrifugation, Tracer Techniques, Isotopes in environmental analysis.

Unit III

Separation techniques: Chromatography – theory, instrumentation and applications of thin layer, paper, ion-exchange, size exclusion, high performance liquid and gas, Methods of preparing biological samples for chromatographic analysis, GC-MS.

Unit IV

Bioanalysis techniques: Immunoassay – Principle, methods and applications and Biosensors – components, characteristics, applications, impacts and challenges. **Nanotechnology:** Preparation of nanoparticles, characterization and applications

VI. Practical

Estimation of environmental parameters by UV-Visible spectrophotometer, Estimation by AAS, Estimation of environmental parameters using HPLC, Estimation of environmental parameters using GC/GC-MS, Estimation of environmental parameters by CHNS analyser, etc.

VII. Suggested Reading

- APHA, AWWA and WEF. 2009. *Standard Methods for the Examination of Water and Wastewater* (Eaton AD, Clesceri LS, Rice EW, Greenberg AE), 21st edition. American Public Health Association, Washington DC.
- Bryan M Ham and Aihui MaHam. 2016. *Analytical Chemistry: A Chemist and Laboratory Technician's Toolkit*, Wiley.
- Fishbein L. 1973. *Chromatography of Environmental Hazards: Metals, Gaseous and Industrial Pollutants.* Elsevier Publications, Amsterdam.
- GR Chatwal and Sham Anand. 2011. *Instrumental Methods Of Chemical Analysis*, Himalaya Publishing House.
- Jeffery GH, Basset J, Mendham J and Denney RC. (Eds.). 1989. *Vogel's Textbook of Quantitative Chemical Analysis*. Longman Publishers, Singapore.
- Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT and Sumner ME. (Eds.). 1996. *Methods of Soil Analysis:* Part 3 - Chemical Methods. SSSA-ASA, Madison.

I. Course Title : Climate Change: Impact and Management

II. Course Code : AEM 504

III. Credit Hours : 1+0

IV. Aim of the course

- To understand global warming, its impact on the aquatic environment and fisheries
- To know about the different legislation across the country to combat climate change

V. Theory

Unit I

Weather and climate, Greenhouse effect, Radiative balance, Climatic migration, Impact on women; Carbon Sequestration and trading, Projected trends of climate change and disasters.

Unit II

Climate change, Its impacts, Aquatic ecosystem, Capture and culture fisheries, Carbon footprint in fisheries and aquaculture.

Unit III

Ocean acidification, Global ocean circulation, El Nino and Southern Oscillation, IPCC and its reports, UNFCCC, Kyoto Protocol, Politics of climate change.

Unit IV

Climate change adaptation and mitigation, Vulnerability assessment, Mitigation and Adaptation measures, Climate-resilient aquaculture, Climate smart villages-NICRA.

VI. Suggested Reading

- Hulme M. 2009. *Why we disagree about climate change: Understanding controversy, inaction and opportunity.* Cambridge University Press.
- Murphy RP and Boomer D. 2008. *An Appeal to Reason: A Cool Look at Global Warming*, By Nigel Lawson-super-1. Economic Affairs, 28(4), pp.80-81.
- Pecl GT, Araújo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, Clark TD, Colwell RK, Danielsen F, Evengård B and Falconi L. 2017. *Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science,* 355(6332), p.eaai9214.
- Schmutter K, Nash M and Dovey L. 2017. Ocean acidification: assessing the vulnerability of socioeconomic systems in Small Island Developing States. Regional environmental change, 17(4), pp.973-987.

I. Course Title : Aquatic Pollution and Management

II. Course Code : AEM 505

III. Credit Hours : 2+1

IV. Aim of the course

- To impart fundamental and advanced knowledge on different aspects of aquatic pollution
- To impart fundamental and advanced knowledge on management of different aquatic resources

V. Theory

Unit I

Aquatic pollution: Sources, types and impacts, Pollution problems of groundwater resources (arsenic, fluoride, nitrate, pesticides), Sources of contamination and management issues.

Unit II

Pollutants: Sewage, pesticides, hydrocarbons, nutrients, Metals, Radioactive wastes, Biomedical wastes, hazardous chemicals, Microplastics, Nanoparticles; Dispersal and fate of pollutants.

Unit III

Air and soil pollution: Smoke, Smog, Photochemical smog and SPM, Impact of air and soil pollution on the aquatic environment.

Unit IV

Methods of waste disposal, water quality criteria: National and International standards; ISO-14000(EMS), EIA, Management strategies, Emerging issues in aquatic environment.

Unit V

Waste waters: Their nutrient potentials, Scope and limitations, Treatment methods; Recovery of nutrients from liquid and solid wastes, Ecological sanitation, closing the loop.

Unit VI

Integrated water management: Water conservation measures, Water use and reuse in aquaculture, Water use efficiency, Restoration ecology and rehabilitation

VI. Practical

Determination of total dissolved and suspended solids, Determination of BOD,

Determination of COD, Determination of NH_3–N, Determination of Nitrate/Nitrite-N, Determination of Phosphate-P, Determination of metals and pesticides, Visit to a sewage treatment plant/fish processing unit/industries.

VII. Suggested Reading

- APHA (American Public Health Association). 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd Edition. American Public Health Association, Washington, D.C.
- Baird DJ, Beveridge MCM, Kelly LA and Muir JF. 1996. *Aquaculture and Water Resources Management.* Blackwell Science Ltd., Oxford.
- Clark RB. 2001. *Marine Pollution.*Oxford University Press.
- Czernuszenko W and Rowinski P. 2005. *Water quality hazards and dispersion of pollutants*. Springer Science and Business Media.
- Gray NF. 2004. *Biology of Wastewater Treatment*. Oxford University Press, London.
- Mason C. 2002. *Biology of Freshwater Pollution*. 4th edition, Benjamin Cummings, 400 pp.
- Trivedy RK. 1998. *Advances in Wastewater Treatment Technologies*. Global Science, Aligarh.

I. Course Title : Eco-toxicology

II. Course Code : AEM 506

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on toxicological aspects of various pollutants

- To impart the knowledge on emergent toxicants, their fate in aquatic environment and risk assessment
- To impart knowledge on the effects of toxic chemicals on populations, communities and aquatic ecosystems

V. Theory

Unit I

Toxicity: Factors influencing toxicity, Environmental, genetic and nutritional, Ecological effects of toxicants, Genotoxicity, Neurotoxicity, Toxicology of emerging contaminants, PBDE, New generation pesticides and antibiotics, Antibiotic resistance.

Unit II

Toxicity evaluation: Toxicity Testing, Microcosm and mesocosm Tests, Dose-Response Relationships, Bioassay, Physiological and molecular evaluation

Unit III

Metabolism: Metabolism of toxic substances by aquatic microbes and other organisms consequences, synergistic and antagonistic effects, Acute poisons and accumulative poisons, Biomonitoring and biosensors.

Unit IV

Bioaccumulation, Bioconcentration and Biomagnification, Systemic effects of toxic metals, Pesticides and Herbicides; Effect of select toxicants on aquatic life and detoxification mechanisms, Interrelationship of xenobiotics with other environmental variables, biofilter organisms.

VI. Practical

Toxicity evaluation of heavy metals on selected organisms by bioassay techniques,

Toxicity testing methods, Toxicity assessment of pesticides and other contaminants on selected organisms.

VII. Suggested Reading

- Calow PP. 2009. *Handbook of Ecotoxicology*. Blackwell Science, 871 pp.
- Gasol JM, Kirchman DL. 2014. *Microbial Ecology of the Ocean*. 3rd Edition, Wiley Blackwell, 507 pp.
- Hoffman DJ. 1995. *Handbook of Ecotoxicology*. Lewis Publication, Boca Raton.
- Jorgensen SE. 2010. *Ecotoxicology*. Academic Press. 389 pp.
- Kumar A. (Ed). 2008. *Aquatic Environment and Toxicology,* Daya Publishing House, New Delhi.
- Mayer H. 1977. *Aquatic Toxicology and Hazards Evaluation*. ASTM Publication, Philippines.
- Newman MC. Clements, W.H. 2008. Ecotoxicology: A comprehensive treatment. CRC press. 852 pp.
- Rand GM and Petrocelli SR. 1994. *Fundamentals of Aquatic Toxicology*. Hemisphere Publishing Corporation, Washington.
- Raymond JM, Neisink RJM, de Vries J and Hollinger MA. 1996. *Toxicology: Principles and Applications*. CRC Press, New York.
- Ware GW. 2002. *Review of Environmental Contamination and Toxicology*. Springer –Verlag, New York.
- Walker CH, Hopkin SP, Sibly KM, Peakall DB. 2014. *Principles of Ecotoxicology*, 2nd Edition. Taylor and Francis, 308 pp.

I. Course Title : Coastal Ecology and Management

II. Course Code : AEM 507

III. Credit Hours : 2+1

IV. Aim of the course

- To impart theoretical and practical knowledge about fundamental and advanced aspects of marine ecology.
- To acquaint the students with the recent approaches for coastal resources management.

V. Theory

Unit I

Coastal resources: Characteristics of coastal ecosystems (flora and fauna, trophic relationship, nutrient production, cycle and transport).

Unit II

Mangrove ecosystem: Species diversity, distribution and importance; Other intertidal systems - Seagrass, Sandy beach, Lagoon and estuary.

Unit III

Developmental activities and biodiversity loss: Human settlements, Industries, Shore protection works, Ports, transport systems and Waste disposal.

Unit IV

Ecological issues, Impacts of environment changes, Threats to biodiversity, Habitat destruction; Depletion of fisheries resources.

Unit V

Coastal Zone Management: Integrated Coastal Zone Management (ICZM) - its benefits, Principles, Goals and objectives, scope, zonation.

Unit VI

National and international policies and planning for coastal resource management: Natural hazards and disasters -protection and management; Socioeconomic impacts and its assessment.

VI. Practical

- Analysis of soil and water characteristics of coastal areas and determination of different factors.
- Collection, preservation and identification of coastal biological communities
- Survey of different coastal zones.

VII. Suggested Reading

- Cairns J Jr. 1994. *Implementing Integrated Environmental Management* Virginia Tech University.
- Clark JR. 1992. *Integrated Management of Coastal Zones*. FAO Fisheries Technical Paper No. 327, Rome.
- *Coastal Area Management and Development* 1982. U.N. Department of International Economic and Social Affairs, New York.
- David S and Jeremy P. 2001. *Inshore Fisheries Management. Methods and Technologies in Fish Biology and Fisheries* (vol. 2). Kluwer Academic publishers, London.
- Khanna BK. 2000. *All You Wanted to Know About Disasters*. New India Publishing Agency.
- Ramkumar M, James A, Menier D, Kumarswamy K. 2018. *Coastal Zone Management: Global Perspective*, Regional Processes, Local Issue. Elsevier.

I. Course Title : Aquatic Microbiology

II. Course Code : AEM 508

III. Credit Hours : 1 +1

IV. Aim of the course

- To impart knowledge on aquatic microorganisms with reference to their role in the aquatic environment and bioprospecting.
- To impart knowledge and skill on culture and culture independent techniques for microbial studies.

V. Theory

Unit I

Distribution and classification: Microbial community in freshwater; Estuarine and marine environment (types and abundance); Factors affecting microbial growth and abundance; Extremophiles and their significance.

Unit II

Microbial interaction: interrelationships, Microbial degradation of persistent organic pollutants (POPs); Microorganisms and public health: Water-borne pathogens of public health importance - Protozoans, bacteria, enteroviruses; Microbial toxins; Algal toxins; Disinfection methods; Microbial standards for different water uses.

Unit III

Principles and applications of bioprocesses: Bioremediation, Biofertilization, Biofilms, Biofloc, Probiotics, Bio-leaching, Bio-corrosion, Bio-fouling; Microorganisms as Bioindicators and Biosensors.

Unit IV

Methods of assessing microbial biomass production; Bioprospecting: Current practices in bioprospecting and biopiracy; Microbial metabolites and its industrial application.

VI. Practical

- Isolation, identification and enumeration of algae and bacteria from polluted aquatic habitats
- Maintenance of algal and bacterial cultures
- Microbial sensitivity testing
- Bio-activity testing
- Disinfection methods

VII. Suggested Reading

- Dhevendaran K. 2008. *Aquatic Microbiology*, Daya Publishing House, New Delhi.
- Droop MR, Jannasch HW. 2012. *Advances in Aquatic Microbiology*. Volume One. Academic Press, 388 pp.
- Frobisher M, Hinsdill RD, Crabtree KT and Goodheart CR. 1974. *Fundamentals of Microbiology*. WB Saunders Company, Philadelphia.
- Maier RM, Pepper IL, Gerba CP. 2009. *Environmental Microbiology,* 2nd Edition, Academic Press, 624 pp.
- Pepper IL, Gerba CP, Gentry TJ and Maier RM. (Eds.) 2009. *Environmental Microbiology*, 2nd Edition, Academic Press, 624 pp.
- Rheinheimer G. 1992. *Aquatic Microbiology*. John Wiley and Sons, Sigee, D.C. 2005. Freshwater microbiology, Wiley Publisher, 517pp.
- Singh J, Sharma D, Kumar G, Sharma NR. 2018. *Microbial Bioprospecting for Sustainable Development*. Springer publisher, 396 pp.
- Stanier R, Ingraham JL and Adelberg EA. 1976. *General Microbiology*. MacMillan Publishers, London.
- Vernam AH and Evans M. 2000. *Environmental Microbiology*. Blackwell Publishing, U. K.

I .Course Title : Aquatic Environment and Biodiversity

II. Course Code : AEM 509

III. Credit Hours : 1+1

IV. Aim of the course

- To acquaint the students with the theoretical and practical aspects of the aquatic environment and biodiversity concept.
- To impart knowledge on biodiversity conservation and ecosystem approach to resource management.

V. Theory

Unit I

Basic ecological concepts - Habitat ecology, systems ecology, Synecology, Autecology; Characteristic features of different biomes; Concept of community, Continuum, Community attributes, Community development, Ecological succession, Changes in ecosystem production, Concept of climax.

Unit II

Biodiversity – Definition and concept; Categories of biodiversity - Species diversity, Genetic Diversity; Habitat Diversity; Ecosystem services and Economic appraisal of biodiversity

Unit III

Biodiversity indices and their significance; Concepts of Index of Biotic Integrity (IBI).

Unit IV

Biodiversity Conservation - Global diversity patterns and loss of biodiversity; Conservation measures; Biodiversity hotspots, Biosphere reserves; National parks, sanctuaries; Marine protected areas; Convention on Biological Diversity; IUCN; CITES; WWF; Ramsar Convention; Man and Biosphere Programme; Indian legislations to biodiversity conservation, Ecological Sensitive Areas (ESAs)

VI. Practical

- Collection and identification of flora and fauna from different ecosystems.
- Calculation of biodiversity indices – Shannon-Wiener index; Simpson index, Hill index etc.
- Visit to biodiversity hotspots and ESAs.

VII. Suggested Reading

- Barnes RSK and Mann KH. eds. 2009. *Fundamentals of aquatic ecology*. John Wiley and Sons.
- Carter RWG. 1998. *Coastal Environments: An Introduction to the Physical, Ecological and Cultural Systems of Coastlines*. Academic Press, London.
- Dodds W and Whiles M. 2010. *Freshwater Ecology*, 2nd Edition, Concepts and Environmental Application of Limnology. Academic Press, London.
- Kormondy EJ. 1986. *Concepts of Ecology*, Prentice-Hall, New Delhi.
- Okuda N, Watanabe K, Fukumori K, Nakano SI and Nakazawa T. 2014. *Biodiversity in aquatic systems and environments*: Lake Biwa. Springer Japan.
- Park CC. 1980. *Ecology and Environmental Management.* Butterworths, London.

I. Course Title : Plankton Ecology and Trophic Dynamics

II. Course Code : AEM 510

III. Credit Hours : 1+1

IV. Aim of the course

- To impart theoretical knowledge about the ecology of plankton in diverse aquatic environment with a reference to their ecological role in trophic dynamics.
- To improve the technical skills for sampling, identification and effects of different ecological conditions on plankters.

V. Theory

Unit I

Plankton diversity and productivity: Definition, Classifications and functions in aquatic ecosystem; Primary and secondary production - Production - Biomass (P/B ratio), factors affecting production.

Unit II

Sampling and preservation techniques- Plankton nets and recorders, Cryopreservation methods and their significance, Indices of diversity.

Unit III

Ecology of phytoplankton: Freshwater and marine, Spatial and temporal variations, succession; Contribution of nanoplankton to primary production; Algal

blooms and algal toxins; Nutrient manipulation for algal growth and control; Biological control of algal blooms; Mass culture of phytoplankton as a live-feed; Role of microalgae in carbon sequestration.

Unit IV

Ecology of zooplankton: Freshwater and marine –Feeding behavior, Reproduction of important zooplankters; Swarms; Indicator species; Predator-prey relationship; Impact of grazing on the aquatic ecosystem; Vertical migration of zooplankton in relation to fish catch; Importance of zooplankton in the larval rearing of fish; Environmental manipulation for live-feed production; Mass culture of zooplankton as a live-feed.

VI. Practical

- Collection, preservation and estimation of phytoplankton and zooplankton
- Periphyton estimation.
- Identification and classification of various phytoplankton and zooplankton.
- Mass culture of Phytoplankton and zooplankton.
- Preparation of permanent slide and sectioning.

VII. Suggested Reading

- Castellani C and Edwards M. eds. 2017. *Marine Plankton: A Practical Guide to Ecology, Methodology, and Taxonomy*. Oxford University Press.
- Fasset NG. 1997. *A Manual of Aquatic Plants*. Allied Scientific Publishers, Bikaner.
- Kiørboe T. 2008. *A mechanistic approach to plankton ecology*. Princeton University Press.
- Lund HC and Lund JWG. 1995. *Freshwater Algae*. Biopress Ltd., Bristol.
- Mitra A. 2006. *Introduction to Marine Phytoplankton*, Narendra Publishers, New Delhi.
- Sournia A. 1978. *Phytoplankton Manual*. UNESCO Publication, Paris.
- Sardet C. 2015. *Plankton: wonders of the drifting world*. University of Chicago Press.
- Tomas CR. 1997. *Identifying Marine Phytoplankton*. Academic Press, San Diego.
- Harris RP, Wiebe PH, Lenz J, Skjoldal HR and Huntley M. (eds). 2000. *ICES Zooplankton Methodology Manual*. Academic Press.

I. Course Title : Environmental Biotechnology

II. Course Code : AEM 511

III. Credit Hours : 1+1

IV. Aim of the course

- To impart basic knowledge on biological methods for environmental management
- To impart basic knowledge on isolation of bacteria implicated in bioremediation and demonstration of their potential for environmental management
- To impart basic knowledge on Application of Molecular techniques in environmental management

V. Theory

Unit I

Fundamentals of environmental biotechnology: Environmental biotechnology-Concepts and Scope; Conventional and Modern approaches; IPR issues related to environmental biotechnology.

Unit II

Environmental monitoring: Cellular and molecular markers of environmental pollution monitoring; Bioindicators; Biosensors and nano-sensors.

Unit III

Remediation: Bioremediation; Genetically-improved/engineered organisms - Basic concepts; Applications in remediation of metals, Pesticides and hydrocarbons.

Unit IV

Consortia of microbes for environmental protection – Concept, Scope and Feasibility, Recombinant DNA technology, Culture intendent nucleic acid-based techniques.

VI. Practical

- Genomic, Metagenomic and plasmid DNA isolation.
- Case studies on wastewater treatment using biotechnological tools.
- PCR amplification of 16S rRNA gene as a tool for biomonitoring.
- PCR application of functional gene implicated in bioremediation.
- Screening of microbes for biodegradation properties.

VII. Suggested Reading

- Buck RP, Hatfield WE, Umana M and Bowden E F. 1990. *Biosensor Technology - Fundamentals and Applications*. Marcel Dekker, New York.
- Evans GG and Furlong J. 2011. *Environmental Biotechnology: Theory and Application*. John Wiley and Sons.
- Fujita M and Ike M. 1994. *Wastewater Treatment Using Genetically Engineered Microorganisms*. Technomic Publishing Co. Inc., Lancaster.
- Kingsman SM and Kingsman AJ. 1988. *Genetic Engineering: An Introduction to Gene Analysis and Exploitation in Eukaryotes*. Blackwell Scientific, Oxford.
- Sambrook J and Russel DW. 2001. *Molecular Cloning: A Laboratory Manual*. CSHL Press, New York.
- Sangeetha J, Thangadurai D, David M and Abdullah MA. eds. 2016. *Environmental Biotechnology: Biodegradation, Bioremediation, and Bioconversion of Xenobiotics for Sustainable Development*. CRC Press.
- Sayler GS, Sanseverino J and Kimberely DL. 1997. *Biotechnology in Sustainable Environment*. Plenum Press, New York.

I. Course Title : Fisheries Oceanography

II. Course Code : AEM 512

III. Credit Hours : 1+1

IV. Aim of the course

- To educate the students on the oceanographic concepts related to fisheries and impart skill to operate oceanographic equipment.
- To understand the role of different oceanographic parameters on fisheries production.

V. Theory

Unit I

Oceanographic factors in fisheries: Effects of physio-chemical and biological oceanographic factors on adaptation, Behaviour, Abundance and distribution of aquatic organisms; Primary and secondary productivity in ocean, Productivity changes in the ocean.

Unit II

Synoptic oceanographic analysis: El Nino and Southern Oscillation; Stratification; Mud banks, Upwelling and circulation patterns.

Unit III

Forecasting systems: Fisheries forecasts – Interpretation and use of ocean thermal structure; Fisheries forecasting system in India and other countries – Remote sensing; GIS, Application in fisheries; Application of echo-sounders and SONAR; Potential fishing zones.

Unit IV

Factors affecting marine fisheries: Environmental factors influencing the seasonal variations in fish catch in the Arabian Sea and the Bay of Bengal.

VI. Practical

- Use of tide tables.
- Oceanographic data analysis – water temperature, salinity, pH, nutrients, benthos and sediment characteristics.
- Fisheries forecasting systems.
- Oceanographic equipment and fish finding devices.

VII. Suggested Reading

- Grasshoff K, Ehrhardt M and Kremling V. 1983. *Methods of Seawater Analysis*. Verlag Chemie, Weinheim.
- Kennish MJ. 1989. *Practical Handbook of Marine Science*. CRC Press, New York.
- Laevastu T and Hayes ML. 1981. *Fisheries Oceanography and Ecology*. Fishing News Books, Farnham, U.K.
- Lalli CM and Parsons TR. 1993. *Biological Oceanography: An Introduction*. Elsevier Science Ltd., Oxford.
- Miller CB. 2004. *Biological Oceanography*. Blackwell Publications, Oxford.
- Pond S and Pickard GL. 2013. *Introductory Dynamical Oceanography*. Elsevier.
- Reddy MPM. 2007. *Ocean Environment and Fisheries,* Science Publishers, USA.
- Tomczak M and Godfrey JS. 2013. *Regional Oceanography: An Introduction*. Elsevier.

I. Course Title : Utilization and Management of Aquatic Algal Resources

II. Course Code : AEM 513

III. Credit Hours : 2+1

IV. Aim of the course

- To provide a holistic knowledge about the aquatic algal resources and their utilization for alternate livelihood
- To convey the information about the strategies and protocols for the management of aquatic algal resources

V. Theory

Unit I

Role of algae in fisheries and aquaculture, Batch and mass cultivation, Selection of culture medium, Isolation and maintenance of algal cultures; Water quality for algal culture, Algal culture as a livelihood option

Unit II

Bio-prospecting of algal resources for value-added compounds/products-pigments, Agar agar, Carrageenan, Single cell protein, Nutraceuticals and pharmaceuticals

Unit III

Production of nanoparticles; Biofuels, Food and Feed, Algal compounds in cosmetics

and Natural colourants, Polar algal resources and their applications.

Unit IV

Value addition through food chain; Enhancement of productivity of phytoplankton - Use of thermal energy, Artificial upwelling, Wastewater utilization for algal cultivation.

Unit V

Role of algae in global warming mitigation; Nutrient supplementation of sea for productivity enhancement, Exotic algal species source and Preventive measures.

Unit VI

International regulations for discharge of ballast water, Algal blooms and control measures.

VI. Practical

- Techniques for algal cultivation
- Maintenance of pure cultures
- *Spirulina* and *Chlorella* cultivation – indoor and outdoor
- Extraction of pigments from algae (Carotenoids and Phycocyanin)

VII. Suggested Reading

- Borowitzka MA. 1988. *Micro-algal Biotechnology*, Cambridge University Press, U.K.
- Edmondson WT. 2003. *Freshwater Biology*. Textbook Publishers, 1248 pp.
- Graham LE, Graham JM and Wilcox LW. 2009. *Algae*, Pearson Benjamin Cummings, San Francisco.
- Kumar HD and Singh HN. 1990. *A Textbook on Algae*, Affiliated East-West Press Private Ltd., New Delhi.
- Lavens P and Sorgeloos P. (eds.). 1996. *Manual on the production and use of live food for aquaculture*. FAO Fisheries Technical Paper. No. 361. Rome, FAO, 295pp.
- Mamta Rawat, SumitDookia. 2012. *Biodiversity of Aquatic Resources* , Daya Publishing House, New Delhi.
- Sournia A. 1978. *Phytoplankton Manual*, UNESCO publication, Paris.
- Stein JR. 1973. *Handbook of Phycological Methods*, Cambridge University Press, London.
- Vonshak A. 1997 *Spirulina platensis* (*Arthrospira*): *Physiology, Cell-biology and Biotechnology*, Taylor and Francis, London.

I. Course Title : Restoration Ecology

II. Course Code : AEM 514

III. Credit Hours : 1+1

IV. Aim of the course

- To update and widen the knowledge about basic principles and recent concepts in ecology.
- To equip the students with an updated theoretical and practical knowledge and skills about restoration of aquatic ecosystems.

V. Theory

Unit I

Ecological restoration; Ecological processes and structures, Regional and Historical contexts, and sustainable culture practices; Ecosystem integrity; Community ecological principles; Disturbance, Succession, Fragmentation; Ecosystem function and Services.

Unit II

Emerging concepts-Assembly, Stable states; Environmental flows and cultural interactions; Application of theory-Invasion, Competitive dominance and resource use.

Unit III

Restoration planning; Wetland Assessment, Delineation, and Regulation; Recovery process, Mitigation, Rehabilitation**,** and Reclamation; Ecological Engineering – Ecosystem approach for restoration; Dynamics and restoration of degraded wetlands; Removal of threats to the health and integrity of the restored ecosystem, Use of constructed wetlands to eco-restoration.

Unit IV

Ecosystem modeling; Ecosystem auditing; Socioeconomics of recovery process; Ecosystem Health Cards

VI. Practical

- Collection and segregation of native and non-native species from a degraded environment
- Making list of historical and cultural interactions, status of assemblages
- Calculation of Index of Biotic Integrity
- Listing of the threats to the integrity of the ecosystem
- Organizing different participatory programs
- Designing a sustainable ecosystem

VII. Suggested Reading

- Cooke GD, Welch EB, Peterson S and Nichols SA. 2016. *Restoration and management of lakes and reservoirs*. CRC press.
- Gupta T, Agarwal AK, Agarwal RA, Labhasetwar NK. (Eds.). 2018. *Environmental Contaminants Measurement, Modelling and Control*, springer.
- Jørgensen SE, Xu L and Costanza R. eds. 2016. *Handbook of ecological indicators for assessment of ecosystem health*. CRC press.
- Keith W Little. 2017. *Environmental Fate and Transport Analysis with Compartment Modeling*, CRC press.
- Laevastu T, Clancy M and Stroud A. 1974. *Computation of Tides, Currents and Dispersal of Pollutants in Lower Bay and Approaches to New York with Fine Medium Grid Size Hydrodynamical-Numerical Models*. Part 3. National Technical Information Service Springfield, Virginia.
- Roy MH. (Ed). 1982. *Pollution: Causes, Effects and Control*. The Royal Society of Chemistry, England.
- Wlodzimierz C and Pawel R. 2005. *Water Quality Hazards and Dispersion of Pollutants,* Springer, USA.

Course Title with Credit Load
Ph.D. in Aquatic Environment Management

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
AEM 601	Techniques in Aquatic Environmental Studies	0+2
AEM 602	Dispersal and Fate of Pollutants	1+1
AEM 603	Water Issues: Challenges and governance	1+0
AEM 604	Management and Utilization of Waste and Waste Water	2+1
AEM 605	Environmental Impact Assessment	1+1
AEM 606	Ecology of Plankton and Benthos	1+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
AEM 607	Estuarine and Coastal Oceanography	1+1
AEM 608	Biotechnology in Aquatic Environment Management	1+2
AEM 609	Aquatic Plant Resource and its Management	1+1
AEM 610	Application of Remote Sensing and GIS in Fisheries	1+1
	Supporting courses	**5 credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Credits	**23 credits**
	Doctoral Seminar	**2 credits**
AEM 691	Doctoral Seminar-I	0+1
AEM 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 credits**
AEM 699	Doctoral Research (Semester II)	0+15
AEM 699	Doctoral Research (Semester III)	0+15
AEM 699	Doctoral Research (Semester IV)	0+15
AEM 699	Doctoral Research (Semester V)	0+15
AEM 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 credits**

Course Contents
Ph.D. in Aquatic Environment Management

I. Course Title : Techniques in Aquatic Environmental Studies
II. Course Code : AEM 601
III. Credit Hours : 0+2

IV. Aim of the course

To impart skill on various techniques in aquatic environment studies

V. Practical

- Analysis of ions
- Calculation of shoreline development index and other indices of lake productivity
- Eutrophication studies in natural waters-tanks and ponds
- Estimation of bio-indicator organisms in polluted waters
- Bioremediation experiments using different bio-agents
- Use of MS-GC in analysis of pesticide and other volatile and semi volatile organic substances
- Water quality improvement evaluation trials
- Field visits
- Visits to different institutes to learn the other techniques

VI. Suggested Reading

- APHA (American Public Health Association). 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd Edition Edition. American Public Health Association, Washington, D.C.
- Cheremisinoff NP. 2002. *Handbook of Water and Waste Water Treatment Technologies*. Butterworth – Heinemann, Woburn.
- Cairns JE. 2017. *Biological Monitoring in Water Pollution*. Elsevier.
- Sakhare VB. (Ed.). 2007. Advances in Aquatic Ecology Vol. 1. Daya Publishing House, New Delhi.

I. Course Title : Dispersal and Fate of Pollutants
II. Course Code : AEM 602
III. Credit Hours : 1+1

IV. Aim of the course

- To impart knowledge on dispersal of pollutants.
- To impart knowledge on fate of pollutants.

V. Theory

Unit I

Common transport processes of pollutants, Influence of winds, tides, waves and currents on the dispersal of pollutants.

Unit II

Pollutant dispersion in rivers, Coastal waters, estuaries and near outfall sites;

Pollutant dispersal, Dye diffusion studies.

Unit III

Mobility and speciation of pollutants; Nano particles; Recent advances in study of pollutants and their monitoring

Unit IV

Lifecycle analysis; Bio-concentration, Bioaccumulation and Bio-magnification

VI. Practical

- Techniques of computation of dispersion coefficients
- Calculation of Richardson number
- Numerical analysis of estuarine dispersion
- Simple plume experiments – designs of waste discharge and thermal systems

VII. Suggested Reading

- Ciambrone DF. 2018. *Environmental life cycle analysis*. CRC Press.
- John J, William R and Feiss GP. 1998. *People and the Earth: Basic Issues in the Sustainability of Resources*, Cambridge University Press.
- Laevastu T, Clancy M and Stroud A. 1974. *Computation of Tides, Currents and Dispersal of Pollutants in Lower Bay and Approaches to New York with Fine Medium Grid Size Hydrodynamical-Numerical Models*. Part 3. National Technical Information Service Springfield, Virginia.
- Roy MH. (Ed). 1982. *Pollution: Causes, Effects and Control*. The Royal Society of Chemistry, England.
- Rieuwerts J. 2017. *The elements of environmental pollution*. Routledge.
- Wlodzimierz C and Pawel R. 2005. *Water Quality Hazards and Dispersion of Pollutants*, Springer, USA.

I. Course Title : Water Issues: Challenges and Governance
II. Course Code : AEM 603
III. Credit Hours : 1+0

IV. Aim of the course

- To understand the current scenario and future challenges regarding water use.
- To understand different management measures for sustainable use of water.

I. Theory

Unit I

3R concept in water resource management, Best utilisation of water resources, Water as a global issue, Key challenges and needs, Policy option for water conservation and Sustainable use.

Unit II

Water availability in different regions of world, Factors affecting it and conservation; Role of society, Ancient wisdom.

Unit III

Conflicts in water resources utilisation and management, Social and religious importance of water resources.

Unit IV

National and international regulations for management and utilisation of water

resources, Current scenario and future challenges of water resource management at National and International level.

II. Suggested Reading

- Cao G and Orrù R. eds. 2014. *Current environmental issues and challenges* (Vol. 31). New York: Springer.
- Costa-Pierce BA. 2002. *Ecological aquaculture*. Oxford, UK.: Blackwell Science.
- Giupponi C, Jakeman AJ, Karssenberg D and Hare MP. 2006. *Sustainable management of water resources*. Edward Elgar Publishing.
- Singh A, Saha D and Tyagi AC. eds. 2019. *Water Governance: Challenges and Prospects*. Springer.

I. Course Title : Management and Utilization of Waste And Wastewater
II. Course Code : AEM 604
III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge on management and utilization of waste and wastewater.

V. Theory

Unit I

Industrial and domestic wastewater characteristic; Conventional and advanced treatment methods for wastewater, Use of Nanotechnology in treatment; Nano-structured material.

Unit II

Waste recycling and utilisation (including solid waste) in aquaculture, Plant assisted bioremediation.

Unit III

Urban Drainage Sewage System; Theoretical principles and design - Screens, Equalization basin, Grit chamber, Primary and secondary settling tanks, Advanced Wastewater Treatment – Need and technologies used, Nitrification and Denitrification Processes, Phosphorous removal, Wastewater disinfection, The management of residuals from water and wastewater treatment.

Unit IV

Hazardous waste disposal (by incineration), Required minimum incineration temperature, The thermal treatment of halogenated waste, Present-day waste incinerators, Waste minimization, Role of human behavior in waste managment

Unit V

Production of Biogas and bio-fuel from waste; Wastewater-fed aquaculture, Integrated wastewater management, Green water technology, IMTA.

Unit VI

Wastewater disposal criteria - National and international standards; Monitoring-Role of Central and state pollution control boards and other agencies.

VI. Practical

- Estimation of physicochemical characteristics of wastewater (BOD, COD).

- Estimation of nutrients and contaminant of wastewaters.
- Analysis of living communities associated with treatment processes.
- Demonstration of liquid waste treatments (ozonization, chlorination, aeration, precipitation, coagulation etc.).
- Synthesis of nanostructured materials for wastewater treatment.

VII. Suggested Reading

- Baird DJ, Beveridge MCM, Kelly LA and Muir JF. 1996. *Aquaculture and Water Resources Management*. Blackwell Science Ltd., Oxford.
- Cheremisinoff NP. 2002. *Handbook of Water and Waste Water Treatment Technologies*. Butterworth – Heinemann, Woburn.
- Cairns JE. 2017. *Biological Monitoring in Water Pollution*. Elsevier.
- Eckenfelder, W. W. 2000. *Industrial Water Pollution Control*. McGraw Hill, New York.
- Gray NF. 2004. *Biology of Wastewater Treatment*. Oxford University Press, London.
- Letcher TM and Vallero DA. eds., 2019. *Waste: A handbook for management*. Academic Press.
- Rhyner CR, Schwartz LJ, Wenger RB. and Kohrell MG. 2017. *Waste management and resource recovery*. CRC Press.
- Trivedy RK. 1998. *Advances in Wastewater Treatment Technologies*. Global Science, Aligarh.
- Liu SX. 2014. *Food and Agricultural Wastewater Utilization and Treatment*. 2nd Edition, Wiley-Blackwell, New York, 260 pp.

I. Course Title : Environmental Impact Assessment

II. Course Code : AEM 605

III. Credit Hours : 1+1

IV. Aim of the course

- To impart theoretical and practical knowledge of environment impact assessment for sustainable development.
- To give exposure of Environment Impact Assessment report preparation.

V. Theory

Unit I

Environmental legislations; Concepts and approaches to Environmental Impact Assessment (EIA), EIA with reference to aquaculture projects, Coastal industries and Other developmental activities.

Unit II

Social Impact Assessment (SIA), Process, Scope and Significance, Social auditing.

Unit III

Ecosystem services; Environmental economics; Analysis and computation, Environmental auditing, Importance in planning.

Unit IV

International and national environmental protection standards; Environmental quality monitoring; ISO-14000.

VI. Practical

- Field visits for EIA and SIA of certain aquacultural projects.
- Case study and EIA report preparation.
- Setting of the environmental audit programme.

VII. Suggested Reading

- Canter LW. 1994. Environmental Impact Assessment. Mc-Graw Hill, New York.
- Fortlage CA. 2017. *Environmental assessment: a practical guide*. Routledge.
- Grilbert M and Gould R. 1998. *Achieving Environmental Standards*. Pitman Publishing, London.
- Keith L. 2017. *Environmental sampling and analysis: a practical guide*. Routledge.
- UNEP. 2002. *Environmental Impact Assessment Training Resource Manual*, 2nd Edition, UNEP, 573 pp.
- Wathern P. (Ed.). 1988. *Environmental Impact Assessment: Theory and Practice*. World Research Institute, Routledge, London.

I. Course Title : Ecology of Plankton and Benthos

II. Course Code : AEM 606

III. Credit Hours : 1+1

IV. Aim of the course

- To impart and enrich the theoretical and practical knowledge of the students about ecology of plankton and benthos.
- To develop the competence for analysis of plankton diversity.

V. Theory

Unit I

Plankton- Predator-Prey relationship; Role of plankters in food chain, Trophic level and food-webs; Factors affecting plankton distribution.

Unit II

Characterization of benthic habitats; Benthic resources; Role of benthos in bio-turbation and reclamation, Detrital food chain; Factors affecting benthos distribution.

Unit III

Spatial and temporal variation of plankton and benthos; Assessment methods for plankton and benthos, Modern tools.

Unit IV

Plankters and Benthos as pollution indicators; Biofilters and Bio-monitors.

VI. Practical

- Collection and analysis of soil and water in relation to plankton and benthic ecology.
- Collectionand preservation of plankton and benthos; Identification of plankters, benthos.
- Experiment to explore the role of benthos in nutrient transformation.

VII. Suggested Reading

- APHA (American Public Health Association). 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd Edition. American Public Health Association, Washington, D.C.
- Bellinger EG and Sigee DC. 2015. *Freshwater algae: identification and use as bioindicators*. John Wiley and Sons.
- Cole GA. 1988. *Textbook of Limnology*. 3rd Edition. Waveland Press, Prospect Heights, Illinois.
- Cuffney TF, Gurtz ME and Meador MR. 1993. *Methods for Collecting Benthic Invertebrate Samples as Part of the National Water-Quality Assessment Programme*. U.S. Geological Survey Open-File Report 93-406. U.S.G.S., Raleigh, North Carolina.

- Dawson CL and Hellenthal RA. 1986. *A Computerized System for the Evaluation of Aquatic Habitats Based on Environmental Requirements and Pollution Tolerance Associations of Resident Organisms*. EPA/600/S3-86/019. Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon.
- Downing JA and Rigler FH. (Eds.). 1984. *A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters*. 2nd Edition. IBP Handbook 17. Blackwell Scientific Publications, Oxford, England.
- Haskins J. 2017. *Standards for Water, Wastewater updated in book:* New edition brings water safety to forefront for public health.
- Whitton BA. (Ed.). 1975. *River Ecology*. University of California Press, Berkeley, California.

I. Course Title : Estuarine and Coastal Oceanography

II. Course Code : AEM 607

III. Credit Hours : 1+1

IV. Aim of the course

- To strengthen the knowledge base of the students about the characteristics of estuarine ecosystems.
- To enhance the practical skills for the study of estuarine and coastal oceanography.

V. Theory

Unit I

Estuary; significance, Zonation, characteristics; Buoyancy input as freshwater; Biodiversity, Mangroves.

Unit II

Esturine and Coastal dynamics, Flow and circulation; productivity, Fish and fisheries of estuaries, World famous estuaries and their ecological significance

Unit III

Salinity distribution; Freshwater fraction; Flushing time of an estuary and methods of determination; Sediment transport in estuarine ecosystem

Unit IV

Waves in shallow waters, Transformation, Refraction and reflection; Mass transport, Return flow, Momentum balance

VI. Practical

- Analysis of tidal heights – Net flow and residence time computations
- Computation of salt and nutrient flux
- Construction of wave refraction diagrams
- Visit to coastal and mangrove areas
- Study of coastal profiles

VII. Suggested Reading

- Beer T. 2017. *Environmental oceanography*. CRC Press
- Carter RWG. 1998. *Coastal Environments: An Introduction to the Physical, Ecological and Cultural Systems of Coastlines*. Academic Press, London.
- Clark JR. 1992. *Integrated Management of Coastal Zones*. FAO Fisheries Technical, Paper No. 327, Rome.
- Eden C and Iske A. eds., 2019. *Energy Transfers in Atmosphere and Ocean*. Springer.
- Kormondy EJ. 1986. *Concepts of Ecology*. Prentice-Hall, New Delhi.
- Park CC. 1980. *Ecology and Environmental Management*. Butterworths, London.

- Vallega A. 1999. *Fundamentals of Integrated Coastal management,* Kluwer Academic Publishers
- Vallega A. 1992. *Sea Management A Theoretical Approach*. Elsevier Science Publishers Ltd.

I. Course Title : Biotechnology in Aquatic Environment Management

II. Course Code : AEM 608

III. Credit Hours : 1+2

IV. Aim of the course

- To educate about the application of biotechnology in aquatic environment management.
- To impart practical knowledge about various biotechnological tools used in aquatic environment management.

V. Theory

Unit I

Bioremediation: Microbial and Phyto-remediation of contaminated water and pollutants, Biotechnological approaches for bio-energy

Unit II

Biosensor, Bioreactor, Bioreactor for single cell protein, Microbial enzymes and bio-molecules, Industrial application.

Unit III

Molecular tools for biotechnological applications-it's use toxic studies- Pollution bio-indicators and biomarkers; Culture-independent techniques.

Unit IV

Application of biotechnology in aquaculture; Aquatic organisms in industrial/medical biotechnology.

VI. Practical

- Isolation of prospective bacteria as bio-remediators
- Isolation of prospective bacteria as bio-fertilizers
- Enzyme assays
- Mass culture of bacteria
- Gel electrophoresis
- DNA isolation and amplification
- RFLP analysis
- Meta-genomics
- Genomic libraries

VII. Suggested Reading

- Arora S, Singh AK and Singh YP. eds., 2017. *Bioremediation of salt affected soils: an Indian perspective*. Springer.
- Buck RP, Hatfield WE, Umana M and Bowden EF. 1990. *Biosensor Technology - Fundamentals and Applications*. Marcel Dekker, New York.
- Crespi RS. 1991. *Biotechnology and Intellectual Property*, Part 1 and 2. TIBTECH, 9
- Fingerman M. ed., 2016. *Bioremediation of aquatic and terrestrial ecosystems*. CRC Press.
- Moo-Young M, Anderson WA and Chakrabarty AM. 2006. *Environmental Biotechnology: Principle and Applications.* Kluwer Academic Press.

- Sambrook J and Russel DW. 2001. *Molecular Cloning: A Laboratory Manual*. CSHL Press, New York.
- Sayler GS, Sanseverino J and Kimberely DL. 1997. *Biotechnology in Sustainable Environment*. Plenum Press, New York.
- Yoxen, E. 1988. *The Gene Business: Who should Control Biotechnology*. Oxford University Press.

I. Course Title : Aquatic Plant Resources and its Management

II. Course Code : AEM 609

III. Credit Hours : 1+1

IV. Aim of the course

- To broaden the knowledge base of the students about aquatic plant resources and their significance.
- To improve the capacity of the students for better management of ecosystem.

V. Theory

Unit I

Aquatic plant resources- Definition and concept; Species diversity of aquatic plants in diverse habitats, Bio-prospecting- definition and concept, Bio-prospecting of aquatic plants.

Unit II

Economic importance of aquatic plants in fisheries and aquaculture, Environmental factors affecting aquatic plant resources, Role of aquatic plants as bio-filter in decontamination and Management of wastewater.

Unit III

Management of aquatic plant resources, Methods for increasing productivity of water bodies through thermal energy and Artificial upwelling, Artificial sea ranching, Plants as FAD's.

Unit IV

Utilization of aquatic plants for environmental management, Algae and angiosperms as bio-indicators, Global warming mitigation through algal biomass and biofuel production; Cultivation of economically important aquatic vegetation *viz.* Trapa and makhana.

VI. Practical

- Documentation of economically important plants from freshwater and marine habitats.
- Techniques for algal cultivation and maintenance of pure cultures, Spirulina and Chlorella cultivation – indoor and outdoor.
- Extraction and analysis of pigments from algae (Carotenoids and Phycocyanin)
- Heavy metal and dye removal by algae and macrophytes.

VII. Suggested Reading

- Borowitzka MA. 1988. *Micro-algal Biotechnology*, Cambridge University Press, U.K.
- Cooke D and Welch EB. 2005. *Restoration and Management of Lakes and Reservoirs*, CRC Press, USA.
- Gautam A. 1998. *Conservation and Management of Aquatic Resources*, Daya Publishing House, New Delhi.

- Gopal B. 1990. *Ecology and Management of Aquatic Vegetation in Indian Sub-continent,* Kluwer, Academic Publishers.
- Gangstad EO. 2018. *Weed Control Methods for River Basin Management: 0*. Crc Press.
- Lucas JS, Southgate PC and Tucker CS. eds. 2019. *Aquaculture: Farming aquatic animals and plants*. Wiley-Blackwell.
- Pullin RSV, Bartley DM and Kooiman J. 1999. *Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources*, International Centre for living aquatic resources management, Rome, Italy.
- Sahoo S. 2002. *Plant Resource Utilization*, Allied Publishers Pvt. Ltd., New Delhi.

I. Course Title : Application of Remote Sensing and GIS in Aquatic Environmental Studies

II. Course Code : AEM 610

III. Credit Hours : 1+1

IV. Aim of the course

- To impart knowledge and skill on application of Remote sensing and GIS in Oceanographic studies and aquatic environment management planning.
- To impart knowledge on use of modern RS tools in ecosystem management.

V. Theory

Unit I

General consideration, Survey planning, Position fixing; Sampling frequency and duration, Data storage and transmission, Sensors for temperature and salinity (*via* conductivity); Measurement of depth (via pressure); CTD units for estuarine and open ocean work; Sensor calibration techniques; Sensors for measuring flow; Tracking of drogue buoys, Acoustic Doppler current measurements.

Unit II

In situ determination of pigment concentration; Remote sensing optical methods; Satellite measurements of temperature (*via* thermal IR), Interpretation of Microwave (geotropic currents, waves, surface winds), Optical measurements; transmittance and subsurface reflectance.

Unit III

Geographical Information System (GIS): Definition, Concepts, Spatial data management, Database management system, Data Capture, Digitization, Data integration, Projection and Registration, Data Structure, Data Modeling, Visual Image Interpretation; Applications of GIS in Aquatic Environment Management; Digital Image Processing (DIP), Different Methods and Approaches.

Unit IV

Recent advances in RS technologies and its applications in different studies, use of Artificial Intelligence, etc.

VI. Practical

- Position fixing techniques
- Various types of current meters and measurement of currents
- Wave recorders and measurements
- Determination of pigment concentrations
- Remote sensors – interpretation of data

- Practical on visual interpretation of data from map
- Digital Image Processing (DIP)
- Field practical on the Application of GPS
- Mapping of aquatic environment resources through GIS softwares (ARCVIEW, MAPINFO etc.)

VII. Suggested Reading

- Elangovan K. 2005. *GIS: Fundamentals, Applications and Implementations*. New India Publishing Agency.
- ESRI. 2007. *Understanding GIS, The ARC/INFO Method*. Environmental System Research Organization, Inc., USA.
- Lillesand TM, Kiefer RW, Chipman JW. 2004. *Remote Sensing and Image Interpretation*. John Wiley and Sons (Asia) Pvt. Ltd., Singapore.
- Meaden GJ and Do Chi, T. 1996. *Geographical Information System: Applications to Marine Fisheries*. FAO Technical Paper No. 356, Rome.
- Meaden GJ and Kapetsky JM. 1991. *Geographical Information System and Remote Sensing in Inland Fisheries and Aquaculture*. FAO Technical Paper No. 318, Rome.
- Quattrochi DA, Wentz E, Lam NSN and Emerson CW. eds., 2017. *Integrating Scale in Remote Sensing and GIS*. CRC Press.

List of Suggested Journals

- *ActaOecologica – International Journal of Ecology*
- *Agriculture, Ecosystem and Management*
- *AnalyticaChemica*
- *Applied Environmental Microbiology*
- *Applied Microbiology and Biotechnology*
- *Applied Soil Ecology*
- *Aquaculture*
- *Aquaculture Engineering*
- *Aquatic Microbial Ecology*
- *Australian Journal of Ecology*
- *Australian Journal of Soil Research*
- *Biology and Fertility of Soils*
- *Bioresource Technology*
- *Bulletin of Environmental Contamination and Toxicology*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *Coastal Aquaculture*
- *Communication in Soil and Water analysis*
- *Current Opinion in Biotechnology*
- *Ecological Restoration- Journal published by the University of Wisconsin Press*
- *Ecological Engineering*
- *Ecotoxicology and Environmental Safety*
- *Environment and Ecology*
- *Environmental Pollution*
- *Environmental Science*
- *Environmental Studies*
- *Environmental Technology*
- *Environmental Toxicology*
- *Estuarine, Coastal and Shelf Science*
- *FEBS Letters*
- *FEMS Microbiology Ecology*
- *FEMS Microbiology Letters*
- *FEMS Microbiology Reviews*
- *Fisheries Oceanography*

- *Fisheries Science*
- *Functional Ecology*
- *Geo-Marine Letters*
- *Hydrobiologia*
- *Indian Journal of Environment and Toxicology*
- *Indian Journal of Marine Sciences*
- *International Journal of Ecology and Environmental Sciences*
- *Journal of Aquatic Botany*
- *Journal of Chromatography*
- *Journal of Ecotoxicology*
- *Journal of EnvironmentalQuality*
- *Journal of Marine Research USA*
- *Journal of Phycology*
- *Journal of Plankton Research*
- *Journal of Sustainable Agriculture*
- *Limnology and Oceanography*
- *Marine Biology*
- *Marine Ecology*
- *Marine Pollution Bulletin*
- *Oceans*
- *Restoration Ecology*
- *Science of the Total Environment*
- *Seaweed Research and Utilization*
- *Society for Ecological Restoration International*
- *Soil Science Society of America Journal*
- *Spill Science and Technology Bulletin*
- *Systematic and Applied Microbiology*
- *Toxicon*
- *Trends in Biotechnology*
- *Water Research*
- *World Journal of Microbiology and Biotechnology*

List of Suggested e-Resources

- https://www.neonscience.org/
- https://www.nationalgeographic.com/environment/freshwater/aquatic- ecosystems/
- https://www.environment.gov.au/
- https://www.oecd.org
- https://www.epa.gov/
- https://www.kmae-journal.org/
- http://www.mbgnet.net
- https://gisgeography.com/
- https://interact-gis.org
- http://www.remss.com
- https://www.geospatialworld.net/
- https://www.nrdc.org
- http://npic.orst.edu/factsheets/ecotox.html
- https://cfpub.epa.gov/ecotox/
- https://www.ipcc.ch
- https://climate.nasa.gov
- http://www.coastalwiki.org
- http://www.fao.org/inland-fisheries/en/
- https://www.jcomm.info
- https://www.niwa.co.nz/education-and-training/schools/students/estuaries
- https://www.nationalgeographic.org/encyclopedia/estuary/
- https://www.nationalgeographic.org/encyclopedia/wetland/

- https://www.worldwildlife.org
- https://www.usgs.gov/science/science-explorer?term=816

Suggested Broad Areas for Master's and Doctoral Research

- Prospecting algae as source of biofuel
- Isolation and characterization of microbes
- Interactive effect of warming and eutrophication on microbial CH_4 and N_2O conversions
- Utilization of agricultural waste in aquaculture as nutrient input
- Interventions for productivity enhancement in aquatic ecosystems
- Utilization of wastewater for mass cultivation of algae
- Bioactive compounds from aquatic organisms
- Ecotoxicity studies of industrial pollutants
- Role of aquatic macrophytes in biological treatment of wastewater
- Genetic improvement of microbes for pollution management
- Soil – water – nutrient interaction
- Nutrients in fish productivity
- Pollutant cycling in aquatic environment
- Coastal pollution assessment
- Conservation of ecologically important species
- Impact of coastal zone regulations and policies on coastal zone
- Resource assessment through remote sensing and GIS
- Bioaccumulation of toxicant
- Effects of toxicant on aquatic biota
- Development of methods for efficient and rapid analysis
- Comparison of different analytical techniques
- Documentation of plankton in diverse aquatic habitats
- Diversity analysis and algal indices of pollution load
- Evaluation of plankton for fish food
- Marine pollution and fisheries production
- Seasonality of fish catch and meteorological factors
- Application of GPS and remote sensing in marine fisheries
- Microbial pollution indicators
- Biomonitoring of aquatic environment
- Microbial indicators of pollution
- Use of microbes for improving soil fertility
- Factors affecting benthic population
- Abundance and distribution of benthic communities
- Benthic organisms as pollution indicators and biomonitors
- Measurement of tidal currents in estuaries
- Dynamics of estuarine circulation
- Measurement of rates of production from changes in phytoplankton biomass
- Application of remote sensing in studies on chlorophyll and other pigments
- Principles and practices of EIA
- Preparation of environmental audit
- Removal of nitrogen and phosphorus from wastewater
- Effect of selected toxicants on aquatic life and detoxification mechanism
- Toxicity assessment of pesticides and oil on selected organisms
- Applications of GIS in aquatic resource identification
- Application of remote sensing and GIS in oceanographic studies
- Computation of dispersion coefficients
- Analysis of estuarine dispersion
- Design of marine waste disposal systems
- Dynamics and restoration of degraded wetlands
- Removal of threats to the health and integrity of the restored ecosystem
- Environmental modeling

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Genetics and Breeding

Preamble
(Fish Genetics and Breeding)

In India, there was tremendous growth in fish production post-independence era. In 1950–51, fish production in India was 0.752 million tonnes, which comprised 0.534 million tonnes and 0.218 million tonnes from marine and inland sectors, respectively. In 2018–19, the provisional fish production in India was 13.421 million tonnes, which comprised 3.712 million tonnes and 9.709 million tonnes from marine and inland sectors, respectively. India has achieved a 17-fold increase in fish production in just six decades (indiastat.com). Currently, the country aims for the Blue Revolution and is investing massively in the fisheries sector through PMMSSY Scheme. However, an essential part of increasing the future aquaculture production is to improve the biological productivity of farmed species of fish, shellfish (crustacean and mollusks), and seaweeds.

Animal genetics and breeding have played an essential role in increasing the production efficiency of animals in a cumulative way. Similarly, the applications of the principles of animal genetics and breeding in aquaculture species, viz., salmon, tilapia, rohu, vannamei, and other species have helped improve the overall performance of these species. An increase in the global demand for food of animal origin is expected. Aquaculture production, however, faces many challenges, including the impact of climate change on fish and agricultural production systems and the impact of aquaculture on the environment and climate. There are further challenges concerned with the increasing scarcity of natural resources and feed, or concerns about animal welfare, anti-microbial resistance, and genetic diversity. The role of genetics is immense in this regard. Genetic technologies can be utilized in aquaculture for a variety of reasons. The primary use is to improve production, develop disease resistance, alter body shape, color, and conserve natural resources.

Investments in well planned and managed breeding programs are unique because genetic gains obtained in such programs are eternal and cumulative. They are never 'used up' and never 'wear out.' Genetic improvement programs can be used to provide short-term or long-term gains. Linking the use of genetic technologies in fishing and aquaculture will increase the efficiency and efficacy of the technologies. However, it should be noted that many of these technologies require specialized equipment and highly skilled staff. In this background, it is essential to develop well trained human resources to apply principles of genetics and breeding in boosting aquaculture production. The postgraduate and doctoral courses offered in Fish Genetics and Breeding are meticulously designed and meet the international standards. The students passing these courses will be well trained human resources for hatcheries, national and international breeding companies, data analysts, scientists, breeders, and entrepreneurs. They shall play a significant role and bring a paradigm shift in aquaculture production based on genetically improved stocks.

The salient features of revised syllabi indicating major changes made including new courses/topics/aspects added

Revising the syllabus is an exercise towards developing a human resource to meet society's demand for the 21st century. Determining what these needs are, how to address them, and how to revise the established curriculum is a challenging job. In the present

exercise, the syllabus of the Masters' and Doctoral program of Fish Genetics and Breeding program was revised to meet the challenges of the sector and bring it to an international standard. To change and develop a new syllabus, the approved syllabus of the ICAR-Central Institute of Fisheries Education, Mumbai was taken as the base. Further, this syllabus was compared with the courses offered at Six European universities and with the ICAR approved Animal Genetics and Breeding syllabus. Discussion with the FGB Master's and Doctoral scholars was held, and also the feedback was obtained from the former Students. The revised syllabus was sent to Faculty, Scientist, s and present and past students, Fish, Plant, and Animal Geneticists in India and abroad. We received the suggestions/comments from 13 eminent geneticists.

Based on the suggestions and comments, the following exercise was carried.

- One New Course Microbial Genetics FGB511 (1+1) was added to MFSc Syllabus. Microbial genetics is the fundamental requirement in the biotechnology and fermentation industry. Moreover, this course is an independent course, and students from various disciplines like biotechnology, aquatic animal health, post-harvest technology, fish physiology, and biochemistry course can opt for this.
- The nanotechnology course was dropped as it was found not directly related to the Fish Genetics and Breeding program but was more appropriate to be taught to the Biotechnology students.
- In the recent past, the Cytogenetic has moved from the traditional banding and karyotyping to the molecular aspects. Hence, there is a need to add new developments in molecular elements into the existing syllabus of the cytogenetic course. It was also essential to avoid duplicity in the earlier courses of cytogenetic ad molecular genetic. Hence, by merging the relevant syllabus from both these courses, a new course, Molecular and Cytogenetic, with 2+1 credit was formed. The course also includes recent developments in both cyto and molecular genetics. This further helps the students more opportunity to choose the courses and also reduce the burden of the exams.
- The shellfish and ornamental fish culture are gaining more popularity and are contributing to aquaculture production. The selective breeding of these species is in progress in many countries. However, it is not so in India. To meet the demand of the industry, and develop new strains, attention to developing the breeding programs of these species is essential. They need to be studied separately as their breeding, and the inheritance of economic traits is different. To meet the above-mentioned requirements, the course Fish breeding Plan was modified, and from 1+1 credit, it was made into 2+1 course by incorporating the breeding plans for shellfish and ornamental fish.
- Major changes were made to course, FGB 505, FGB 507, and FGB 509. Conservation of aquatic biodiversity is essential. Similarly, the preservation of genetic variation in the hatchery population is equally important. The changes made to the syllabus of Conservation Of Fish Genetic Resources FGB 505 will help students gain in-depth knowledge about genetic resource conservation. The advent of genotyping of the individuals has opened up new tools for genetic selection. The use of molecular markers in genetic selection is the latest trend, and to impart this knowledge, the course on Molecular breeding was revised by adding topics related to QTL and MAS, molecular pedigree assigning GWAS.
- A new course, Fish Genome and Genomic Selection (2+1), was added to the Ph.D.

syllabus. This course is in tune with the developments in whole genome sequencing and incorporating the related technologies into genetic selection programs.

- Based on the feedback from the students and others and a detailed comparative study, it was observed that the syllabus of Genetics in commercial aquaculture, Advances in Cytogenetic, and Transgenic production and GMOs is not much different from the similar courses offered in the Masters' program. Further, their use in the field is minimal hence, these courses were dropped. However, the care was taken to add the relevant topics from these courses to the syllabus of other proposed courses.
- Courses merged: The courses 'Linear models (1+1) and Experimental designs in fish genetics (1+1)' were merged in to 'Linear models and experimental designs in fish genetics' (1+2).
- Significant changes were made to courses, FGB 601 and FGB 602, by adding the new developments in fish genetic selection and breeding, emphasizing case studies, and solving the industry problems.
- The advisory committee should decide the minor courses and optional courses considering the students' research topics.

Course Title with Credit Load
M.F.Sc. in Fish Genetics and Breeding

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FGB 501*	Principles of Genetics and Breeding*	2+1
FGB 502*	Population and Quantitative Genetics*	2+2
FGB 503*	Principles of Selection and Selection Methods*	2+1
FGB 504*	Fish Breeding Plans*	2+1
FGB 505	Conservation of Fish Genetic Resources	2+1
FGB 506	Bioinformatics and Computer Applications in Fish Genetics	0+2
FGB 507	Molecular and Cytogenetics@	2+1
FGB 508	Cell and Tissue Culture#@	1+1
FGB 509	Molecular Breeding	1+1
FGB 510	Microbial Genetics#@	2+0
	Minor Courses (From the subjects closely related to a students major subject)	**8 Credits**
FBT 501	Fundamentals of Molecular Biology	2+1
AQC 504	Aquaculture Policy and Planning	1+1
AQC 512	Commercial Ornamental Fish Breeding and Culture	1+1
FBT 509	Molecular Markers	2+1
FGB 510	Microbial Genetics#@	2+0
	Minor Courses (From the subjects closely related to a students major subject)	**8 Credits**
FBT 501	Fundamentals of Molecular Biology	2+1
AQC 504	Aquaculture Policy and Planning	1+1
AQC 512	Commercial Ornamental Fish Breeding and Culture	1+1
FBT 509	Molecular Markers	2+1
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**

Course Code	Course Title	Credit Hours
	Common Courses	**5 credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	**1 Credit**
FGB 591	Master's Seminar	0+1
	Masters' Thesis Research	**30 Credits**
FGB 599	Master's Research (Semester III)	0+15
FGB 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

*****Major compulsory courses

Course Contents
M.F.Sc. in Fish Genetics and Breeding

I. Course Title : Principles of Genetics and Breeding
II. Course Code : FGB 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic principles of genetics and breeding and their application to fisheries management and aquaculture

V. Theory

Unit I

Historical development of genetics and breeding; Aim and scope of genetics and breeding; Domestication; Society and Genetics-Ethical issues; Basic statistical parameters-Probability concepts; Mean, Variance, Coefficient of variation, Correlation, Regression and Analysis of Variance.

Unit II

Cell structure, cell division and physical basis of heredity; Mendel's Principles: Scope, Limitation; Modifications to Mendel's ratios: Multiple alleles, Epistasis; Chromosomal theory of inheritance; Genetic variation: Causes and measurement; Linkage and crossing over, Recombination, Interference, Linkage disequilibrium.

Unit III

Modern concept of gene; DNA as genetic material, Replication of DNA; Genetic code and protein synthesis, Transfer and regulation of genetic information; Introduction to bioinformatics in fish genetics and breeding; Fish Genome: Zebrafish genome, Fish as genetic model.

Unit IV

Cytogenetics; Cytogenetics and evolution; Karyotyping and chromosome banding; Genetic basis of sex determination; Sex-linked, Sex-limited, and Sex-influenced traits, Y-linked inheritance; Chromosome manipulation: Ploidy induction, Sex reversal, Gynogenesis and Androgenesis; Chromosomal aberrations; Mutations-Natural and Induced, Mutagens.

Unit V

Basic concepts of Population Genetics: Individual vs population; Gene and Genotype frequency; Hardy-Weinberg Principles and factors affecting them; Mutation; Fate of mutant allele in the population; Genetic drift; Concept of inbreeding and its management; Application of population genetics in fish resource conservation, preservation of gametes.

Unit VI

Basic Concepts of Quantitative Genetics; Polygenic inheritance; Basis of genetic selection; Qualitative vs Quantitative traits; Pleiotropy; Penetrance; Natural Vs

Artificial Selection, Aim of genetic selection and breeding, Present status of selective breeding in aquaculture; Economic traits of fishPedigree and its importance in fish breeding; Methods and aid to genetic selectionApplication of selection for performance improvement Cross breeding and Hybridization.

VI. Practical

- Probability in genetics
- Exercises on Mendel's principles, Multiple alleles, Epistasis, Linkage and crossing over
- Exercises on Hardy-Weinberg principles Estimation of gene and genotype frequencies
- Karyotyping; Nucleic Acid isolation
- Quantification of Inbreeding; Estimation of kinship coefficient
- Record keeping in fish breeding
- Estimation of genetic parameters

VII. Suggested Reading

- Gjedrem Trygve *et al*. 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Kirpichnikov VS. 1981. *Genetic Basis of Fish Selection*. Springer-Verlag
- KorOldenbroek en Liesbeth van der Waaij. 2014. *Textbook Animal Breeding and Genetics*. Wageningen University and Research Centre, the Netherlands
- Lakra WS, Abidi SAH, Mukherjee SC and Ayyappan S. 2004. *Fisheries Biotechnology*. Narendra Publ. House.
- Lutz CG. 2003. *Practical Genetics for Aquaculture*. Wiley-Blackwell.
- Lynch M and Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland.
- Purdom CE. 1993. *Genetics and Fish Breeding*. Chapman and Hall.
- Snustad DP and Simmons MJ. 1999. *Principles of Genetics*. 2nd Ed. JohnWiley and Sons.
- Stansfield WD. 1991. *Theory and Problems of Genetics*. McGraw-Hill.
- Tave D. 1993. *Genetics for Fish Hatchery Managers*. 2nd Ed. Chapman and Hall.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20 and%20Genetics-v17-20151122_1057.pdf

I. Course Title : Population and Quantitative Genetics

II. Course Code : FGB 502

III. Credit Hours : 2+2

IV. Aim of the course

Understanding the concepts of genetic structure of the population and inheritance of quantitative traits

V. Theory

Unit I

Historical developments; Review of basic concepts of genetics and statistics; Scope and applications Biometrical techniques: Introduction to matrix algebra, Determinants, ANOVA, Regression and Correlations Basic concepts of General Linear Mixed Models (GLMM)

Unit II

Definition of population, Individual vs. population, quantitative vs. qualitative characters Genetic structure of random mating populations. Polygenic inheritance: Limitation of single gene model; Polygenes and major genes; Polygenic model-

importance and limitations; Polygenic segregation and linkage

Unit III

Hardy -Weinberg principles; Test, application and properties of equilibrium populations –Systematic and dispersive forces changing gene and genotype frequencies, Concept of Mutation, Balance between mutation and selection Genetic bottleneck; Genetic drift, Drift equilibrium, Effect on population structure –Intensity of selection, Fisher's theorem of natural selection; Wahlund effect

Unit IV

Coefficient of genetic differentiation – F_{ST}, R_{ST}, Q_{ST}, G_{ST} - their relative merits and demerits, Genetic similarity, distance and population divergence, Null alleles – Path coefficient; theory, analysis and applications –Basis of relationships; Independent and correlated causes –Idealized population and its properties, Effective population size. Concept of inbreeding- Calculating coefficient of kinship, Relationship, Inbreeding and Population size; Types and Methods of estimation and consequences-Change of mean and variance –Mechanisms of evolution and speciation; Delineation of species and/or stocks.

Unit V

Quantitative variation: Gene effects; Mode of inheritance and continuous variation; Population mean; Components of phenotypic value, Genotypic value, Average effect of gene and Gene substitution Estimation, tools for population genetic parameters – Variance component estimation with complex pedigree –Genetic parameters; heritability- Concept of heritability, Effective heritability, Different methods of estimation, Variance of heritability, Properties and applications of heritability; Repeatability, Maternal effects; Correlation between traits- Composition of genetic and Phenotypic covariance genetic, Phenotypic and Environment correlations and their standard errors, Concept of co-heritability

Unit VI

Breeding value: Biometrical relationship among relatives; Estimating fixed factors and Predicting random effects-BLUE and BLUP; Models for EBV –Selection: Aids and methods; genetic gain and correlated response; Recurrent and reciprocal recurrent selection Heterosis; Theories and estimation, Combining ability-GCA, SCA; Utilization of non-additive genetic variance –Genomics and Phenomics

VI. Practical

- Exercise on various statistical procedures and matrix algebra- Components of Variance, Covariance, Correlation and Regression, ANOVA in genetic parameter estimation
- Estimation of gene and genotype frequencies and factors affecting them, Equilibrium in sex linked genes
- Genetic stock structure analysis with dominant and co-dominant markers- Type I and Type II markers; Pedigree construction through Molecular marker information
- Path coefficient
- Estimation of effective population size, Rate of inbreeding, in breeding co-efficient,
- Estimation of Heritability and Repeatability and their accuracies;
- Building of pedigree files and construction of relationship matrix and its inverse;
- Estimation of breeding values-EBV, BLUE and BLUP
- Genetic gain

VII. Suggested Reading

- Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag.
- Falconer DS and Markay TFC. 1996. *An Introduction to QuantitativeGenetics*. 4th Ed. Addison Wesley Longman.
- Hartl D. 1988. *A Primer in Population Genetics*. Sunderland
- Hartl D and Clarke AG. 2007. *Principles of Population Genetics*. 4th Ed. Sunderland
- Li CC. 1955. *Population Genetics*. University of Chicago Press.
- Lynch M and Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland.
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.
- Turner HN and Young SSY. 1969. *Quantitative Genetics in Sheep Breeding*. Cornell University Press.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding %20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

I. Course Title : Principles of Selection and Selection Methods

II. Course Code : FGB 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn the application of genetic tools for genetic improvement of aquatic species

V. Theory

Unit I

Genetic Selection and Breeding: Scope, Application, Role of genetics in fish selection and breeding National and International scenario of selective breeding programmes in aquaculture.

Unit II

Selection: Basis of selectionIntroduction to variance components –Estimation of selection differential, intensity of selection, response to selection –Identification of animals with high genetic merit –Estimation of breeding values- variance and accuracy of predicted breeding value; Various sources of information- Individual, information from relatives; Least squares and BLUP methods; Accuracy of selection

Unit III

Combined selection: Combined selection –Selection index-selection Objective and criterion, selection criterion coefficients –Methods of selection –Realized heritability, Repeatability, Genetic, Phenotypic and Environmental correlations.

Unit IV

Factors affecting rate of genetic improvement –Short term response to selection-Variance in response-Bidirectional selection, Selection limits Renewed selection gain –Threshold characters- Heritability of threshold traits, genetic correlation among threshold traits, selection for threshold traits –Scale effects

Unit V

Formulation of breeding plans: Stock improvement plans for different population sizes and environments, Control population and experimental design –Development of new strains/synthetic population; Crossbreeding and hybridization. Domestication and inadvertent selection –Selection and mating designs for select traits: Mating

systems and genetic consequences; Small stock and inbreeding effects, Inbreeding Depression; causes and methods to overcome; Out breeding; Crossbreeding, Utilization of heterotic effects, Selection and mating designs for growth, Disease resistance, color enhancement, Genotype×Environment interaction and its role in fish/shellfish breeding.

Unit VI

Major genes and QTLs- Major and minor genes, Tests for detecting major genes, Application of markers in selection programmes, Status and their relevance; QTL and its application in selection, Marker Assisted Selection in Fisheries; Genomic selection.

VI. Practical

- Estimation of genetic parameters: heritability, repeatability and genetic correlation; Estimation of phenotypic and environmental correlations Estimation of Breeding Values from various sources of information and their accuracies
- Construction of selection indices
- Designing and conducting challenge test for disease resistance
- Selection: basis of selection, genetic gain
- Response to selection and factors affecting response
- Aids to selection; Methods of selection
- QTL and MAS

VII. Suggested Reading

- Cameron ND. 1997. *Selection Indices and Prediction of Genetic Merit in Animal Breeding*. CABI.
- Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag.
- Falconer DS and Mackay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman.
- Gjedrem, Trygve *et al*., 2005. *Selection and Breeding Programs in Aquaculture* Springer
- KorOldenbroek en Liesbeth van der Waaij. 2014. *Textbook Animal Breeding and Genetics*. Wageningen University and Research Centre, the Netherlands
- Lynch M and Walsh B. 1997 *Genetics and Analysis of Quantitative Traits*. Sinauer, underland.
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.
- Turner HN and Young SSY. 1969. *Quantitative Genetics in Sheep Breeding*. Cornell university Press.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Fish Breeding Plans

II. Course Code : FGB 504

III. Credit Hours : 2+1

IV. Aim of the course

To learn the applications of genetic techniques for stock improvement

V. Theory

Unit I

Historical development of fish breeding and domestication, Current status of aquaculture in world and India Maintaining pedigree, Physical and molecular tagging and maintaining breeding records

Unit II

Economic traits in cultured species-Performance- Growth, Disease resistance, productive and reproductive traits, Recapture frequency, Behavior, Quality traits and their inheritance, Recording economic traits, Study of growth curves and their components, Influence of non-genetic factors on economic traits

Unit III

Formation of base population, Designing mating plans, Effect of breeding programme on genetic diversity of farmed animals, Present status of breeding, Cross breeding in aquaculture; Broodstock management –Inbreeding depression and heterosisin various economic characters –Role of Breeders' associations in national breeding programmes Fish breeding guidelines, Policies, Programs and economic analyses of breeding programmes, Their present status in India and World, Prospectus and challenges.

Unit IV

Reproductive cycle, Factors affecting sexual maturation, Adapatability and reproduction, Age at maturity, Gonadal development stages in fin/shellfish and levels of hormonal intervention; Sex determination, Cryopreservation of gametes, Live feed development for larvae, Larval feeding and maintenance, Packaging and transport of fish; Nursery systems and their operation; Biosecurity.

Unit V

Application of recent technologies in stock improvement –Biosafety issues involved with genetically modified organisms, Release and registration of new varieties, Quality seed; Classes, production practices and maintenance of pure seed, Seed purity standards; Seed quality and fish seed certification.

Unit VI

Shellfish breeding: Reproductive cycle of the shellfish; controlled mating of the shellfish; Economic traits and their recording. Ornamental fish breeding: Introduction to ornamentation and their inheritance Selection and mating systems, Inbred strains, transgenic strains, Production of gene knock-out fish, Genetic control and monitoring, Record keeping and ethics.

VI. Practical

- Tagging methods
- Construction of growth curves

- Record keeping of stock; Standardization of the performance records for genetic parameters estimations
- Breeding plan and design of breeding programme from successful case studies
- Morphometric analysis- Truss analysis
- Practical on synchronization of spawning, Closed lifecycle and controlled mating- Hormone induced ovulation; Collection of fish gametes, Assessing gamete quality
- Cryopreservation

VII. Suggested Reading

- Chattopadhyay NR. 2016. *Induced fish breeding: A practical guide for hatcheries*. Academic Press.
- Gjedrem, Trygve *et al*. 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Hoar WS and Randall DJ.1988. *Fish Physiology*. Academic Press.
- Kinghorn BP. 1981. *Quantitative Genetics in Fish Breeding*. University of Edinburgh.
- Lee CS and Donaldson EM. eds. 2012. *Reproductive biotechnology in finfish aquaculture*. Elsevier.
- Purdom CE. 1993. *Genetics and Fish Breeding*. Chapman and Hall.
- Rath RK. 2018. *Freshwater aquaculture*. Scientific Publishers.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- Weatherely AH and Gill HS. 1988. *The Biology of Fish Growth*. Blackwell Synergy.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture,*
- *Aquaculture Reports,*
- *Aquaculture Research,*
- *Genetics,*
- *Indian Journal of Fisheries,*
- *Journal of Fish Biology,*
- *The Journal of heredity*

I. Course Title : Conservation of Fish Genetic Resources

II. Course Code : FGB 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on application of genetic principles in conservation and management of aquatic resources.

V. Theory

Unit I

Fish genetic resources; Sample survey and distribution, Threatened aquatic species of India and world, Assessing threats to species and populations, Conflicts between nature conservation and other goals of the society.

Unit II

Evolutionary Genetics- Genetic diversity, Importance, Influencing factors, Characterizing Genetic diversity, Evolution in large and small population, Maintenance of genetic diversity, Conservation and preservation of aquatic species;

Effect of population size, Loss of genetic diversity in small population, Inbreeding, Population fragmentation, Issues and strategies, Risk status/population viability analysis and classification, Breeding strategies of threatened species for restocking and live gene bank.

Unit III

Importance of mutation, Migration and their interaction with selection in conservation Application of molecular genetic tools for management of small population for conservation.

Unit IV

Gene bank: Concepts, Objectives, Resources, Uses Institutes and Societies associated with conservation, Impact of inbreeding on genetic diversity and conservation; Evolutionary potential and heritability; Genetics and management of wild and captive populations, Introduction, domestication and acclimatization, Genetic management for reintroduction; *In situ* and *ex-situ* conservation; Gene pool concept - Primary, Secondary and Tertiary gene pool, and Gene introgression, Cryopreservation of sperm, Eggs and embryos.

Unit V

Effective population size and population structure; Factors threatening indigenous species; IPR issues of genetic resources; Regulations regarding introduction of exotic germplasm; Export import rules and regulations on conservation of aquatic genetic resources; Fish quarantine – status, procedures, scope and significance – Convention on Biodiversity and National Biodiversity Authority of India

Unit VI

Taxonomy and related issues, DNA barcoding, Characterization and identification of stock; Identification of farm escapees, Interaction between farmed and wild population Application of nanobiosensor for tracking of fish –Genomics in Conservation: Effect of climatic change on biodiversity.

VI. Practical

- Tagging methods for population
- Estimation of gene and genotypic frequencies
- Estimation of genetic diversity and relatedness using morphometric and molecular information
- Application of molecular genetic markers for estimation of effective population size, rate of inbreeding and genetic bottleneck Analysis of genetic variance in population
- Morphometric analysis of stocks Visit to Gene Bank/National/Regional Research Centres
- Studies on Domestic and international quarantine process; its weaknesses and measures for its strengthening
- Case studies on rescue and release of animals

VII. Suggested Reading

- Allendorf FW. 2007. *Conservation and the Genetics of Populations*. Blackwell. \
- Bruce Walsh and Michael Lynch, 2018. *Evolution and Selection of Quantitative Traits*. Oxford University Press in the UK
- Cloud JG and Thorgaard GH. 1993. *Genetic Conservation of Salmonid Fishes*. NATO ASI Series, Life Sciences, Springer.

- Frankham R, Ballou JD and Briscoe DA. 2004. *A Primer of Conservation Genetics*. Cambridge University Press.
- Frankham R. 1995. *Introduction to Conservation Genetics*. Annual Reviews of Genetics.
- Hartl D. 1988. *A Primer in Population Genetics*. Sunderland.
- Roff, Derek A. 2012. *Evolutionary quantitative genetics*. Springer Science and Business Media.
- http://agtr.ilri.cgiar.org/overview
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf

Suggested Journals

- *Aquaculture,*
- *Aquaculture Reports,*
- *Aquaculture Research,*
- *Genetics,*
- *Indian Journal of Fisheries,*
- *Journal of Fish Biology,*
- *The Journal of heredity*

I. Course Title : Bioinformatics and Computer Applications in Fish Genetics

II. Course Code : FGB 506

III. Credit Hours : 0+2

IV. Aim of the course

To learn the application of information technology and software packages for the Fish Genetics and Breeding studies

V. Practical

Unit I

File Transfer Protocols; Work stations Application of spreadsheets in maintaining fish breeding records and breeding data management –Fish breeding data bases – Data input, Import, export, Modification; Data cleaning, manipulation and transformations; Data normalization, Graphical analysis and representation of breeding data.

Unit II

Introduction to basic matrix algebra, Definition, Addition, Multiplication, Determinants, Inverse of matrix.

Unit III

Usage of various computer packages for genetic analyses: SAS, R, AsReml and others, Analysis of variance, Variance component estimations, Estimation of genetic parameters; Inbreeding estimation.

Unit IV

Software for molecular genetics data analysis (SAS Genetics, SAS Genomics, R), Estimation of population parameters, Estimation of 'F' Statistics.

Unit V

Introduction to Bioinformatics and various operating systems employed, Exposure to various open source online bioinformatics tools and applications, Use of Perl and R-Bio conductor packages, Introduction to Bioinformatics databases, Information

retrieval from various sequence and structure databases and mock sequence submission, Database searching, Sequence formats and alignments; BLAST, Conversion and handling of various sequence formats, Usage of online sequence alignment tools.

Unit VI

Sequence analysis; Annotation, Sequence conversion and translation, Sequence comparison, Phylogenetic analysis, Protein structure analysis and its analysis; analysis of amino acids sequence, NGS data formats and data cleaning, Use of bioinformatics tools for identifying QTL and selection of elite germplasm.

VI. Suggested Reading

- Attwood TK and Smith DJP. 1999. *Introduction to Bioinformatics*. Addison Wesley Longman.
- Brown SM. 2000. *Bioinformatics: A Biologist's Guide to Biocomputing and the Internet*. Eaton Publ.
- Cody RP and Smith JF. 1997. *Applied Statistics and SAS Programming Language*. Elsevier.
- Lesk AM. 2008. *Introduction to Bioinformatics*. Oxford University Press.
- Isik, Fikret, James Holland, and Christian Maltecca. 2017. *Genetic data analysis for plant and animal breeding*. New York: Springer.
- Littell RC, Milliken GA, Stroup WW and Wolfinger RD. 1996. *SAS System for Mixed Models*. SAS Institute.
- Mount DW. 2001. *Bioinformatics: Sequence and Genome Analysis*. ColdSpring Harbor Press.
- Rashidi HH and Buehler LK. 2005. *Bioinformatics Basics: Applications in Biological Sciences and Medicine*. CRC Press.
- Saxton AM. 2004. *Genetic Analysis of Complex Traits Using SAS*. SAS Publ.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of Heredity*

I. Course Title : Molecular And Cytogenetics

II. Course Code : FGB 507

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on different tools of molecular and cytogenetic

V. Theory

Unit I

Introduction, Historical background, Importance, Chromosome theory of inheritance; Chromosomal models and their ultra-structure, Chromosomal movements and position effect –Cytogenetic and evolution.

Unit II

DNA and RNA as genetic material; Chemistry and structure of DNA, Fine structure

of gene, Split genes, Pseudogenes, Overlapping genes and Multigene families, Mechanisms of DNA replication, Extra Chromosomal Inheritance / Cytoplasmic Inheritance; Mitochondrial DNA.

Unit III

Biochemical markers: Allozyme polymorphism and its application in estimating population genetic parameters, Genetic basis of immunity.

Unit IV

Molecular markers; RAPD, RFLP, AFLP, EST, SNP, Minisatellites and Microsatellites and application in population genetic analysis and gene mapping, FISH–principle and application, Maternally and paternally inherited genetic markers, Molecular pedigree, Major genes, Poly genes and QTLS, Application of molecular markers in genetic selection, QTL and MAS, Association studies, Genomic selection.

Unit V

Genetics of Sex determination and differentiation; Genotypic sex determination (GSD); Environmental Sex determination (ESD); Sex manipulation, Production of monosex population, Sex chromatin and Lyon's hypothesis; Chromosome numbers in fish and karyotyping, Chromosome banding techniques Molecular Cytogenetics; Fluroscence *In Situ* Hybridisation (FISH) –Application of nanotechnology in chromosome and genome mapping, Mitochondria and Y chromosome.

Unit VI

Genotoxicity and mutagenicity –Chromosomal aberrations; Single cell gel electrophoresis, MNT, SCE; Genetic and evolutionary implications.

VI. Practical

- Biochemical markers and Molecular markers
- DNA sequence polymorphism and related software for alignment and analysis
- Genomic DNA isolation from prokaryotes and eukaryotes
- Interpretation of gels and data analysis using various software
- Isolation of RNA and RT-PCR, Agarose gel electrophoresis of DNA and RNAPCR, primer designing, PCR-RFLP, extraction of DNA from agarose gels
- Preparation of chromosome spreads; Karyotyping; Banding techniques; MNT, SCE, Comet Assay.

VII. Suggested Reading

- Lakra WS, Abidi SAH, Mukherjee SC and Ayyappan S. 2004. *Fisheries Biotechnology*. Narendra Publ. House.
- Pasteur N, Pasteur G, Bonhomme F, Catalan J and Britton-Davidian J. 1988. *Practical Isozyme Genetics*. Ellis Horwood.
- Pisano E. 2007. *Fish Cytogenetics*. Science Publ.
- Reddy PVGK, Ayyappan S, Thampy DM and Krishna G. 2005. *FishGenetics and Biotechnology*. ICAR. 4. Caetano-Anolles G and Gresshoff PM. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH.
- Sambrook J and Russel WD. 1989. *Molecular Cloning: A Laboratory Manual*. Vols. I-III. Cold Spring Harbor Laboratory Press

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*

- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Cell and Tissue Culture

II. Course Code : FGB 508

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on cell and tissue culture techniques and their application in gene banking, genetic characterization and health management.

V. Theory

Unit I

Introduction: Structure and Organization of animal cell; Equipment and materials for animal cell culture technology, Cell lines and media; Primary and established cell line cultures; Media supplements, their metabolic functions; serum and protein free defined media and their application.

Unit II

Cell culture: Basic techniques of cell culture *in vitro*; Development of primary cultures, Cell separation, Maintenance of cell lines; Biology of cultured cells, Transformation and differentiation of cell cultures, Characterization of cell lines; Measurement of viability and cytotoxicity assays; Measuring parameters of growth; Karyotyping, Isozyme assays, Cryopreservation, Assessment of contaminants.

Unit III

Cell cloning: Micromanipulation, cell transformation, application of fish cell culture, 3D cell culture, Scaling-up of cell culture, Cell hybridization; Somatic cell fusion, hybridoma technology, Production and Application of monoclonal antibodies.

Unit IV

Stem cell culture and its application, Bio-products from cell culture, Cryopreservation of embryos and cells.

VI. Practical

- Principles of sterile techniques and cell propagation
- Preparation of different cell culture media
- Primary cell culture techniques; Establishing cell lines: isolation, characterization identification of cell lines
- Pure culture techniques; Maintenance and preservation of cell lines
- Propagation of cells in suspension cultures
- Hybridoma technology: strategy and techniques
- Production of monoclonal antibodies
- Cryopreservation of cell lines

VII. Suggested Reading

- Barnes D and Mathur PJ. 1998. *Methods in Cell Biology*. Vol. 57. *Animal Cell Culture Methods*. Academic Press.
- Basega R. (Ed.). 1989. *Cell Growth and Division: A Practical Approach*.IRL Press.

- Butler M and Dawson M. (Ed.). 1992. *Cell Culture*. Bios Scientific Publ. 4. Clynes M. 1998. *Animal Cell Culture Techniques*. Springer.
- Freshney I. 1994. *Culture of Animal Cells: A Manual of Basic Techniques*. 4th Ed. Wiley-Liss.
- Harrison AM, Rae FI and Harris A. 1997. *General Techniques of Cell Culture*. Cambridge University Press.
- Lan FR. 1994. *Culture of Animal Cells*. 3rd Ed. Wiley-Liss.
- Masters RW. 2000. *Animal Cell Culture-Practical Approach*. Oxford University Press

I. Course Title : Molecular Breeding

II. Course Code : FGB 509

III. Credit Hours : 1+1

IV. Aim of the course

To apply basic concepts of molecular genetics in fish breeding

V. Theory

Unit I

Introduction to Molecular Breeding; Molecular mechanism of genetic recombination, Molecular taxonomy and its application in Fisheries; Phylogenetics and its application –Genetics of Sex determination; Genotypic sex determination (GSD); Environmental Sex determination (ESD); Sex manipulation, production of monosex population.

Unit II

Single genes in fish breeding; Mapping and Identifying single genes; Types of DNA sequence responsible for alterations to create single gene effect –QTL and MAS identification; Marker assisted selection with markers in linkage disequilibrium with QTL –Molecular pedigree Assigning.

Unit III

Major genes, Poly genes and QTLS, Tests for detecting major genes, Complex segregation analysis, Genetic maps and candidate genes, Genome-wide association studies (GWAS) in pedigreed population, Methods and tools for GWAS.

Unit IV

Introduction to genomic selection; Methodologies for genomic selection; Estimation of Genomic breeding value, Factors affecting the accuracy of genomic selection, Genomic selection with low marker density; Genomic selection across populations and strains, Re-estimation of the chromosome segments, Designing breeding programs with genomic information.

VI. Practical

- LD Analysis
- Molecular pedigree construction
- Power of association studies; Building the IDB matrix from linkage disequilibrium information; marker assisted selection with linkage disequilibrium
- Genomic Relationships and GBLUP
- Realized Genomic Relationships; Calculation of G Matrices; Genomic BLUP; Genomic selection using BLUP; Genomic selection using a Bayesian approach; Bayesian Approach using a prior for chromosome segment variances with a large weight at zero (Bayesian)

VII. Suggested Reading

- Caetano-Anolles G. and Gresshoff, P.M. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH.
- Lehninger LA, Nelson DL and Cox MM. 2008. *Principles of Biochemistry*. 4th Ed. WH Freeman.
- Lewin B. 2004. *Genes VII*. International Ed. John Wiley and Sons.
- Pasteur N, Pasteur G, Bonhomne F, Catalan J and Britton–Davidian J. 1988. *Practical Isozyme Genetics*. Ellis Horwood.
- Sambrook J and Russel WD. 1989. *Molecular Cloning: A LaboratoryManual*. Vols. I-III. Cold Spring Harbor.
- Stryer L, Berg JM and Tymocz KJL. 2004. *Biochemistry*. 5th Ed. WH Freeman.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20 Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture,*
- *Aquaculture Reports,*
- *Aquaculture Research,*
- *Genetics,*
- *Indian Journal of Fisheries,*
- *Journal of Fish Biology,*
- *The Journal of heredity*

I. Course Title : Microbial Genetics

II. Course Code : FGB 510

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of genetics applicable to microbes

V. Theory

Unit I

Basic of microbial existence: Why study the prokaryotic genetics History of Microbiology –Bacterial genetics, Conjugation, Sex factors; High frequency recombination; Transduction (generalized and specialized), Bacterial transformation; Mutation types, Repair mechanism, Selection of mutants, Genetics of Bacteriophage-Bacteriophage classification, Types, PhageT4-Structure, Gene expression and genome organization, Lamda phage replication, Lytic and lysogeneic cycles, Mechanisms of repressor synthesis and its control, Auto regulation, One step growth curve; Importance of bacteriophages, Coalescent of bacterial population, Population reproduction models, Time and effective population size, Demography – Recombination and gene conversion.

Unit II

Linkage, Selection and the clonal complex- Recombination, Linkage and substructure, Neutrality versus Selection, Clustering Techniques; Sequence based population structure analysis.

Unit III

Population Genetics-Natural Selection, Methods for detecting presence of natural selection, Measure of genetic diversity, The concept of Effective population size,

Population sub division, Population Genomics, Population structure and genetic evolution, Similarities and differences, Bacterial Population genomics, MLVA and SNP for analysis in population genetic study, Phylogenetic resolution, Phylogeographic resolution.

Unit IV

Gene Maps, Tools and protocols World Wide Web Databases, Genetically modified organisms (GMOs) Technological advances Controls and cautions.

Unit V

Transposable Elements: IS elements, Tn3 family and medical significance, The Genetic and evolutionary significance of transposable elements; Use in genetic analysis and evolutionary issues.

Unit VI

Microbial strain improvement techniques; Identification of ideal microorganisms for bioprocess, Microbial strain improvement, Genetic engineering and evolutionary engineering, Bioprocess optimization and applications in industry, Agriculture and health.

VI. Suggested Reading

- Maloy SR, Cronan JE and Freifelder D. 2009. "*Microbial Genetics*", Narosa Book Distributors, 2nd edition.
- Pelczar MJ, Chan ECS and Kreig NR. 2001. "*Microbiology*", McGraw Hill Publishers, 5th edition.

Course Title with Credit Load
Ph.D. in Fish Genetics and Breeding

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FGB 601	Design of Breeding Programs	2+1
FGB 602	Genetic Selection of Complex Traits	2+1
FGB 603	Fish Genome and Genomic Selection	2+1
FGB 604	Linear Models and Experimental Designs in Fish Genetics	1+2
	Minor Courses (From the subjects closely related to a student's major subject)	**6 Credits**
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	**5 Credits**
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
FGB 691	Doctoral Seminar	0+1
FGB 691	Doctoral Seminar	0+1
	Doctoral Research	**75 Credits**
FGB 699	Doctoral Research (Semester II)	0+15
FGB 699	Doctoral Research (Semester III)	0+15
FGB 699	Doctoral Research (Semester IV)	0+15
FGB 699	Doctoral Research (Semester V)	0+15
FGB 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fish Genetics and Breeding

I. Course Title : Design of Breeding Programs
II. Course Code : FGB 601
III. Credit Hours : 2+1

IV. Aim of the course

To learn the recent advances and development of breeding plans

V. Theory

Unit I

Genetics in Broodstock management of commercially important fish and shellfish, Assembling base population, Choosing selection objectives and criterion, Pedigree identification, Physical and molecular tagging; Maintaining breeding records.

Unit II

Genetic parameters, Heritability, Repeatability, Genetic, Phenotypic and Environmental correlations Factors influencing genetic progress, Comparison of Selection Systems, Criteria and procedure for comparison, Long term program, Short term program, Single population program; Open Nucleus Breeding System (ONBS), Case study of national and international genetic improvement programs viz., Jayanti Rohu, *Clarias magur*, GIFT Tilapia, Norwegian Salmon, Pacific White Shrimp *L.vannamei* and others.

Unit III

Important reproductive tools for implementation of breeding plan; Captive maturation, Synchronization of spawning Cryopreservation of gametes Application of Hybridization, Ploidy manipulation, Monosex culture, Genetic engineering, Transgenesis for commercial purpose.

Unit IV

Designing mating plans Inbreeding, Types of inbreeding, Genetic and Phenotypic effect of Inbreeding; Consequences of inbreeding and management of genetic variation in fish breeding program Genetic selection and its impact on natural stock Outbreeding, Forms of outbreeding, Effects of Outbreeding, Breeding plans to exploit additive and non-additive genetic variation, Maternal influence and its estimation, Genetic mechanisms in adaptation, measurement and adaptability indices, G x E interaction.

Unit V

Breeding plans for shellfish improvement, Controlled mating in shellfish Developing new ornamental strains of fishes: Inheritance of ornamentation traits; Sex linked inheritance of ornamentation; Recording ornamentation traits; Molecular genetics of body pigmentation.

Unit VI

Genetics of developing SPR strain; Immune system in fish and shell fish and genetics of immune system Genetics of disease susceptibility; application of genetic tools to predict disease susceptibility; Developing plans for genetic selection of threshold traits Fish genetics and welfare; A continued need for genetic selection scientific, regulatory and public acceptance issues Ethical, moral and fish welfare issues Ownership of genetically improved strain through public sector funding.

VI. Practical

- Developing Growth curves and their components
- Estimation of Genetic Parameters; Selection and genetic gains
- Path coefficient and calculation of inbreeding coefficient and relationship
- Designing breeding programs for threshold traits, Estimation of heritability of threshold traits
- Preservation of gametes; Synchronization of spawning
- Developing the protocols for evaluating the various genetic improvement programs and their impacts
- Survey on impact of the program on farmers and consumers
- Impact of climate change on fish germplasm
- The focus will be on critical review of contemporary applied breeding programs and journal articles - students are also expected to prepare a term paper for submission at the end of the semester

VII. Suggested Reading

- Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag.
- Falconer DS and Markay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman.
- Gjedrem, Trygve et al., 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.
- Thomas PC, Rath SC and Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Genetic Selection Of Complex Traits

II. Course Code : FGB 602

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the efficiency of different selection methods

V. Theory

Unit I

Introduction: Past and present status of fish breeding, Complex traits and their inheritance, Recording complex traits.

Unit II

Strain comparison, Factors affecting the rate of genetic improvement, Performance testing; Estimation of genetic gain under different selection program.

Unit III

Influence of non-genetic factors on growth, Factors influencing production and reproductive traits, Correction and standardization of animal breeding data, Simultaneous prediction of breeding values for several traits, Recurrent and Reciprocal Recurrent Selection –Crossbreeding and hybridization.

Unit IV

QTL and MAS; Breeding values for binary traits, Threshold characters and their selection procedure, Selection and breeding for disease resistance and survival analysis –Diallel analysis; Selection for single trait and multiple traits.

Unit V

Organizing breeding programs, Structure of breeding programs, Breeding for optimum production, Economic value of each animal, Cost of broodstock production, Organizing field trial –Farmers cooperatives, breeding companies, National or local breeding programs

Unit VI

Dissemination procedures and issues, Breeding nucleus, Multiplier centers –Socio-economic impact, Technological adoption, Increased production –Economic Evaluation of Genetic Breeding Programs**,** Criteria for Economic Evaluation; Profit Horizon, Interest Rate, and Return on Investment, Environmental impact of improved varieties/strains.

VI. Practical

- Application of various computer software for genetic analyses: SAS, R, AsReml etc.
- Application of Mixed models for estimation of genetic parameters-Heritability, Correlations;
- Construction of selection index
- Diallele crossing
- Developing and evaluating the dissemination programs of genetically improved strain
- Estimation of breeding values EBV, BLUE, BLUP
- QTL parameter estimation; Analysis of QTL as random effect

VII. Suggested Reading

- Cameron ND. 1997. *Selection Indices and Prediction of Genetic Merit in Animal Breeding*. CABI.
- Falconer DS and Markay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman.
- Gjedrem, Trygve *et al*. 2005. *Selection and Breeding Programs in Aquaculture* Springer
- Isik, Fikret, James Holland, and Christian Maltecca. 2017. *Genetic Data Analysis for Plant*

and Animal Breeding. New York: Springer.
- Joel Ira Weller. 2016. *Genomic Selection in Animals*. John Wiley and Sons, Inc., New Jersey. • Morde
- Lynch M and Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Fish Genome and Genomic Selection

II. Course Code : FGB 603

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on understanding genomes, application of genomic tools and strategies for enhancing production performances and conservation of fish genetic resources

V. Theory

Unit I

Organisation of genomes: Genome, Genomics, Transcriptomics, and Proteomics, Genome size estimation, Genome size in model organisms, C-value paradox, Genome diversity, Taxonomy and significance of genomes, Classification of genomics, Vertebrate genome evolution –Establishing phylogeny on the basis of genomics, Comparative genomics, Population genomics, Limitation and application of genomics, Structural genomics; Linkage maps and QTL, Haplotype structure of genome; Genetic, physical and transcription maps, Fluorescent *in situ* hybridisation, Radiation hybrid mapping, Sequence tagged site mapping, Restriction mapping.

Unit II

Functional genomics: NGS data analysis, Sequence assembly, Gene identification, Gene prediction rules, Gene annotation and pathway analysis genome databases and browsers, Gene ontology assignment, Mining of transcriptome data for protein coding genes, Differentially expressed genes, Short and long non coding RNA and their target genes –Next generation sequencing; Second and third generation sequencing platforms, NGS platforms such as Illumina, Roche 454, SOLiD, Ion torrent, PacBio, Oxford, Nanopore Technologies, Principles, Applications and Limitations.

Unit III

Genome projects: The human genome project, HapMap project, The 100 genome project, Encode project, Ethical, legal and social issues of human genome project, Fish genome projects: Fugu, Tetraodon, Elephant shark, Atlantic salmon, Zebra

fish, Common carp, Rainbow trout, Channel catfish, Fishes in Genome 10 K project, Status of fish genomics research in India, IPR issues; Patent at one place and not in another, Access to fish genetic resources.

Unit IV

Genomic tools: Genome wide association studies, Custom microarray technologies, DNA microarray, SNP array, Subtractive hybridization, Comparative genomic hybridization.

Unit V

Application of markers in fish breeding, Genomic resources: ESTs, RFLPs, Microsatellite markers, SNPs, BAC library, Molecular pedigree assigning, Molecular, kinship estimation, Experimental designs to detect QTL, Generation of linkage disequilibrium –Limits to response via MAS; Implementing MAS in breeding programs.

Unit VI

Genomic Selection- Overview of Implementation and Benefits of Genomic Selection Genomic Best Linear Unbiased Prediction (GBLUP); Two Equivalent Mixed Models for GBLUP of Breeding Values; GBLUP for Individuals without Phenotypic Observations, Genomic Estimation of Variance Components; Genomic Estimation of Heritabilities; Genomic Relationship and Correlation.

VI. Practical

- Tools for NGS data analysis
- QTL Analysis, Hapalotype based QTL analysis
- Genomic approaches to selection for disease resistance
- Genomic tools: Genome wide association studies, custom microarray technologies, DNA microarray, SNP array, Subtractive hybridization comparative genomic hybridization
- Estimation of GBLUP; Genomic Estimation of Variance Components; Genomic Estimation of Heritabilities; Genomic Relationship and Correlation

VII. Suggested Reading

- Brown TA. 2017. Genomes 4 (4th edition). Garland Science, US, 544 pp.
- David Siegmund and Benjamin Yakir. 2007. The statistics of Gene Mapping. Springer, USA.
- Dunham I. 2003. Genome mapping and sequencing, Panima Publishing Corporation-New Delhi, 470 pp.
- Hartwell LH, Hood HL, Goldberg ML, Reynolds AE, Silve LM and Veres RG. 2004. Genetics: From Genes to Genomes McGraw-Hill Education.
- Isik Fikret, James Holland and Christian Maltecca. 2017. Genetic data analysis for plant and animal breeding. New York: Springer.
- Joel Ira Weller. 2016. Genomic Selection in Animals. John Wiley and Sons, Inc., New Jersey
- Primrose SB and Twyman RM. 2006. Principles of Gene Manipulation and Genomics (7th edition). Blackwell Publishing, Oxford UK., 672 pp.
- Primrose SB and Twyman RM. 2006. Principles of gene manipulation and genomics.
- Sahai S. 2002. Genomics and Proteomics, Functional and Computational Aspects, Kluwer Academic Publishers, New York.
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

Suggested Journals

- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Genetics*
- *Indian Journal of Fisheries*
- *Journal of Fish Biology*
- *The Journal of heredity*

I. Course Title : Linear Models and Experimental Designs in Fish Genetics

II. Course Code : FGB 604

III. Credit Hours : 1+2

IV. Aim of the course

To learn the application of different statistical models in breeding data.

V. Theory

Unit I

The Binomial, Poisson, Normal models; ANOVA, Multiple regression and correlation Testing of genetic hypothesis, Test of hypothesis, Hierarchical classification, Variance Components, Linear Mixed Models (LMMs) an overview, Clustered data, Repeated measures, Longitudinal data; Levels of Data; Types of factors and their related effects in LMM, Fixed effects, Random effects.

Unit II

Matrix operations: Determinants, Inverse of matrix, Linear equations, the matrix algebra of regression analysis.

Unit III

Specification of LMM: General specification for an individual observation General matrix specification-Covariance structure for the D and R matrix, Mixed models: Predicting Random effects, Best Linear Unbiased Predictors (BLUP), their application in estimation of genetic variance components and parameters, BLUP Under the Animal Model; BLUP with Repeated Records; Analysis of non-orthogonal and multivariate data.

Unit IV

Maximum likelihood (ML) estimation of variance-covariance components, Structure of Variance, Covariance Matrix as a Function of Partial Derivatives, ML Estimation of Variance, Covariance Components, Restricted maximum likelihood estimation (REML) of Variance-covariance components, General REML Equations; REML Using the CE and the MME methods of BLUP.

Unit V

ANOVA –Challenge Test-Designing the challenge tests, Data collection protocols

Unit VI

Model building and simulations; Simulation of phenotypes; Simulation of fish breeding in different conditions

VI. Practical

- Matrix operation, matrix inversion, matrix algebra of regression analysis
- Least Squares analysis in one way classification
- Use of various statistical packages for genetic parameter estimations: SAS, R, AsReml, PEST, SelAction
- One way classification with regression and covariance
- Two way classification with and without interactions
- Multiple and nested classification
- Predicting Random effects- Best Linear Unbiased Predictors (BLUP)
- Maximum likelihood estimation of genetic parameters, Analysis of non-orthogonal and multivariate data
- Genomic Best Linear Unbiased Prediction (GBLUP)
- Genomic Estimation of Variance Components
- Genomic Estimation of Heritability
- Survival analysis- commonly used survival functions, Kaplan-Meier estimate of survival function, Cox regression method, Hazard ratio and survival

VII. Suggested Reading

- Dutkowski G and Gilmour A. 2005. *AsReml Cook Book*. Statistical Software Package.
- Isik, Fikret, James Holland, and Christian Maltecca.2017. Genetic data analysis for plant and animal breeding. New York: Springer.
- Kruschke J.K. 2015. Doing bayesian data analysis. Second Edition. Academic Press
- Littell RC, Milliken GA, Stroup WW and Wolfinger RD**.** 1996. *SAS Systemfor Mixed Models*. SAS Institute.
- Lynch M and Walsh B. 1997. Genetics and Analysis of Quantitative Traits. Sinauer, Sunderland.
- Saxton AM. 2004. *Genetic Analysis of Complex Traits Using SAS*. SAS Publ.
- West B.T. Welch, K.B. and Gatecki, A.T. 2015. Linear Mixed Models. CRC press
- https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20 Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf
- https://www.jmp.com/en_us/academic/jmpg-course-materials.html

List of Suggested Journals

- *Acta Cytologica*
- *Advances in Genetics Incorporating Molecular Genetic Medicine*
- *Animal Genetic Resource Information*
- *Animal Genetics*
- *Annual Review of Genetics*
- *Aquaculture*
- *Aquaculture Reports*
- *Aquaculture Research*
- *Bioinformatics*
- *Biological Conservation*
- *BMC Bioinformatics*
- *BMC Molecular Biology*
- *Breeding Science*
- *Briefings in Bioinformatics*
- *Briefings in Functional Genomics and Proteomics*
- *Cancer Genetics and Cytogenetics*
- *Conservation Biology*
- *Conservation Genetics*
- *Cytogenetics*
- *Genetics*

- *In Silico Biology*
- *Indian Journal of Agricultural Statistics*
- *Indian Journal of Cytology and Genetics*
- *Indian Journal of Fisheries*
- *Indian Journal of Genetics and Plant Breeding*
- *Indian Journal of Statistics*
- *Journal of Animal Breed and Genetics*
- *Journal of Animal Science*
- *Journal of Applied Statistics*
- *Journal of Bio-Chemistry and Molecular Biology*
- *Journal of Computational and Graphical Statistics*
- *Journal of Fish Biology*
- *Journal of Genetics*
- *Journal of Heredity*
- *Journal of Molecular Biology*
- *Journal of Official Statistics*
- *Journal of Statistical Software*
- *Journal of Statistics Education*
- *Journal of Tissue Culture Methods*
- *Molecular and Cellular Biology*
- *Molecular Cytogenetics*
- *The Journal of heredity*

List of Suggested e-Resources

- http://www.ncbi.nlm.nih.gov/
- http://www.genome.gov
- http://www.hgsc.bcm.tmc.edu/projects/bovine
- http://www.animalgenome.org
- http://www.blackwell-synergy.com
- http://www.genomics.liv.ac.uk
- http://www.biomedcentral.com
- http://www.genomealliance.org.au
- http://www.csiro.au
- http://www.isag.org.uk
- http://www.ebi.ac.uk/imgt/
- http://www.csrees.usda.gov

Suggested Broad Areas for Master's and Doctoral Research

- Cryopreservation of gametes of species of commercial importance
- Estimation of gene and genotype frequencies using various population genetic tools (markers)
- Estimation of effective population size, inbreeding accumulation rate in a breeding population
- Genetic stock structure analysis; genetic variability studies of species o commercial importance
- Estimation of genetic parameters in species of commercial importance
- Developing breeding plans for different commercial fish and prawn species
- Estimation of genetic parameters in species of commercial importance
- Estimation of heterosis and Inbreeding depression in breeding population
- Construction of growth curves for different commercial fish and prawn species Developing breeding plans for different commercial fish and prawn species
- Cryopreservation of gametes of species of commercial importance
- Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
- Estimation of genetic diversity and relatedness using molecular information
- Morphometric analysis of stocks

- Milt quality analysis and cryopreservation of milt
- Estimation of linkage disequilibrium using molecular genetic data
- Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
- Estimation of genetic diversity and relatedness using molecular information
- QTL Analysis and application in selective breeding
- Estimation of linkage disequilibrium using molecular genetic data
- Application of molecular genetic markers for estimation of effective population
- size, rate of inbreeding
- Estimation of genetic diversity and relatedness using molecular information
- QTL Analysis and application in selective breeding
- Chromosome mapping for different commercial fish and prawn species
- Karyotyping and chromosome spread preparation for different commercial fish and prawn species
- Estimation of genetic parameters using various statistical packages like SAS, AsREML, PEST
- Molecular data analysis using softwares like GENEPOP
- Establishing cell lines
- Construction of growth curves for different commercial fish and prawn species
- Estimation of genetic and non-genetic parameters
- Developing breeding plans for different commercial fish and prawn species
- Cryopreservation of gametes of species of commercial importance
- Developing breeding plans for different commercial fish and prawn species
- Estimation of genetic parameters in species of commercial importance
- Estimation of genotype-environment Interaction
- Estimation of heterosis and Inbreeding depression in breeding population
- Socio-economic impact studies for genetically improved varieties
- Evaluation of International genetic improvement programmes
- Chromosome mapping for different commercial fish and prawn species
- Karyotyping and chromosome spread preparation for different commercial fish and prawn species
- Pedigree assigning using molecular data
- Estimation of genetic parameters using molecular data
- Estimation of genetic and non-genetic parameters using various statistical packageslike SAS, AsREML, PEST

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Nutrition and Feed Technology

Preamble

(Fish Nutrition And Feed Technology)

Over the last decade, spectacular growth has taken place in aqua farming with deployment of formulated feeds. The bulk of high-value freshwater and marine carnivorous finfish/ shellfish is produced by intensive farming systems using high-cost nutrient inputs in the form of "nutritionally-complete formulated diets".

Thus, nutrition and feeding will continue to play an essential role in the sustained development of aquaculture which however, must take into account and ensure that the needs of competing users are met, and that environmental integrity is protected by formulating eco-friendly feeds

Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds, fertilizers etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved.

Thus, good nutrition is of paramount importance for economic production of healthy and high quality product. In fish farming, nutrition of fish is critical because feed represents 40-50% of the production costs. Fish nutrition research has advanced in recent years with the development of commercial diets that promote fish growth and health. Development of species-specific feed formulations support the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products.

Culturing fish in captivity, nothing is more important than sound nutrition and adequate feeding. Hence growth is affected either due to less intake of feed or under utilization of feeds. An under nourished animal cannot maintain its health and be productive, regardless of the quality of its environment.

Thus, the production of nutritionally balanced feed for fish requires efforts in research, quality control, and biological evaluation. Faulty nutrition obviously impairs fish productivity and result in a deterioration of health until recognizable diseases ensues. The borderlines between reduced growth and diminished health, on the one hand, and the apparent disease, on the other, are very difficult to define. However, the problem of recognizing a deterioration of performance in its initial stages and taking corrective action will remain an essential part of the skill of fish culturist.

Like any other terrestrial animal, fish also needs the same type of nutrients for their growth. However, the amount of these nutrients varies due to variation of metabolic rate. Hence, supply of these nutrients is warranted in fish feed. Unlike animals, the availability of these nutrients to fish is different due to their surrounding environment. Some nutrients are available form water, which needs to be considered critically while formulating feed for fish.

Finfish require around 40 nutrients for optimal growth and wellbeing. The proteins, lipids/fats and carbohydrates are considered as "macro nutrients", while vitamins and minerals put together constitute "micronutrients" required for the healthy growth in fish.

Thus, careful attention has to be paid in understanding the nutritional requirements and formulating a nutritionally balanced feed.

Fish feed technology is one of the developing sectors of aquaculture, particularly in the third world countries. Commercial formulations of feeds are generally proprietary secrets, and the ingredients used are often too expensive to be used in fish farming. The need for developing suitable feeds based on locally available inexpensive ingredients has therefore, been widely recognized.

The technology of feed processing has undergone substantial improvement in recent years. It was only sixty years ago that feeds stuffs were mixed on the warehouse floor by the use of a shovel. Feed processing has progressed from the simple mixing of several ingredients by hand to mechanical mixing, to continuous mixing, and now to computer controlled mixing and pelleting. However, the basic concept of mixing ingredients together to result in a nutritionally balanced feed has remained unchanged.

To accomplish the mixing of different ingredients, grinding these ingredients to similar particle sizes, and then putting them together in a single unit, requires a considerable amount of specialized equipment and technical expertise. Some feed plants are versatile and designed for multitasking of producing different feeds for several animals such as poultry feeds, canine feeds etc. including fish feeds.

Whatever good quality feed may be produced but the manner in which it is offered to fish becomes prime important. Considerable innovations have been made the world over in production of feed broadcasting equipment to manage feeding and feeding schedules to prevent overfeeding or underfeeding to maximise growth.

The intensive aqua farming practices to raise high production per unit area has resulted in emergence several of the diseases driving the farmer to economic losses. Thus, the farming industry has focused its attention in enhancing immunity of aquatic animals through functional feeds. Though lot of research was generated on the use of probiotics and prebiotics, but yet find their place as commercially viable technologies.

It is with this background that the members of the BSMA committee and the invited experts from farm and feed industry reviewed the existing PG and Ph.D. course syllabus critically several times, incorporated the recent content learning both in theory and practical to bring it in this elevated format to groom the fish nutrition and feed technology specialists and professionals to the industry, R and D and academics. The committee took note of several considerations like relevance of course title, objectives and unit contents, merging of units to bring uniformity in avoiding content repetition in units while ensuring uniform distribution of units as far as possible to 6-7 units in 2+1 course and minimum 3-4 units in 1+1 courses.

Under M.F.Sc. program major changes in title and contents of as many as 6 courses has been made with minor changes in other 6 courses. In Ph.D. program, only one course was subjected to major changes and upgraded to include feed mill management as new content of learning for feed industry needs while in other 7 courses only minor modifications were made. A new course “Introduction to Biomolecules” has been introduced in Ph.D. program to expose the students to an emerging science on feed biomolecules in fish biosystem.

Course Title with Credit Load
M.F.Sc. in Fish Nutrition and Feed Technology

Course Code	Course Title	Credit Hours
	Major courses	**20 Credits**
FNT 501	Principles of Fish Nutrition	2+1
FNT 502	Nutrient Digestion and Growth	2+1
FNT 503	Feeds and Feed Technology	2+1
FNT 504	Nutritional Energetics	2+1
FNT 505	Nutritional Requirement and Feeding Management	2+1
FNT 506	Feed Ingredients and Additives	2+1
FNT 512	Nutraceuticals	1+1
	Minor Courses (From the subjects closely related to a student's major subject)	**8 Credits**
FNT 507	Shellfish Nutrition and Feeding	2+1
FNT 508	Protein Nutrition	1+1
FNT 509	Lipid Nutrition	1+1
FNT 510	Carbohydrate Nutrition	1+1
FNT 511	Vitamins and Minerals Nutrition	1+1
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common courses (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques 5. Agricultural Research, Research ethics and Rural Development Programmes	**5 credits**
	Total Course Work Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FNT 591	Master's Seminar I	0+1
	Masters' Thesis Research	**30 Credits**
FNT 599	Master's Research (Semester III)	0+15
FNT 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fish Nutrition and Feed Technology

I. Course Title : Principles of Fish Nutrition
II. Course Code : FNT 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic principles of fish nutrition and the role of different nutrients.

V. Theory

Unit I

Protein nutrition: Protein and amino acids, Their specific functions, Classification and evaluation criteria of dietary protein (nutrient gain, nutrient efficiency, TGC, PER, NPU, BV, EAAI, chemical score), Protein deficiency symptoms.

Unit II

Lipid nutrition: Lipids and fatty acids, Their specific functions, Classification and evaluation of lipid quality, Lipid deficiency symptoms.

Unit III

Carbohydrate nutrition: Carbohydrates, Functions, Classification and Utilization of carbohydrate in fish diets.

Unit IV

Vitamin and mineral nutrition: Specific functions, Classification, Sources of vitamins and minerals and their deficiency symptoms.

Unit V

Nutritional energetics: Definition, Different forms of energy and energy value of feed (gross energy, digestible energy, metabolizable energy, net energy), Importance of protein-energy ratio in fish diets.

Unit VI

Larval and Brood stock nutrition: Larval gut morphology, importance of live feed and formulated feeds in larval nutrition, Nutrients required for egg and sperm quality and reproductive efficiency.

VI. Practical

Proximate analysis: Moisture, Crude protein, Crude lipid, Gross energy, ash, acid insoluble ash, crude fibre, nitrogen free extract of feed and fish tissue, analysis of fatty acids and amino acids, calcium, phosphorus, vitamin C content of feed.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome.
- De Silva, S. S. and Anderson, T. A. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.

- FAO *training manual related to feed analysis*.
- Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. *Nutrition and Feeding of Fish and Crustaceans,* Springer Praxis Publishing, Chichester, U.K.
- Halver J. E. 1989. *Fish Nutrition*, Academic Press, San Diego, Califonia.
- Halver, J. E. and Tiews, K. T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver, J. E. and Hardy, R. W. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher, B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell, R. T. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Paulraj, R., 1993. Aquaculture Feed. CMFRI publication, 84 pp.

I. Course Title : Nutrient Digestion and Growth

II. Course Code : FNT 502

III. Credit Hours : 2+1

IV. Aim of the course

To understand digestion, absorption and transportation of nutrients and nutrient induced growth in fish and shell fish

V. Theory

Unit I

Digestive system of fish: Digestive organs and their roles, Anatomy and histology, Feed ingestion, Feeding mechanism, Gastro-intestinal motility.

Unit II

Digestive system of shellfish: Digestive organs and their roles, Anatomy and histology, Feed ingestion, Feeding mechanism, Gastro-intestinal motility.

Unit III

Digestion: Digestion of proteins, Lipids and carbohydrates, Methods of determining digestibility; Direct and indirect methods, Advantages and disadvantages of methods, Digestibility value of feed ingredients and Factors affecting digestibility, Role of gut micro flora in digestion.

Unit IV

Absorption and Transportation: Active, passive and facilitated absorption of nutrients, Transport of nutrients and cellular uptake.

Unit V

Regulation of digestion: Appetite and satiation, Factors influencing appetite and satiation, Hormonal regulation and Factors affecting digestion.

Unit VI

Growth: Concept of growth, Growth curve, Biotic and abiotic factors affecting growth, Correlation of growth with body weight and length.

VI. Practical

Dissection and examination of digestive organs; Histological preparation of digestive organs; Assays of enzyme activity of amylase, proteases and lipases; *In vivo - in vitro* digestibility studies.

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in*

Aquaculture Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*, Springer Praxis Publishing, Chichester, U.K.
- Halver JE. 1989. *Fish Nutrition*, Academic Press, San Diego, Califonia.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.

I. Course Title : Feeds and Feed Technology

II. Course Code : FNT 503

III. Credit Hours : 2+1

IV. Aim of the course

To learn basic concept of feed formulation and different feed processing techniques

V. Theory

Unit I

Feed formulation: General principles and criterions, Different methods of feed formulation; Pearson's square method and least cost formulation (quadratic equation, solver function, Graphic solution, Linear programming and software assisted formulations), Limitations of formulation methods.

Unit II

Types of feed: Wet, Moist and Dry (pellets – steam compressed, extruded and crumbled, flakes, powdered/ mash, micro-encapsulated, micro-bound and micro-coated diets). Farm made feeds, Experimental diets; Reference diet, purified and semi-purified diet, Compact pellet, Floating and slow sinking pellet feeds; Starter, grower, Finisher and broodstock feeds, High energy eco-friendly and medicated feed.

Unit III

Feed processing technology: Receiving of raw materials, Equipments used in feed manufacture and processing; Grinder/pulverizer, Mixer, Pelletizer/extruder, Crumbler, Drier, Vacuum coater/ fat sprayer, automatic bagging and sealing, Role of pre-conditioning in feed preparation, Effects of processing on the nutritional value and availability of nutrients.

Unit IV

Feed storage: Hydro-stability of feed and their storage; Prevention of spoilage from rancidity, Fungus and associated toxins; Vectors of fish disease in feed and quality control; Nutritional value in relation to feed storage.

Unit V

Feed additives and supplements: Binders, carotenoids, Attractants, Antioxidants, Probiotics, Prebiotics, Synbiotics, Immunostimulants, Nutraceuticals, Acidifiers and Preservatives, Bile acids, Herbal additives and Vitamins, minerals, Limiting amino acids, Essential fatty acids, Phospholipids, and Cholesterol.

Unit VI

Quality control in fish feed manufacturing: Quality control procedures, Raw

materials, Finished products; Safety of farm fish products, Harmful residues (pesticides, antibiotics, and pollutants).; Geometrical, and physical feature; Mechanical characteristics in air, Behavioural characteristics in water, Feed economics and evaluation.

VI. Practical

Feed formulation, Preparation of mineral and vitamin premix, Feed additives, binders, water stability test, and available lysine, Determination of feed particle size, Development of feed dispensers both for laboratory and pond feeding as part of project assignment, Visit to feed processing industries.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology,* ADCP/REP/80/11.F.A.O., Rome.
- D' Abramo, L.R., Conklin, D.E. and Akiyama, D.M. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva, S.S. and Anderson, T.A. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, UK.
- Halver, J.E. and Tiews, K.T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver, J.E. 2002. *Fish Nutrition.* Academic Press, San Deigo, C.A.
- ICAR-IRRI Outreach programme
- Lovell, R.T. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers
- Muir, J.F., and Robert, D. (Eds.). 1998. *Recent Advances in Aquaculture* Vol.II., Blackwell Science
- New, M.B. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O. Rome.

I. Course Title : Nutritional Energetics

II. Course Code : FNT 504

III. Credit Hours : 2+1

IV. Aim of the course

Nutritional energetics of different macromolecules and energy producing pathways.

V. Theory

Unit I

Concepts of nutritional energetics: Energy budget equation; Energetic efficiencies and energy flow/partitioning in biological systems; Gross energy, Digestible energy, Metabolizable energy, Net energy, Heat increment of feeding (specific dynamic action, SDA); Factors influencing energy metabolism.

Unit II

Energy requirement: Energy requirement of fish and shellfish, Factors influencing energy requirements; Energetics of maintenance and methodology of estimating the maintenance requirement.

Unit III

Energy estimation: Direct and indirect methods of estimation of energy of feed and feed components based on chemical compositions.

Unit IV

Energetics of growth: Relationship between feeding and growth; Energy exchange in biological systems; Growth and maturation

Unit V

Energetics of reproduction: Gonadal maturation and reproduction in relation to feeding

Unit VI

Energetics of intermediary metabolic pathways: Aerobic and anaerobic glycolysis, TCA cycle, Glycogenolysis, Beta oxidation, Electron transport chain, Effect of biotic and Abiotic factors on energy metabolism.

VI. Practical

Estimation of gross and digestive energy of feed and feed ingredients; Estimation of digestibility of nutrients, Bomb- calorimetry; Energy budget equation based on experimental data; Determination of standard metabolism in fish; Assay of metabolic enzymes.

VII. Suggested Reading

- Berg JM, Tymoczko JL and Stryer L. 2002. *Biochemistry*. W.H. Freeman and Company.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*.Chapman and Hall Aquaculture Series, London.
- Devlin TM. 1997. *Textbook of Biochemistry with Clinical Correlations*. Wiley-Liss, Inc.
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRC Press.
- Florkin M and Mason HS. 1963. *Comparative Biochemistry*. Academic Press, New York.
- Halver J and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell Science Ltd., London.
- Jobling M. 1994. *Fish Bioenergetics*. Chapman and Hall, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Murray RK, Granner DK, Mayes PA and Rodwell VW. 2000. *Harper's Biochemistry*. Appleton and Lange.
- Nelson DL and Cox MM. 2005. *Lehninger Principles of Biochemistry*. W.H. Freeman and company.
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry*. John Wiley and sons, Inc.

I. Course Title : Nutritional Requirement and Feeding Management

II. Course Code : FNT 505

III. Credit Hours : 2+1

IV. Aim of the course

To learn nutritional requirements, feeding methods and feed management of commercially important fish and shellfish.

V. Theory

Unit I

Nutritional requirements of finfish and shell fish: Nutritional requirements of larvae, growout and broodstock of commercially important finfish and shellfish. Methods of studying nutritional requirements; Qualitative and quantitative methods; Nutrients deficiency symptoms.

Unit II

Nutritive value of live food: Algae, Artemia, Cladocerans, Ostracods, Rotifers and copepods, Bio enrichment of artemia and zooplankton, Experimental diets; Reference diet, Purified and Semi-purified diet.

Unit III

Response indices for nutrient requirement studies: Weight gain, Specific growth rate (SGR)/ daily growth coefficient (DGC), Thermal growth coefficient (TGC) and, feed conversion ratio (FCR), Protein efficiency ratio (PER), Net protein utilization (NPU), Physiometabolic parameters, Dose response curves, Gonadosomatic index (GSI)

Unit IV

Body composition of fish and shellfish: Influence of nutrients on body composition and flesh quality; Effect of rations on fecundity and egg quality.

Unit V

Feeding methods and devices: Broadcasting, Bag feeding, Tray feeding, Raft feeding, demand feeder, Mechanical automatic feeder, Blower feeder. Check tray feed monitoring, Ration size/ feeding rate and feeding frequency, Restricted feeding and mixed feeding.

Unit VI

Feeding management: Application of research findings to farming situations, Record keeping, Growth prediction and Feeding management.

VI. Practical

Determination of feed intake in fry and fingerlings; Determination of nutrient requirements of fish/prawn using purified diet; Analysis of experimental data from growth study; Measures of protein quality (PER, NPU, BV); Exercise on feeding.

VII. Suggested Reading

- Cho CH and Kaushik SJ. 1990. *Nutritional Energetics in Fish: Energy and Protein Utilization in Rainbow Trout*. World Review on Nutrition and Dietetics.61: 132-172.
- D' Abramo LR, Conklin DE and Akiama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II, Heenemann, Berlin.
- Halver JE. 1989. *Fish Nutrition*. Academic Press, San Diego, CA.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell Science Ltd., London.
- Kaushik SJ. 1998. *Nutritional Bioenergetics and Estimation of Waste Production in Non-Salmonids*. *Aquat living resour* 11(4): 211-217
- New MB. 1987. *Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture*. ADCP/REP/87/26 F.A.O., Rome.
- NRC. 2011. *Nutrient Requirements of Fish and Shrimp*. National Academies Press, Washington D.C., USA

I. Course Title : Shellfish Nutrition and Feeding

II. Course Code : FNT 507

III. Credit Hours : 2+1

IV. Aim of the course

To study the nutritional requirements of shellfish, feed formulation and feeding strategy

V. Theory

Unit I

Nutritional requirements: Protein, carbohydrate, Lipid, Vitamin, Mineral, Essential amino acid, Fatty acid at various life stages, Methods for determining nutrient requirements, Factors affecting nutritional requirements.

Unit II

Energy requirements: Protein-energy ratio, Protein sparing and methods for determining energy requirement and factors affecting energy requirements.

Unit III

Food and feeding: Food and feeding habits, Natural food organisms, Micro-particulate diets (MBD, MCD, MED, MEM, PARA) for hatcheries; Grow-out and finisher feeds; Broodstock feeds for conditioning, Maturation and reproduction.

Unit IV

Digestion, absorption and metabolism: Feed ingestion and feeding mechanism, Digestion, Absorption and Assimilation of nutrients, Gastro-intestinal motility, Factors affecting digestibility; Importance of microbial digestion.

Unit V

Feeding management: Ration size/feeding rate and feeding frequency; Feed dispensing methods and devices.

Unit VI

Feed Additives and health: Role of feed additives in shellfish nutrition, Immunity and health, Nutrient deficiency diseases in shellfish.

VI.Practical

Study of digestive system of shrimps, prawns, lobsters, crabs; Formulation and preparation of diet with specific additives; nutrient requirement study in crustacean; water stability test

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26. F.A.O., Rome

- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and Crustaceans*. National Academy Press, Washington.
- Boyd CE. 2015. *Water quality: an Introduction*. Springer.

I. Course Title : Feed Ingredients and Additives

II. Course Code : FNT 506

III. Credit Hours : 2+1

IV. Aim of the course

To learn the requirement and availability of ingredients for aqua-feed and different types of additives used.

V. Theory

Unit I

National and international scenario: Present production trend and future requirements of feed ingredients, International coding of feed ingredients.

Unit II

Ingredient classification: Conventional and unconventional feed ingredients, Plant (protein and energy-carbohydrate and lipid) and Animal (protein and energy-lipid) sources.

Unit III

Quality evaluation of feed ingredients: Physical, Chemical (proximate composition, amino acids, EAAI, chemical score, fatty acids, vitamins and minerals profile and energy estimation, Anti- Nutritional Factors (ANFs) and other adventitious toxins) and Biological methods, Classification, Mode of action and Methods of detoxification of ANFs, Adulterants in feed ingredients.

Unit IV

Feed additives and supplements: Classification, Function; Gustatory stimulants and feed attractants; Nutraceuticals, Non-nutrient feed components.

Unit V

Feed raw material storage and spoilage: Grain storage, Liquid storage, Meal storage and Vitamin storage methods and practices, Prevention and management of raw material spoilage**,** Factors responsible for spoilage, Design criteria of storage shed, Silos, Bins, Roof ventilation and Aeration management etc., Temperature Monitoring, Silo Aeration system management and fumigation system to prevent spoilage.

Unit VI

Enhancing nutrient status of feed raw material: Application of genetic engineering and production of genetically modified plant ingredients. Amino acids deficient in plant ingredients. Manipulating biosynthesis pathways to enhance essential amino acids in plant ingredients.

VI. Practical

Identification of feed ingredients; Amino acid analysis of feed ingredients; Estimation of gross energy; Estimation of ANFs (Tannin, gossypol, phytate, protease inhibitors, cyanogens) and aflatoxin

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Joachim WH and Pascual FP. 2000. *Handbook on Ingredients for Aquaculture Feeds*. Kluwer Academic Publishers, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Rechcigl M. 1977. *CRC Handbook Series in Nutrition and Food*. CRC press.
- Rechcigl M. 1983. *Handbook of Nutritional Supplements*. CRC press.
- https://www.feedipedia.org
- http://www.iaffd.com

I. Course Title : Shellfish Nutrition and Feeding

II. Course Code : FNT 507

III. Credit Hours : 2+1

IV. Aim of the course

To study the nutritional requirements of shellfish, feed formulation and feeding strategy

V. Theory

Unit I

Nutritional requirements: Protein, Carbohydrate, Lipid, Vitamin, Mineral, Essential amino acid, Fatty acid at various life stages, Methods for determining nutrient requirements, Factors affecting nutritional requirements.

Unit II

Energy requirements: Protein-energy ratio, Protein sparing and Methods for determining energy requirement and Factors affecting energy requirements.

Unit III

Food and feeding: Food and feeding habits, Natural food organisms, Micro-particulate diets (MBD, MCD, MED, MEM, PARA) for hatcheries; Grow-out and finisher feeds; Broodstock feeds for conditioning, Maturation and reproduction.

Unit IV

Digestion, absorption and metabolism: Feed ingestion and feeding mechanism, Digestion, Absorption and Assimilation of nutrients, Gastro-intestinal motility, Factors affecting digestibility; Importance of microbial digestion.

Unit V

Feeding management: Ration size/feeding rate and feeding frequency; Feed dispensing methods and Devices.

Unit VI

Feed Additives and health: Role of feed additives in shellfish nutrition, Immunity

and health, Nutrient deficiency diseases in shellfish.

VI. Practical

Study of digestive system of shrimps, prawns, lobsters, crabs; Formulation and preparation of diet with specific additives; nutrient requirement study in crustacean; water stability test.

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L.A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26.F.A.O., Rome
- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and Crustaceans*. National Academy Press, Washington.
- Boyd CE. 2015. *Water quality: an Introduction*. Springer.

I. Course Title : Protein Nutrition

II. Course Code : FNT 508

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of protein in aquafeeds and relationship of protein with energy metabolism

V. Theory

Unit I

Protein requirement and their sources: Conventional and non-conventional, Plant and animal origin; Non-protein nitrogen; Protein requirement for maintenance, Growth and reproduction, Essential and non-essential amino acids, Amino acid antagonism, Protein and amino acid deficiency symptoms.

Unit II

Protein energy ratio: Factors affecting protein requirement, Importance of protein energy ratio (P/E Ratio).

Unit III

Digestion, absorption and metabolism: Digestion of protein, Absorption of amino acids and Their metabolism; Amino acid pool and Protein turnover.

Unit IV

Evaluation of protein quality: PER, NPU, BV, ANPU, Kjeldahl Nitrogen Conversion factors. Ideal protein concept.

VI. Practical

Extraction and purification of protein, Microkjeldahl method; Estimation of protein by methods of Biuret, Lowry and Bradford, total free amino acids; *In vivo* and *In*

vitro protein digestibility.

VII. Suggested Reading

- Cho CY, Cowey CB, Watanabe T. 1985. *Finfish Nutrition in Asia: Methodological Approaches to Research and Development*. Ottawa, Ont.IDRC.155pp.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Wilson K and Walker J. 1995. *Principles and Techniques of Practical Biochemistry*. Cambridge University Press.

I. Course Title : Lipid Nutrition

II. Course Code : FNT 509

III. Credit Hours : 1+1

IV. Aim of the course

To understand the importance of lipids in aqua feeds and the relationship of dietary lipid and tissue lipid

V. Theory

Unit I

Requirement of lipid and their sources: Terrestrial and aquatic origin; Optimum dietary lipid level; Essential fatty acid requirements for growth, Reproduction and health importance of other fat soluble substances (vitamins, carotenoids etc.). Interspecies differences in lipid requirement.

Unit II

Lipid metabolism: Lipid digestion, Absorption, Transportation/mobilization, Metabolism and storage, Protein sparing effect of lipids.

Unit III

Lipids and their fatty acids: Role of lipids and essential fatty acids, Their qualitative and quantitative requirement.

Unit IV

Lipids quality: Oxidation of fats/lipids, Antioxidants and evaluation of lipid quality, Deficiency symptoms.

VI. Practical

Estimation of total lipids, phospholipids and free fatty acids, peroxide value, saponification number, iodine value Separation and quantification of individual fatty acids by GCMS.

VII. Suggested Reading

- Berg JM, Tymoczko JL and Stryer L. 2002. *Biochemistry*. W.H. Freeman and Company.
- Cho CY, Cowey CB, Watanabe T. 1985. *Finfish Nutrition in Asia: Methodological Approaches to Research and Development*. Ottawa, Ont.IDRC.155pp.
- Cowey CB and Sargent JR. 1972. *Fish Nutrition. In Advances in Marine Biology* (Vol. 10, pp. 383-494). Academic Press.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall

Aquaculture Series, London.
- Halver J and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Murray RK, Granner DK, Mayes PA and Rodwell VW. 2000. *Harper's Biochemistry*. Appleton and Lange.
- NRC (National Research Council). 2011. *Nutrient Requirements of Fish*. National Academy Press, Washington.
- Sargent JR. 1997. *Fish Oils and Human Diet. British Journal of Nutrition*, 78(1), pp.S5-S13.
- Sargent JR, Tocher DR and Bell JG. 2003. *The Lipids. In Fish Nutrition* (Third Edition) (pp. 181-257).
- Voet D, Voet JG and Pratt CW. 2006. *Fundamentals of Biochemistry*. John Wiley and Sons, Inc.

I. Course Title : Carbohydrate Nutrition

II. Course Code : FNT 510

III. Credit Hours : 1+1

IV. Aim of the course

To understand the importance of carbohydrate in aquafeed and their protein sparing effect

V. Theory

Unit I

Sources: Carbohydrate sources and digestible energy supply, Role of digestible and non-digestible carbohydrates; Dietary levels of carbohydrate for carps and catfishes.

Unit II

Digestibility and interactions with other nutrients: Carbohydrate digestibility, Factors affecting starch utilization, Carbohydrate and Interaction with other nutrients and protein sparing effect.

Unit III

Constraints and utilization: Constraints of carbohydrate utilization in fish, Non-starch polysaccharides, Strategy to enhance carbohydrate utilization; Gelatinization, Exogenous amylases, Glucose Intolerance; Carbohydrates and immunity.

Unit IV

Economic importance aquafeeds: Maximum and inclusion levels for different fish species, Uses of carbohydrates for low cost feed formulations.

VI. Practical

Estimation of starch gelatinization in different feed processing methods; Blood glucose estimation; Estimation of crude fibre and non-starch polysaccharides.

VII. Suggested Reading

- D' Abramo, LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L.A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, UK.

- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.
- NRC (National Research Council). 1993. *Nutrient Requirements of Fish*. National Academy Press, Washington.
- Kamalam BS, Medale F and Panserat S. 2017. *Utilisation of dietary carbohydrates in farmed fishes: New insights on influencing factors, biological limitations and future strategies*. Aquaculture, 467, pp.3-27.
- Kamalam, B.S., Medale, F., Larroquet, L., Corraze, G. and Panserat, S., 2013. *Metabolism and fatty acid profile in fat and lean rainbow trout lines fed with vegetable oil: effect of carbohydrates*. *PloS One*, 8(10), p.e76570.
- Hemre, G.I., Mommsen, T.P. and Krogdahl, Å., 2002. *Carbohydrates in fish nutrition: effects on growth, glucose metabolism and hepatic enzymes*. *Aquaculture Nutrition*, 8(3), pp.175-194.
- Kamalam, B.S. and Panserat, S., 2016. *Carbohydrates in Fish Nutrition*. International Aquafeed, pp.20-23.

I. Course Title : Vitamin and Mineral Nutrition

II. Course Code : FNT 511

III. Credit Hours : 1+1

IV. Aim of the course

To learn the importance of vitamins and minerals in fish and crustacean nutrition

V. Theory

Unit I

Vitamins: Classification and sources, properties and functions of water and fat soluble vitamins; Vitamin as co-enzymes and prosthetic groups of enzymes.

Unit II

Vitamin requirements and sources: Vitamin requirements of different species; dietary sources of vitamins; factors affecting vitamin requirements; Loss of vitamins during feed processing and storage.

Unit III

Vitamin deficiency: Manifestation of vitamin deficiency; Vitamin –mineral interactions. Hypo- and hyper-vitaminosis.

Unit IV

Minerals: Classification and sources, macro, micro minerals and heavy metals toxicity. Minerals requirements for different aquaculture species, dietary sources of minerals, factors affecting mineral requirement; nutrient-minerals interaction; Mineral-Mineral interactions; manifestation of mineral deficiency

VI. Practical

Estimation of zinc, phosphorus, magnesium, iron and vitamin A; preparation of vitamin and mineral premix; estimation of vitamin and mineral losses due to leaching

VII. Suggested Reading

- Antony JesuPrabhu P, Schrama JW and Kaushik SJ. 2016. *Mineral requirements of fish: a*

systematic review. *Reviews in Aquaculture*, 8(2), pp.172-219.
- Antony JesuPrabhu P, Schrama JW and Kaushik SJ. 2013. Quantifying dietary phosphorus requirement of fish–a meta analytic approach. *Aquaculture Nutrition*, 19(3), pp.233-249.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- NRC (National Research Council). 2011. *Nutrient Requirements of Fish and Crustacea*. National Academy Press, Washington.
- Prabhu PAJ, Geurden I, Fontagné-Dicharry S, VeronV, Larroquet L, Mariojouls C, Schrama JW and Kaushik SJ. 2016. *Responses in micro-mineral metabolism in rainbow trout to change in dietary ingredient composition and inclusion of a micro-mineral premix. PloS One*, 11(2), p.e0149378.
- Woodward B. 1994. Aquaculture 124, 133-168.

I. Course Title : Nutraceuticals

II. Course Code : FNT 512

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutraceuticals in the physiological wellbeing of fish and shellfish

V. Theory

Unit I

Nutraceuticals/functional foods: Definition, Classification and scope in aquaculture

Unit II

Benefits and modes of action of nutraceuticals: Immunomodulatory proteins, Peptides, Polysaccharides, Oligosaccharides, Herbal extracts/phytochemicals, Carotenoids, Nucleotides, Bioactive compounds from seaweeds etc.

Unit III

Minerals as nutraceuticals: Zinc, Copper, Chromium, Manganese, and Selinium

Unit IV

Role of nutraceuticals: Stress mitigation and Growth enhancement, Immunomodulation and disease prevention

VI. Practical

Estimation of immunomodulatory parameters (lysozyme, NBT, MPO, antibody titre), estimation of antioxidant enzymes (SOD, catalase, GPx), extraction of bioactive compounds, *in vitro* antioxidant assay.

VII. Suggested Reading

- DeFelice SL. 1995. The nutraceutical revolution: its impact on food industry R and D. *Trends in Food Science and Technology*, 6(2), pp.59-61.
- Debnath D, Sahu NP, Pal AK, Baruah K, Yengkokpam S and Mukherjee SC. 2005. Present scenario and future prospects of phytase in aquafeed. *Asian-Aust. J. Anim. Sci,* 18(12), pp.1800-1812.
- Kalra EK. 2003. Nutraceutical-definition and introduction. *Aaps Pharmsci,* 5(3), pp.27-28.

- KartikBaruah, Asim K Pal, Narottam P Sahu, Kamal K Jain, Subhas C Mukherjee, Dipesh Debnath. 2005. *Dietary protein level, microbial phytase, citric acid and their interactions on bone mineralization of Labeo rohita* (Hamilton) juveniles, 36(8): 803-812.
- Luckstadt C. 2008. Utilization of acidifiers in nutrition and feeding of tropical fish–a mini-review. *Bulletin of Fish Biology* 10(1/2): pp.105-109.

Course Title with Credit Load
Ph.D. in Fish Nutrition and Feed Technology

Course Code	Course Title	Credit Hours
Major courses		**12 Credit**
FNT 601*	Feed Technology and Feed Mill Management	2+1
FNT 602*	Nutrigenomics	1+1
FNT 603*	Larval and Broodstock Nutrition	2+1
FNT 604*	Introduction to Biomolecules	2+1
FNT 607*	Nutraceuticals as Functional Foods	1+1
Minor Courses		**6 Credits**
	(From the subjects closely related to a student's major subject)	
FNT 605	Macro and Micronutrient Nutrition	2+1
FNT 606	Bioenergetics	2+1
FNT 608	Feed intake and feeding behaviour	1+2
FNT 609	Feed and environment	2+1
Supporting courses		**5 credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 credits**
Doctoral Seminar		**2 credits**
FNT 691	Doctoral Seminar-I	0+1
FNT 692	Doctoral Seminar-II	0+1
Doctoral Research		**75 credits**
FNT 699	Doctoral Research (Semester II)	0+15
FNT 699	Doctoral Research (Semester III)	0+15
FNT 699	Doctoral Research (Semester IV)	0+15
FNT 699	Doctoral Research (Semester V)	0+15
FNT 699	Doctoral Research (Semester VI)	0+15
	Total PhD Program Credit Hours	**100 Credits**

*Major compulsory subjects

Course Contents
Ph.D. in Fish Nutrition and Feed Technology

I. Course Title : Feed Technology and Feed Mill Mangement

II. Course Code : FNT 601

III. Credit Hours : 2+1

IV. Aim of the course

To study the feed formulation techniques; design of feed mill and feed manufacturing; feed quality assurance and regulations.

V. Theory

Unit I

National and global scenario of feed ingredients and feed industry: Availability demand and supply; Types of feeds, BIS and international standards for fish feed, Overview of feed mill business.

Unit II

Feed formulation: Different methods of feed formulation, Use of feed formulation softwares; Nutritional and physical quality of feed ingredients; Importance of additives formulation of nutritionally balanced diet (amino acid, micronutrients)

Unit III

Feed manufacturing process and control: Receiving of raw material, Grinding, Mixing, Conditioning, Pelleting /extrusion, Drying and cooling, Coating/top dressing, Packaging and labelling, Factors affecting feed manufacture and stability of nutrients, Effects of processing on the nutritional value of feeds, Processing methods for non-compacting feed; Economics of feed manufacturing.

Unit IV

Emerging new feed ingredients: Scope and exploration of new feed ingredients, Anti-nutritional factors and methods of detoxification (e-beam irradiation, solvent extractions, SSF, protein concentrates/isolates, genetic improvement of plants etc.).

Unit V

Storage and quality control: Ingredient quality assurance, Feed processing quality assurance and Processed feed quality assurance Miscellaneous adventitious toxins and Effect on feed safety; Storage of feed and quality deterioration, CGMPs and HACCP feed regulation, Feed transmitted bioterrorism and its implications.

Unit VI

Design of a feed mill unit: Layout, Feed mill design and safety of operation, Maintenance and record keeping.

VI. Practical

Analysis of anti-nutritional and toxic substances in feed ingredients and feed; Formulation of diets using software, Preparation of different types of feed and

their quality evaluation; Effect of feed storage on nutritional value of feed, Preparation of farm made feeds.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome.
- D'Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Heijden PGM van der. 2016. *The aquaculture sector of Zambezi Valley, Mozambique: Description of the current situation and emerging opportunities*. Centre for advance Innovation.Wageningenuniversity.
- ICAR-IRRI Outreach programme reports.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*, Kluwer Academic Publishers.
- Muir JF and Robert D. (Eds.). 1968. *Recent Advances in Aquaculture* Vol.II. Blackwell Science.
- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.

I. Course Title : Nutrigenomics

II. Course Code : FNT 602

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutrients on gene expression

V. Theory

Unit I

Principles of nutrigenomics: Methodologies, Genomics, Transcriptomics, Proteomics, Metabolomics and Nutrigenomics, Gene structure and Regulation, Nutritionally Important genes, Nutrient-gene interaction and expression.

Unit II

m-RNA and cDNA: Extraction of m-RNA, reverse transcription and cDNA biosynthesis, Cloning techniques; Genomic and differential gene expression.

Unit III

Use of DNA probe: Blotting and hybridization, Microarray; Microarray nitrocellulose hybridization and labelling with P^{32} probes; Quantitative real time polymerase chain reaction (qRT PCR).

Unit IV

Bioinformatics: Gene expression software; BLASTIN, FASTA and PHYLIP etc.; Relative expression software tool (REST); Interpretation of microarray data; Cloning technique.

VI. Practical

Genomic DNA, plasmid DNA and RNA extraction and isolation, m-RNA purification; cDNA synthesis by reverse transcription from fish tissue; Elution of PCR product for gene sequencing; RT PCR, cloning, exploration of bioinformatics tools.

VII. Suggested Reading

- Afman L, Müller M. 2006. *Nutrigenomics: from molecular nutrition to prevention of disease*. J Am Diet Assoc 106: 569-576.
- Fenech M, El-Sohemy A, Cahill L, Ferguson LR, French TA *et al*. 2011. *Nutrigenetics and Nutrigenomics: Viewpoints on the Current Status and Applications in Nutrition Research and Practice*. J NutrigenetNutrigenomics 4: 69-89.
- Fingerman M, Nagabhushanam R and Thompson MF. 1997. *Recent Advances in Marine Biotechnology* (vol1-3). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Glick BR and Pasternak JJ. 1999. *Molecular Biotechnology: Principles and Applications of Recombinant DNA Technology*, ASM Press, Washington, D. C.
- Kaput J, Rodriguez RL. 2006. *Nutraceutical Genomics*. Wiley Interscience Hoboken, New Jersey.
- Lehninger AL. 1984. *Principles of Biochemistry*. CBS Publishing, New Delhi.
- Martin SAM, Król E. *Nutrigenomics and Immune Function in Fish: New Insights From Omics Technologies*. Dev Comp Immunol. 2017; 75(Suppl C): 86–98.
- Panserat S, Kaushik S. 2010. *Regulation of Gene Expression by Nutritional Factors in Fish*. Aquacult Res 41: 751–762.
- Panserat S, Kirchner S, Kaushik S. 2007. *Nutrigenomics*. In: Nakagawa H, Sato M, Gatlin D III (eds) Dietary supplements for the health and quality of cultured fish. CAB International North America, USA, pp 210–229
- Pedro M Rodrigues, Tomé S Silva, JorgeDias and FlemmingJessen. 2012. Proteomics *in Aquaculture: Applications and Trends. Journal of Proteomics*. 75: 4325-4345
- Primrose SB. 1989. *Modern Biotechnology*. Blackwell Scientific, Oxford.
- Rodney B. 1998. *Concepts in Biochemistry*. Cole Publishing Company London.

I. Course Title : Larval and Broodstock Nutrition

II. Course Code : FNT 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand the role of nutrition in reproductive performance and larval development of fish and shellfish

V. Theory

Unit I

Embryonic and larval development: Nutritional profile of egg yolk and mechanism of egg yolk utilization, Degradation of egg yolk platelets and granules, Utilization of egg protein, Amino acid and lipid, Influence of abiotic factors on yolk absorption; Criteria for evaluation of early larval development

Unit II

Larval digestive system: Ontogenesis of digestive systems, Digestion and absorption of protein and lipid, Mechanism of transition from endogenous to exogenous nutrition.

Unit III

Larval nutrition: Importance of live foods, Weaning diets and their importance

in larval nutrition, Nutritional requirements and deficiency symptom, Nutritional status of larvae.

Unit IV

Broodstock nutrition: Effect of nutrition on fecundity, Fertilization, Embryonic development and larval quality.

Unit V

Improving brood-stock performance: Special ingredients and specific nutrients for improving gonadal development and reproductive performance; Effective feeding periods for optimum brood-stock performance.

Unit VI

Feeding strategies: Manual, Mechanical and automatic feeding; Feeding devices and strategies, Larval feeding behaviour and feed management.

VI. Practical

Preparation of larval feed, Nutritional profiling of egg yolk and larvae, Nutritional analysis of live food organisms, Estimation of proteases in larvae, Estimation of gonado-somatic index and fecundity.

VII. Suggested Reading

- CIFE, 1993. *Training Manual on Culture of Live Food Organisms for Aqua Hatcheries*. Central Institute of Fisheries Education, Versova, Mumbai.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer Academic Publishers, London.
- Holt JG. 2011. *Larval Nutrition*. John Wiley and Sons, Inc.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

I. Course Title : Introduction to Biomolecules

II. Course Code : FNT 604

III. Credit Hours : 2+1

IV. Aim of the course

To study the importance of different biomolecules and their biological functions in a biosystem.

V. Theory

Unit I

Definition, types, structure, properties of biomolecules: Protein, Lipids, Carbohydrates, Vitamins, Minerals, Nucleic acids and Water as biomolecules and its applications, Water: importance of water in biological systems with special reference to the maintenance of native structure of biological molecules, Water as a universal solvent, pH, buffers, buffer capacity and their importance in biological systems.

Unit II

Protein and amino acids: Protein and its classification, Structure of proteins, Primary, Secondary (helix and pleated sheet), Tertiary and Quaternary structures of protein and forces stabilizing it, Denaturation and renaturation of proteins, Ramachandran's plot, Amino acidsanditsstructural features, Stereoisomerism, R and S notations, Structure and classification of standard amino acids, pH titration curve, Isoelectric pH of amino acids and pKa value, Peptidesand structure of peptide bond.

Unit III

Lipids: Classification and their biological role, Fatty acids: nomenclature, structure and properties of saturated, Unsaturated, Essential fatty acids, Triacylglycerols; Nomenclature, Physical properties, Chemical properties (hydrolysis, esterification, Rancidity of fats, saponification value, iodine value, Acid value) and significance, Chemistry and biological function of eicosanoids, fats, waxes and phospholipids and cholesterol.

Unit IV

Carbohydrates: Classification and biological importance of carbohydrates, Structure of monosaccharides, stereochemistry, D and L, Epimers, Anomers, Diastereomers and Mutarotation, Disaccharide, Establishment of glycosidiclinkage in sucrose, Maltose, lactose, Deoxy ribose and ribose sugar, Polysaccharides: Types, partial structure, Occurrence and importance of starch, Glycogen, Insulin, Cellulose, Chitin, Pectin, Reactions of carbohydrates Molisch's, Benedicts / Fehlings, picric acid, Barford's, Bials, Seliwanoff's, Osazone test.

Unit V

Vitamins and minerals: Water soluble vitamins –B complex and Vitamin C: Structural formula, Co-enzyme forms, Biological role, Deficiency symptoms and dietary sources, Vitamin C as a redox reagent, Fat soluble vitamins**,** A, D, E, and K: structure, Dietary sources, Requirements, Deficiency symptoms and Biological role, Mineral macronutrients and micronutrients, Dietary sources, Physiological functions, Deficiency disorders, Absorption and excretion, Importance of selenium and fluorine, Metals in biological system: Fe, Co, Ca, Mb, Cu.

Unit VI

Nucleic acids and water: Nucleic acids, Nucleosides and Nucleotides; Structure and properties, Phosphodiester bonds, Chemical differences between DNA and RNA and its significance, Different class of RNAs - mRNA, rRNA, tRNA and snRNA. Primary, secondary and tertiary structure of tRNA, Determination of primary structure (sequencing) of DNA using Maxam-Gilbert method and Sangers method and limitations.

VI. Practical

Preparation of buffers, Qualitative estimation of carbohydrates, Quantitative estimation of glucose and maltose by DNS method and any other methods, Quantitative estimation of protein by Biuret and Folin Lowry's method, Estimation of lipid by Zak's method, Estimation of vitamin C.

VII. Suggested Reading

- *Biochemistry*, 4th Edition Donald Voet, Judith G. Voet.

- *Biochemistry*. Lubert Stryer. W.H. Freeman and company, New York.
- *Experimental biochemistry*. Beedu Sashidhar Rao and Vijay Deshpande. IK international Pvt Ltd.
- *Lab Manual in Biochemistry, Immunology and Biotechnology*. Arti Nigam and ArchanaAyyagari. Tata McGraw-Hill.
- Lehninger Principles of Biochemistry David L. Nelson and Michael M Cox. Publisher: W.H.Freeman and Co Ltd.
- *Principles of Biochemistry* (with special reference to fishes). Prof. Kasturi Samantaray. Narendra Publishing House.

I. Course Title : Macro and Micronutrient Nutrition

II. Course Code : FNT 605

III. Credit Hours : 2+1

IV. Aim of the course

To understand recent developments in macro and micro nutrient nutrition for fish and shellfish

V. Theory

Unit I

Protein and aminoacids: Requirements, Functional roles of aminoacids, Ideal protein concept, Nitrogen excretion, Amino acid antagonism, Improving nitrogen Retention, dietary supply of synthetic amino acids in different forms.

Unit II

Lipid and essential fatty acids: Functions and deficiencies, Fatty acid oxidation, antioxidants, Role of phospholipids and steroids.

Unit III

Optimization of carbohydrates in diets: Strategies for improving carbohydrate utilization; Potential of exogenous enzymes, solid state fermentation (SSF).

Unit IV

Micronutrients: Physiological roles and functions of vitamins and minerals; Forms of supply of minerals and vitamins, Deficiency symptoms.

Unit V

Recent developments in energy nutrition and feed additives: Recent advances in nutritional energetics and feed additives, Medicated feeds (farm-made and commercial), Regulations and certification of feed additives.

Unit VI

Designer fish production: Tailoring flesh quality, food safety, Roles of nutrients and additives (fatty acids, antioxidants, drugs etc.), Flesh quality evaluation (colour, texture and sensory), Estimation of fatty acids, Amino acids and minerals in ingredients, feeds and flesh of fish and shrimp; Dietary effects on nitrogen excretion.

VI. Practical

Protein quality estimation (PER, NPU). Digestibility studies. Estimation of fatty acids and amino acids.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed

Technology. ADCP/REP/80/11. F.A.O., Rome.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U.K.
- Halver JE. 1989. *Fish Nutrition*, Academic Press, San Diego, California.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

I. Course Title : Bioenergetics

II. Course Code : FNT 606

III. Credit Hours : 2+1

IV. Aim of the course

To understand the principles of energetics, nutrient energy and its metabolic scope in larval, growout and broodstock fish

V. Theory

Unit I

Energy requirements of fish: Principles and methods; Factors affecting energy requirement; Energy budgeting, Metabolic rate and Factors affecting it.

Unit II

Metabolic scope: It's variation in herbivores, Omnivores and Carnivores.

Unit III

Larval energetics: Growth, metabolism and energy budget, Energy relationship between egg and hatchlings, Energy flow during early ontogenesis.

Unit IV

Energetics of growout and brood stock: Energetics of feeding and digestion, Energy requirements for growth and reproduction, Energetics of gonadal maturation and gamete production, Bioenergetics of spawning, Relationship between feeding and maturation.

Unit V

Lipids: Lipids as energy source, Net energy supply from lipids, Fatty acid biosynthesis and degradation, Transport and deposition of lipids in finfish and shellfish, Fatty acid bioconversion (elongation and desaturation) in different species, Importance of phospholipids and cholesterol.

Unit VI

Carbohydrates: Carbohydrates as energy source; Net energy supply from carbohydrates; Biosynthesis, Storage and Degradation, Interaction of carbohydrate with lipid and protein.

VI. Practical

Estimation of oxygen consumption; Estimation of energy flow, Estimation of gross energy and digestible energy of feed; Study of energy requirements of, herbivorous

omnivorous and carnivorous fish; Estimation of total and free cholesterol; Estimation of metabolic rates.

VII. Suggested Reading

- Cho CH and Kaushik SJ. 1990. *Nutritional Energetics in Fish: Energy and Protein Utilization in Rainbow Trout. World Review on Nutrition and Dietetics*. 61: 132-172.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.
- Evans DH and Claiborne JB. 2006. *The Physiology of Fishes*. CRCPress.
- Halver JE and Hardy RW. 2002. *Fish Nutrition. Academic Press*, London.
- Houlihan D, Boujard T and Jobling M. eds. 2008. *Food Intake in Fish*. John Wiley and Sons.
- Jobling M. 1994. *Fish Bioenergetics*. Chapman and Hall, London
- Kaushik SJ. 1998. *Nutritional Bioenergetics and Estimation of Waste Production in Non-Salmonids. Aquat Living Resour* 11(4): 211-217.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Tyler P and P Calow. 1985. *Fish Energetics: New Perspectives*. Croom Helm Ltd. Provident House, Burrell Row, Beckenham, Kent, London.

I. Course Title : Nutraceuticals as Functional Foods

II. Course Code : FNT 607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutraceuticals in the physiological wellbeing of fish and shellfish.

V. Theory

Unit I

Functional foods v/s Nutrceuticals: Definitions, concepts and beneficial roles, Application of functional foods in immune modulation and disease prevention.

Unit II

Characteristics of nutraceuticals and delivery systems: Nanotechnology of drug delivery system such as biocompatible polymers, Stimuli responsive polymers

Unit III

Modes of action and benefits: Probiotics, Prebiotics, Stanols and Sterols, Their immunomodulatory effects.

Unit IV

Stress mitigation and growth enhancement: Inter-relationships of stress and growth in fish, Functional feed additives and role of functional foods in stress mitigation and growth enhancement.

VI. Practical

Estimation of immunomodulatory parameters (lysozyme, NBT, MPO, antibody titre), Estimation of antioxidant enzymes (SOD, catalase, GPx), Extraction of bioactive compounds, *in vitro* antioxidant assay, Pro PO.

VII. Suggested Reading

- Debnath D, Sahu NP, Pal AK, Baruah K, Yengkokpam S and Mukherjee SC. 2005. *Present scenario and future prospects of phytase in aquafeed. Asian-Aust. J. Anim. Sci*, 18(12),

pp.1800-1812.
- DeFelice SL. 1995. *The nutraceutical revolution: its impact on food industry R and D. Trends in Food Science and Technology*, 6(2), pp.59-61.
- Kalra EK. 2003. *Nutraceutical-definition and introduction. AapsPharmsci*, 5(3), pp.27-28.
- Kartik Baruah, Asim K Pal, Narottam P Sahu, Kamal K Jain, Subhas C Mukherjee, DipeshDebnath. 2005. *Dietary protein level, microbial phytase, citric acid and their interactions on bone mineralization of Labeo rohita (Hamilton) juveniles*, 36(8): 803-812.
- Luckstadt C. 2008. *Utilization of acidifiers in nutrition and feeding of tropical fish–a mini-review. Bulletin of Fish Biology* 10(1/2), pp.105-109.

I. Course Title : Feed Intake and Feeding Behaviour

II. Course Code : FNT 608

III. Credit Hours : 1+2

IV. Aim of the course

To study the mechanism of feed intake and feeding behaviour.

V. Theory

Unit I

Gustation and feeding behaviour: Chemoreception, olfactory, Peripheral gustation sensation, Gustatory pathways in the Central Nervous System, Taste and feeding behavior.

Unit II

Feed intake: Techniques for the measurement of voluntary feed intake, Stomach content analysis, Chemical markers, Direct observation and video recording, Demand feeder, X-radiography, factors affecting voluntary feed intake, Effect of feeding time on feed intake and growth.

Unit III

Regulation of feed intake: Neuropeptides and hormones, Inhibitory peptides, Stimulatory peptides, Growth hormones, Nutrient receptors and transporters, Hormonal control of metabolism; Nutrients influencing feed intake gustatory feeding stimulants.

Unit IV

Physiological effects of feeding: Methods of feeding and short term effects of meal on post-prandial levels of nutrients; Tissue metabolic physiology; Feeding frequencies, Physiology of starvation and feed restriction.

VI. Practical

Measurement of feed intake by chemical marker, Feed intake measurement with respect to temperature, Experiment on feeding stimulant, Feed intake and blood glucose correlation, Comparative intake of natural vs artificial feed, Monitoring feeding behaviour in different species, Evaluation of fish response to feed in terms of feed detection and intake, Study of crustacean feeding behavior in different life stages, Study of digestive anatomy and morphology and their correlation with digestive physiology, Impact of feeding regimes on feed intake.

VII. Suggested Reading

- Balasubramaniam A, Rigel DF, Chance WT and Fischer JE. 1992. Central and peripheral

effects of sculpin pancreatic polypeptide and anglerfish peptide Y in rats. *Pept. Res.* 5, 106–109.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Houlihan D, Boujard T and Jobling M. 2001. *Food Intake in Fish*. Blackwell Science, France.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*, Kluwer Academic Publishers.
- Volkoff H. 2016. The neuroendocrine regulation of food intake in fish: a review of current knowledge. *Front. Neurosci.* 10: 540.
- Volkoff H, Bjorklund JM and Peter RE. 1999. Stimulation of feeding behavior and food consumption in the goldfish, *Carassius auratus*, by orexin-A and orexin-B. *Brain Res.* 846, 204–209.

I. Course Title : Feed and Environment

II. Course Code : FNT 609

III. Credit Hours : 2+1

IV. Aim of the course

To understand the impact of nutrient utilization on environment

V. Theory

Unit I

Nutrient dynamics: Influence of nutrient cycles on food web/chain. Influence of detrital food web on nutrient distribution, Nutrient loading through feed and fertilizer.

Unit II

Stress and nutrition: Influence of stress on feed intake, Digestion and absorption, Stress indicator and nutritional strategies to mitigate stress.

Unit III

Eco-friendly feed: Use of high energy diets, Optimizing protein energy ratio, Ideal aminoacid profile, Improving nutrient utilization through exogenous phytase and acidifiers, Methods of enhancing feed digestibility, Biofloc and probiotics influences on nutrient utilization.

Unit IV

Impact of feed on environment: Judicious use of feed and nutrients; Nutrient build up on water quality; Nutrient management in different aquaculture systems (extensive, semi-intensive, intensive- recirculatory systems); Nutritional strategies to reduce the nutrient flow in aquaculture system, Contribution of feed waste to organic load of aquaculture production systems, Reducing environmental pollution (use of additives, weeds etc.).

Unit V

Productivity and fish production: Optimization of natural productivity for increasing fish production, Different food chains in aquatic ecosystem, Feeding behavior and feeding niche, Effect of environmental parameters on appetite of fish

Unit VI

Environmental impact assessment: Rules and Regulations on waste management in aquaculture (International and National)

VI. Practical

Assessment of water quality parameters (ammonia, nitrite, nitrate, chloride phosphate etc.) as affected by feeds; Levels of feeding and water quality; Stress enzymes (catalase, SOD, glutathione peroxidase), stress hormone (cortisol).

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980.
- Cho CY and Bureau DP. 1997. Reduction of waste output from salmonid aquaculture through feeds and feeding. *The Progressive Fish-Culturist*, *59*(2), pp.155-160.
- Cho CY and Bureau DP. 2001. A review of diet formulation strategies and feeding systems to reduce excretory and feed wastes in aquaculture. *Aquaculture research*, *32*, pp.349-360.
- Chua TE. 1992. Coastal aquaculture development and the environment: the role of coastal area management. *Marine Pollution Bulletin*, *25*(1-4), pp.98-103.
- Cripps SJ and Bergheim A. 2000. Solids management and removal for intensive land-based aquaculture production systems. *Aquacultural engineering*, *22*(1-2), pp.33-56.
- Folke C and Kautsky N. 1992. Aquaculture with its environment: prospects for sustainability. *Ocean and coastal management*, *17*(1), pp.5-24.
- Halver JE and Hardy RW. 2002. Fish Nutrition. Academic Press, London.
- Kaushik SJ. 1998. Nutritional bioenergetics and estimation of waste production in non-salmonids. *Aquatic Living Resources*, *11*(4), pp.211-217.
- Papatryphon E, Petit J, Van Der Werf HM, Sadasivam KJ and Claver K. 2005. Nutrient-balance modeling as a tool for environmental management in aquaculture: the case of trout farming in France. *Environmental Management*, *35*(2), pp.161-174.
- Tacon AG and De Silva SS. 1997. Feed preparation and feed management strategies within semi-intensive fish farming systems in the tropics. *Aquaculture*, *151*(1-4), pp.379-404.
- Talbot C and Hole R. 1994. Fish diets and the control of eutrophication resulting from aquaculture. *Journal of Applied Ichthyology*, *10*(4), pp.258-270.

List of suggested Journals

- *Animal (Reproduction, Nutrition, Development)*
- *Animal Nutrition and Feed Technology*
- *Aquaculture Nutrition*
- *Archives of Animal Nutrition*
- *Food and Nutrition Bulletin*
- *Indian Journal of Animal Nutrition*
- *International Journal for Vitamin and Nutrition Research*
- *International Journal of Food Sciences and Nutrition*
- *Journal of Animal Physiology and Animal Nutrition*
- *Journal of Nutritional Biochemistry (Nutrition Reports International)*
- *Journal of Nutritional Science and Vitaminology*
- *Fish Physiology and Biochemistry*
- *Aquaculture*
- *Aquaculture International*
- *Aquaculture Research*
- *Journal of Aquaculture*
- *Journal of the World Aquaculture Society*
- *North American Journal of Aquaculture*
- *Reviews in Fisheries Science and Aquaculture*
- *Ichthyological Research*
- *Journal of Applied Ichthyology*

- *Journal of Applied Physiology*
- *Journal of Aquaculture in the Tropics*
- *Animal Feed Science and Technology*
- *Journal of Animal Feed Science and Technology*
- *Journal of Animal and Feed Sciences*

List of suggested e-Resources

- http://www.aquafeed.com
- https://articles.extension.org/pages/58703/fish-nutrition
- https://www.liveaquaria.com/article/198/?aid=198
- https://onlinelibrary.wiley.com/journal/13652095
- https://www.usgs.gov/ecosystems/fisheries-program/science/fish-physiology-and-behavior?
- https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/HealthBenefits
- https://thefishsite.com/articles/
- https://www.ncbi.nlm.nih.gov/books/
- https://nutrigenomicsinstitute.com
- https://www.karger.com/
- https://www.nature.com/subjects/nutrigenomics
- https://www.dnafit.com/

Suggested Broad Areas for Master's and Doctoral Research

- Study on essential aminoacids and vitamins requirement of fishes
- Accurate quantitative requirements of essential fatty acids particularly larval development and maturing broodstock
- Nutrient and energy budget in fed fish culture
- Optimization of inclusion level of non-conventional feed resources in fish feed
- Nutrient gene interaction studies in fish
- Feed additive for promotion of productivity and growth in fishes
- Development of appropriate feed processing technology for improving the feed and nutrient use efficiency
- Microbial nutrition
- Nutraceuticals and functional food acids
- Quantitative estimation of feed intake: natural vs artificial feed
- Digestibility of natural and artificial feed
- Energetics of utilization of natural and artificial feed
- Energetics of utilization of animal vs plant ingredients
- Energetics of growth vs reproduction
- Feeding standards for cultivable species
- Feeding strategy to eliminate waste
- Utilization of refinery waste as single cell protein
- Farmer friendly methods for detoxification of anti-nutritional factors
- Immunostimulants and growth promoters
- Redefining protein-energy ratio in shrimp diet with respect to salinity
- Digestibility due to plant to animal ingredient ratio
- Enhancement of digestibility of plant feed ingredients
- Reduction of dietary protein content through amino acid balance
- Optimizing protein to lipid, protein to carbohydrate content in fish and shrimp diets
- Dietary lipid source and flesh lipid quality
- Optimizing PUFA and HUFA content in individual species
- Impact of lipid peroxidation on growth and flesh quality
- Starch utilization and immunity status
- Optimization of gelatinized to non-gelatinized starch content in feed
- Source of carbohydrate and their utilization
- Study the key enzymes for carbohydrate metabolism
- Development of species specific vitamin and mineral premix

- Energy utilization from carbohydrate sources
- Enzyme coating and feed additives in pelleted feed
- Low cost microencapsulated, micro coated and micro bound diets
- Fortification of larval and broodstock diets
- Utilization of unconventional ingredients
- Nutritional contribution of natural food for growth
- Nutritional comparison of natural and artificial feed
- Biochemical mechanism of endocrine function
- Hormonal regulation of calcium and phosphorous metabolism
- Immunostimulants/Immunomodulators
- Gene regulation by lipids and carbohydrates
- Fasting, feed intake and nutrient utilization.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Aquatic Animal Health Management

Preamble
(Aquatic Animal Health Management)

Aquatic animals play a significant role in our societies and ecosystems. Aquatic animals include not only fish but also a myriad of other animals, viz., amphibians, marine mammals, crustaceans, reptiles, molluscs, aquatic birds, aquatic insects, starfish and corals that live in water for most of their life. The global human population is increasing, so also the demand for aquatic food products. Aquaculture, the culture of aquatic animals for food, is one of the most lucrative economic activities and is considered as one of the means of assuring food and nutritional security for humans. It contributes about 50% of global fish food consumption and presents the fastest growing food-producing sector in the world. The annual growth rate for aquaculture is 8-10% compared to 3% for livestock and 1.6% for capture fisheries. Like humans and terrestrial animals, aquatic animals - both cultured and wild - can be affected by infectious pathogens such as viruses, bacteria, fungi, protozoa and parasites. The occurrence of disease in the aquatic animal was known before the 1900s but was of no practical significance. Over the years, this branch of science is developed separately from the health sciences of other animal groups. It also requires a much different approach than terrestrial animals. Infection and disease in aquatic animals are common but can become severe under certain conditions. It is particularly true in intensive aquaculture practices that tend to provide a platform for the emergence of pathogens. The risk of pathogen transfer is generally considered greater for movement of live aquatic animals. The global trade in aquatic animals and their products offer avenues for the trans-boundary spread of pathogens. Few diseases of aquatic animals are known to have implications for human health. Sustainable growth of aquaculture is threatened by both known diseases and new diseases, which may become pandemic. A disease outbreak can devastate farmed populations and severely impact the short-term profitability and even long-term viability of aquaculture businesses. Around the world, diseases caused serious economic losses to aquaculture. Globally, the economic loss due to diseases in aquaculture is estimated at US$ 1.05 - 9.58 billion/year. Aquatic animal health must, therefore, be managed effectively to protect the productivity of aquaculture industries, access to international markets and aquatic environments. Successful aquatic animal health management relies on the accurate and rapid diagnosis of various diseases. New assays from genetic engineering using nucleic acid probes, next-generation sequencing, etc. have come as a boon to the aquaculture industry. In all cases, a quick response is essential to enable correct diagnosis of the problem and to allow for appropriate measures to be taken.

Recent pandemics have shown that global production systems are epidemiologically connected and, consequently, aquatic animal diseases present a shared global threat that demands global solidarity. The world now depends on a sustainable future for aquaculture and improved aquatic animal health management is critical to its continued and growing contribution to global food security. The improved control of transboundary diseases requires the wider and more consistent implementation of OIE (Office International des Epizooties or World Organisation for Animal Health) standards, particularly on disease notification. For animal (including aquatic animal) health and zoonoses, the World Trade Organization (WTO) recognise the standards developed by the OIE as a reference within the Sanitary and

Phytosanitary Measures (SPS Agreement). The Aquatic Animal Health Code (AAHC) includes standard international trade in the welfare of cultured fish and utilisation of antimicrobial agents in aquatic animals and their merchandise. All members of the WTO, including India, must have an aquatic animal health program that meets the OIE standards. The FAO's Code of Conduct for Responsible Fisheries also provide a good base for the national and international cooperation in harmonizing aquatic animal health management activities. Further, the FAO's "One Health Program" aims for improved animal and public health, enhanced food safety and security, and improved livelihood while protecting the ecosystem.

The information on diseases of national importance may help developing national disease control strategies and to comply with regional and international disease reporting requirements. A national list of diseases would also allow the development of national strategies around some of these diseases. Recently, the Department of Fisheries, Government of India has formulated a Draft on "The Aquatic Animal Disease and Health Management Bill-2019", that justifies the importance of this branch of science. The draft Bill seeks to provide for prevention and control of diseases of aquatic animals, prevention of outbreak, transboundary ingress and inter-regional spread of aquatic animal diseases, regulation of quality usage of inputs in aquaculture, control of residues in aquatic animals and their products for the safety of human health and the environment in view to ensure sustainable production, minimization of economic losses and to meet international obligations of India and for the facilitation of import and export of aquatic animals and their products and matters connected therewith or incidental thereto.

Against these backgrounds, the revised Subject Matter Area under the Aquatic Animal Health Management discipline for the M.F.Sc. and Ph.D. programme aims to generate specialized human resources to benefit aquaculture and allied industries of the country and to understand and manage the aquatic animal diseases and related issues that affect the national and international trade. In this discipline, the conventional courses on bacterial, fungal, viral, parasitic and non-infectious diseases and their pathology have been updated in line with the recent advancements and national and international initiatives as enlightened above, and current subjects such as principles of aquatic animal health management, fish pharmacology and therapeutics, fish immunology, epidemiology and disease surveillance and aquatic wildlife health have been included at Masters level. At the Doctoral level, courses on biotechnological tools in fish health management, molecular virology, fish bacterial diseases mechanisms, pathobiology of fish parasitic infection, immunology and vaccination, cellular pathology, aquaculture medicine and techniques in toxicology have been incorporated in line with the recent developments in disease diagnosis and control as well as national and international regulations.

Course Title with Credit Load
M.F.Sc. in Aquatic Animal Health Management

Course Code	Course Title	Credit Hours
	Major Courses	
AAH 501	Principles of Aquatic Animal Health Management	2+1
AAH 502	Bacterial and Fungal Diseases of Finfish and Shellfish	2+1
AAH 503	Viral Diseases of Finfish and Shellfish	2+1
AAH 504	Parasitic Diseases of Finfish and Shellfish	2+1
AAH 505	Fish and Shellfish Pathology	2+1
AAH 506	Fish and Shellfish Immunology	2+1
AAH 507	Principles of Fish Pharmacology and Therapeutics	1+1
	Minor Courses	**8 Credits**
	(From the subjects closely related to a students major subject)	
AAH 508	Non-Infectious Diseases and Disorders of Finfish and Shellfish	1+1
AAH 509	Epidemiology and Disease Surveillance	1+1
AAH 510	Aquatic Wildlife Health	2+0
AAH 511	Disease Diagnostic Techniques	2+1
	Supporting courses	**6 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 credits**
	(The following courses, one credit each will be offered)	
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
AAH 591	Master's Seminar-I	0+1
	Masters' Thesis Research	**30 Credits**
AAH 599	Master's Research (Semester III)	0+15
AAH 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc in Aquatic Animal Health Management

I. Course Title : Principles of Aquatic Animal Health Management
II. Course Code : AAH 501
III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the principles of aquatic animal health management, biosecurity and specific issues associated with the system. It helps the graduates to methodically address the problems and to improve the production efficiency and reliability, and reduce economic loss due to diseases

V. Theory

Unit I

Introduction to aquatic animal health management: Introduction to various aspects of health management; Stress response; Definition of health and disease; Pathogen carriers; Simple fish disease models.

Unit II

Legislative framework: Principles of quarantine; Zoning and compartmentalization; Live fish transportation; Import risk analysis; Health certification, Principle, Procedure, The regulatory body for aquaculture health certification.

Unit III

One health concept of OIE: World animal health organization and importance for trading; One health concept of OIE.

Unit IV

Health management measures in an open system: Health management measures in cages, Pen, Reservoirs and open-water aquaculture; Interactions of farmed and Wild animals; Disease exchange with wild

Unit V

Management measures for host, environment and pathogen: Management measures for pathogen; Therapeutics and sanitizers; Management measures for the environment; Bioremediators, Biocontrol agents, Shrimp toilet; Management measures for the host; Specific pathogen-free (SPF), Specific pathogen-resistant (SPR) and Specific pathogen-tolerant (SPT); Probiotics; Immunomodulators; Concepts of vaccination.

Unit VI

Developing management practices and biosecurity principles: Health maintenance, Better management practices (BMP), Good aquaculture practices (GAP), Hazard analysis and Critical control point (HACCP) and Biosecurity principles in aquaculture.

VI. Practical

Case study; Disease risk analysis; Demonstration of different management measures; Demonstration of different diagnostic tools; Application of therapeutics; Application of sanitizers, Disinfectants; Visit to SPF shrimp larval production centres, Biosecure shrimp grow-out farms; Documentation and comparison of different management practices at farm/hatchery level.

VII. Suggested Reading

- *Aquaculture Biosecurity*. Blackwell Pub. Professional, Iowa, 2006
- Mishra BK. 2007. *Disease Management in Freshwater Pisciculture* GeetaSomani, Udaipur.
- Ferguson H.W. 2006. *Systematic Pathology of Fish*. Scotain Press, London
- Patra NC. 2014. *Aquatic Animal Diseases and Management*. Narendra Publishing House, Delhi
- Post G. 1987. *Textbook of Fish Health*. TFH Publications, Inc., Canada
- Sindermann CJ. 1990. *Principal Diseases of Marine Fish and Shellfish*. Academic Press Inc., San Diego.
- Stockham SL. 2002. *Fundamentals of Veterinary Clinical Pathology*. Lowa State Press, Lowa 2
- Sugama K. 1998. *Manual of Fish Diseases Diagnosis*. Nippon veterinary and animal science University, Japan.

I. Course Title : Bacterial and Fungal Diseases of Finfish and Shellfish

II. Course Code : AAH 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the bacterial and fungal diseases of finfish and shellfish that affects the global aquaculture industry. It provides an exhaustive knowledge of bacterial and fungal infections, their virulence, pathogenesis, epidemiology, treatment and control. It also aims to train graduates to systematically diagnose the problems and evolve ways to manage bacterial and fungal diseases.

V. Theory

Unit I

Introduction to microbial infection: Pathogenesis, Virulence Mechanisms, Epidemiology, Prophylaxis, Therapeutic measures.

Unit II

Bacterial diseases of finfish: Aetiology, Epidemiology, Pathogenicity, Virulence, Prophylaxis, Treatment and control measures of bacterial diseases of finfish with emphasis on furunculosis, Aeromoniasis, columnaris disease, Bacterial kidney disease, Bacterial gill disease, Vibriosis, mycobacteriosis, Edwardsiellosis, Flavobacteriosis, Francisellosis, Enteric red mouth disease, Pasteurellosis, Piscirickettsiosis, Streptococcosis, Lactococcosis, pseudomonas septicaemia, Chryseobacteriosis, Clostridial disease, *Aerococcus viridans* infection.

Unit III

Bacterial diseases of shellfish: Aetiology, Epidemiology, Pathogenicity, Virulence, Prophylaxis, Treatment and control measures of bacterial diseases of shellfish with emphasis on Vibriosis, Acute Hepatopancreatic Necrosis Disease (AHPND), *Hepatobacter penaei* infection or Necrotizing Hepatopancreatitis (NHP), Rickettsial diseases, Mycobacteriosis.

Unit IV

Fungal diseases of finfish: Aphanomycosis, Epizootic Ulcerative Syndrome (EUS) in fish- Aetiology, Epidemiology, Pathogenesis diagnosis and management, Cotton wool disease, Branchiomycosis; Aspergillosis.

Unit V

Fungal diseases of shellfish *Lagenidium* spp.*, Sirolpidium* spp.*, Haliphthoros* spp., *Fusarium* spp., *Aphanomy cesastaci* infection.

Unit VI

Antimicrobial resistance Use and abuse of antibiotics in aquaculture; Antibiotic resistance; Multidrug resistance; Molecular mechanisms.

VI. Practical

Sampling techniques; Culture techniques; Case study; Examination of moribund fish for bacterial diseases; Isolation and identification of bacterial pathogens; Serological diagnostic techniques; Molecular diagnostic techniques; Antibiotic sensitivity assay; Identification of virulence factors; Isolation, culture and identification of fungal pathogens, Maintenance and preservation of microbial cultures

VII. Suggested Reading

- Austin B. 2007. *Bacterial Fish Pathogens*. Springer Publishers, U.K.
- Bullock LG. 2014. *Diseases of Fishes*. NPH, Delhi
- Chan VL. 2006. *Bacterial Genomes and Infectious Diseases*. Humana Press, New Jersey.
- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle
- Hadwin G. 2017. *Diseases of Fishes*. Bacterial diseases of fishes and identification of fish pathogenic bacteria. Random Pub., New Delhi.
- Inglis V. 1993. *Bacterial Diseases of Fish*. Blackwell Scientific Publications, London
- Inglis V *et al*. 2011. *Bacterial Diseases of Fish*. John Wiley and Sons, New Jersey.
- Snieszko SF. 1971. *Diseases of Fishes*. Book 2A. TFH Publications Inc, Ltd., New Jersey.
- Wilson M. 2002. *Bacterial Diseases Mechanisms*. Cambridge University Press, Oxford.
- Woo PTK and Bruno DW. 2011. *Fish Diseases and Disorders* Vol-3. CABI Publishers, UK.

I. Course Title : Viral Diseases of Finfish and Shellfish

II. Course Code : AAH 503

III. Credit Hours : 2+1

IV. Aim of the course

To provide both basic and applied knowledge on viral diseases of finfish and shellfish that impacted the global aquaculture industry. It imparts an exhaustive knowledge of viral infections, their pathogenesis, epidemiology, treatment and control in fish and shellfish. It also aims to equip graduates to diagnose the problems and evolve ways to manage the diseases.

V. Theory

Unit I

Viral classification, infection and isolation: General biology of viral infections; Virus classification (ICTV); Virus replication; Virulence markers; Viral evasion; Principles of cell culture; Development of primary cell culture; Maintenance of cell lines; Scaling up of cell culture; Characterization and preservation of cell lines.

Unit II

OIE listed viral pathogens of finfish: Pathogenesis, Molecular biology, Epidemiology and control of OIE listed viral pathogens/ diseases of finfish: Epizootic Haematopoietic Necrosis (EHN), Infectious haematopoietic necrosis (IHN), Spring viraemia of carp (SVC), Viral Haemorrhagic Septicaemia (VHS), Infectious salmon anaemia (ISA), Salmonid Alphavirus (SAV) and Red Seabream Iridoviral Disease (RSIVD), Cyprinid Herpesvirus 3 (CyHV-3 or KHV).

Unit III

Non-OIE listed viral pathogens of finfish: Pathogenesis, molecular biology, Epidemiology, and control of non-OIE listed viral pathogens/ diseases of finfish; *Oncorhynchus masou* virus (OMV), Viral Encephalopathy and Retinopathy (VER), Channel Catfish Virus (CCV), Lymphocystis, Tilapia Lake virus (TiLV), Carp Edema Virus (CEV), Piscine orthoreovirus, Cyprinid Herpes Virus-2 (CyHV-2).

Unit IV

OIE listed viral pathogens of shrimp and prawn: Major viral pathogens of commercially important cultured crustaceans with special reference to shrimp and prawn; clinical signs, Pathogenesis, Molecular characterization, Diagnostic methods, Epidemiology and Control associated with white spot syndrome virus (WSSV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Taura Syndrome Virus (TSV), Yellow Head Virus (YHV) genotype-1, Infectious Myonecrosis Virus (IMNV), *Macrobrachium rosenbergii* nodavirus (MrNV).

Unit V

Non-OIE listed viral pathogens of shrimp: Major viral pathogens of commercially important cultured crustaceans with special reference to shrimp and prawn; clinical signs, pathogenesis, molecular characterization, diagnostic methods, epidemiology and control associated with monodon baculovirus (MBV), hepatopancreatic parvo-like virus (HPV), baculovirus penaei (BP), baculovirus midgut gland necrosis virus (BMNV), Laem-Singh virus (LSNV), gill-associated virus (GAV), extra small virus (XSV), shrimp hemocyte iridescent virus (SHIV), reovirus, covert mortality nodavirus (CMNV).

Unit VI

Viral diseases of molluscans: Introduction to viral diseases of molluscans - Ostreid Herpesvirus 1 (OSHV-1), Abalone Herpes Virus (AbHV), Haemocytic Infection Virus disease (HIV), Oyster Velar Virus (OVV)

VI. Practical

Sampling techniques; Case study of viral diseases; Examination of shrimp; freshwater prawn and molluscs for viral infection; Examination of moribund fish for viral diseases, Preservation and processing of samples; Virus isolation and replication, bioassay methods, Serological and molecular diagnostic techniques, Plaque and neutralization assay; Development of primary cell cultures for virus studies, Maintenance of cell lines, Viral bioinformatics.

VII. Suggested Reading

- Adams, JR. 1991. *Atlas of Invertebrate Viruses*. CRC Press, Boca Raton
- Andrewes C. *Viruses of Vertebrates*. Trindall and Cox, Bailliere
- Burnet FM. 1968. *Enzyme, Antigen and Virus*. Cambridge University of Press, Cambridge

- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle.
- Gibbs, EPJ. 1981. *Virus Diseases of Food Animals: A World Geography of Epidemiology and Control*. Academic Press, London
- Kurstak, E. *Control of Virus Diseases*. Marcel Dekker, Inc., New York.
- Polson, A. 1993. *Virus Separation and Purification Methods*. Marcel Dekker, Inc., New York
- Purohit, SS. 1989. *Viruses, Bacteria and Mycoplasmas*. Bikaner Agro Botanical Publishers.
- Smith KM. 1963. *Viruses*. England Cambridge University Press, Cambridge
- *The Flaviviruses: Structure, replication and evolution* Chambers T.J. Publication: London Elsevier Science 2003.
- Wiedbrauk, D.L. 1995. *Molecular Methods for Virus Detection*. Academic Press, San Diego.
- Woo PTK and Bruno DW. 2011. *Fish Diseases and Disorders* Vol-3. CABI Publishers, U.K.

I. Course Title : Parasitic Diseases of Finfish and Shellfish

II. Course Code : AAH 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the parasitic diseases of finfish and shellfish. It helps to comprehend the taxonomy, morphology, biology, pathology and host-parasite relation including control measures of important parasites of aquatic organisms and to understand the significance of parasites in fish health.

V. Theory

Unit I

Host-parasite relationship: Introduction and concepts of different animal associations; Important ecological terms used in parasitology; General introduction to the classification of protozoan and metazoan parasites; Life cycle; Host-parasite relationship.

Unit II

Protozoan parasitic diseases of finfish: Diseases of importance in aquaculture, Clinical signs, Etiology, pathology, Epidemiology, Host-parasite relationship, diagnosis, treatments and control of the disease caused by protozoan parasites; Amoeba- *Neoparamoeba perurans* (Amoebic gill disease-AGD); Ciliates- *Ichthyophthirius, Cryptocaryon*, *Trichodina*; Flagellates- *Ichthyobodo* (*Costia*) *necatrix, Cryptobia, Amyloodinium, Trypanosoma*, *Trypanoplasma*; Microsporidians- *Glugea*, *Pleistophora*etc.

Unit III

Metazoan parasitic diseases of finfish: Diseases of importance in aquaculture, Clinical signs, etiology, Pathology, epidemiology, Host-parasite relationship, Diagnosis, Treatments and control of the disease caused by metazoan parasites, Myxozoans- *Myxobolus cerebralis, Spaerospora arenicola; Kudoa thyrsites, Tetracapsuloides bryosalmonae,* etc., Monogeneans- *Dactylogyrus, Gyrodactylus, Diplectanum, Benedenia;* Digeneans- *Diplostomum, Sanguinicola, Neascuscuticola, Schistosoma* etc., Larval trematode infection (metacercaria); Cestodes: *Diphyllobothrium latum, Caryophyllaeus, Ligula*; Nematodes: *Capillaria, Camallanus*; Acanthocephala: *Neoechinorhynchus*

Unit IV

Crustacean parasitic diseases of finfish: Diseases of importance in aquaculture, Clinical signs, Etiology, Pathology, Epidemiology, Host-parasite relationship, Diagnosis, treatments and control of the disease caused by Crustacean parasites; Branchiurans- *Argulus;* Copepods- *Lernaea, Caligus*, *Lepeophtheirus, Ergasilus;* Isopods- *Cymothoa, Cirolina, Nerocila.*

Unit V

Protozoan parasitic diseases of shellfish: Diseases of importance in aquaculture, Clinical signs, Etiology, Pathology, Epidemiology, Host-parasite relationship, Diagnosis, treatments and control of the disease caused by protozoan parasites; Ciliates-*Zoothamnium, Vorticella, Epistylis*; Cephaline gregarines; Microsporidian: Cotton shrimp disease-causing microsporidians, *Enterocytozoon hepatopenaei* (EHP); Haplosporidian.Parasitic diseases of molluscans: *Bonamia, Perkinsus, Marteilia.*

Unit VI

Antiparasitic drugs and parasitic zoonoses: Common anti-protozoal and anti-metazoal drugs applied in aquaculture; Mode of application and their action; Definition and Classification of zoonoses and Approaches to their management; Parasitic zoonoses of fish/shellfish origin: Trematodes (*Heterophyes, Clonorchis, Opisthorchis, Paragonimus, Echinostoma*etc); Cestodes (*Diphyllobothrium, Spirometra*, *Ligula*); Nematodes (*Gnathostoma, Anisakis, Angiostrongylus, Capillaria*etc.).

VI. Practical

Case studies of different organs and tissues of finfish/shellfish infected with ecto- and endoparasites; Collection, preservation and fixation of suitable samples for laboratory examination; Preparation microscopic examination of tissue impression, blood/haemolymph smears; Wet-mount preparation of gill, mucus, skin scrapings etc; Collection of faecal, intestinal content and recovery of parasites; Collection and identification of parasites; Study of morphological characters of adults and developmental stages of the protozoan and metazoan parasites of importance in aquaculture; Preparation of permanent slides, micrometry and photomicrography; Histopathological analysis of parasite-infected tissues; Examination of intermediate host for larval stages; Microscopic examination of already prepared parasitic specimens (collection of permanent slides); Identification of parasites and histological lesions

VII. Suggested Reading

- Austin B *et al*. 1951. *Infectious disease in aquaculture*. Woodhead publishing series in food science, technology and nutrition, Woodhead Pub. Ltd., Oxford.
- Baker JR. 2004. *Advances in Parasitology*. Vol-56 Elsevier Publisher, London.
- Dash G. 2012. *Freshwater Fish Parasites*. New India Publishing, New Delhi.
- Dogiel *et al*. 1961. *Parasitology of Fishes*. NP. London.
- *Infectious disease in aquaculture*. Woodhead Pub. Ltd., Philadelphia 2012
- Kabata Z. 1985. *Parasites and Diseases of Fish Cultured in the Tropics*. Taylor and Francis, London
- Klaus R. 2005. *Marine Parasitology*. CABI Publishing, U.K.
- Maule, A.G. 2006. *Parasitic Flatworms*. CAB International, USA
- Nair PR. 2008. *Encyclopedia of Fish Diseases*. Dominant Publishers, New Delhi.
- *Parasitic Nematodes*. CABI Pub., New York, 2001.
- Petrushevskii GK. 1957. *Parasites and Diseases of Fish*. Leningrad Israel Program for Scientific Translations

- Schmidt GD. 2000. *Foundations of Parasitology*. McMcgraw Hill, New York
- Singha R. 2014. *Parasite Fauna in the Wetland Fishes of India.* Today and Tomorrow Printers and Publishers, New Delhi
- Wallingford. 2012. *Fish Parasites.* CABI, Oxfordshire; Cambridge, MA
- Wiegertjes GF. 2004. *Host-Parasite Interactions*. BIOS Scientific, USA.
- Woo PTK. 2012. *Fish parasites Pathobiology and Protection*. CABI Publishing, UK.
- Zaccone G *et al*. 2009. *Fish Diseases*. Vol-2. Science Publishers, U.S.A.

I. Course Title : Fish and Shellfish Pathology

II. Course Code : AAH 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the structural and functional changes in cells, tissues and organs in relation to the development of various finfish diseases. It also imparts hands-on experience on the laboratory analyses using the tools of chemistry, biomarkers, clinical microbiology and pathology, haematology, etc.

V. Theory

Unit I

General pathology: Brief introduction to finfish and shellfish anatomy and histology; General pathology of finfish and shellfish

Unit II

Pathophysiology of fish: Pathophysiology of finfish and shellfish; Stress and stressors; General adaptation syndrome; Types of cellular adaptations; Hypertrophy, hyperplasia, Atrophy and metaplasia, Neoplasia.

Unit III

Inflammation and cellular pathology: Reversible cellular changes and accumulations; Fatty changes and pigments; Inflammation; Causes of inflammation; Cellular responses to inflammation; Mediators; various patterns of inflammation; The difference between acute and chronic inflammation; Tissue repair; Cell death; Necrosis, Apoptosis, Autophagy; Necroptosis; Their mechanisms and different morphological patterns.

Unit IV

Clinical pathology: Normal constituents of blood; Alterations in the haematological parameters and enzymes with reference to different pathological conditions in finfish; Haematology of shrimp and molluscans; Clotting mechanisms; other host defence mechanisms.

Unit V

Systemic pathology of finfish: Systemic pathology of finfish integumentary system, Respiratory system, Vascular system, Digestive system, Excretory system, Nervous system, Musculoskeletal and Endocrine system due to bacteria, Parasites and viruses.

Unit VI

Systemic pathology of shellfish: Major pathological changes due to infectious diseases in the integumentary system, Lymphoid organ, Gill, Hepatopancreas, Gut

and other organs of crustaceans; Major pathological changes due to diseases in molluscans.

VI. Practical

Necropsy techniques; Collection and fixation of tissues; Complete histology and different staining techniques; Examination and interpretation of the pathological changes in fish tissues; Complete blood profile of finfish; Routes of blood collection from fish; Different staining techniques for blood cell visualization; Morphology of blood cells; Total leucocyte count; Differential leucocyte count.

VII. Suggested Reading

- Coles EH. 1986. *Veterinary Clinical Pathology*. W B Saunders Co., Philadelphia.
- Coleman WB. and Tsongalis GJ. 2009. *Molecular Pathology*. Elsevier Publisher, Boston
- Cook DJ. 2006. *Cellular Pathology*. Scion Publishers, Oxford.
- Ellis AE. 1985. *Fish and Shellfish Pathology*. Academic Press, London.
- Ferguson HW. 2006. *Systematic Pathology of Fish*. Scotain Press, London.
- Jones TC. 1997. *Veterinary Pathology*. Williams and Wilkins, Philadelphia.
- Killeen AA. 2001. *Molecular Pathology* Protocols. Humana, U.S.A
- Lloyd RV. 2004. *Endocrine pathology*. Humana Press, Totowa.
- Perkins FO. 1990. *Pathology in Marine Science*. Academic Press Inc., San Diego.
- Roberts RJ. 2012. *Fish Pathology*. Wiley-Blackwell, Chichester
- Salle AJ. 1961. *Fundamental Principles of Pathology*. MacGraw-Hill Co., New York.
- Stockham SL. 2002. *Fundamentals of Veterinary Clinical Pathology*. Lowa State Press, Lowa

I. Course Title : Fish and Shellfish Immunology

II. Course Code : AAH 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on basic principles of fish and shellfish immunology, to understand the immune responses to infection by various fish pathogens and to offer scope for the development of disease protective/prevention measures against bacteria, fungi, viruses and parasites of fish.

V. Theory

Unit I

Introduction to fish immunology: Phylogeny and ontogeny of the immune system; Lymphoid tissues and cellular components of the immune system; T and B cells; Mucosal immune system.

Unit II

Non-specific immune system of finfish: Phagocytosis; Mechanism of phagocytosis; Complement system: function, components; Complement activation.

Unit III

Specific immune system of finfish: Memory function and immunological tolerance; Antigens and antigenicity; Antigen processing; Superantigens; Haptens; Antibody: structure, types, Theories of antibody formation; Regulation of immune response.

Unit IV

Antibody-mediated and cell-mediated immunity: Cell-mediated immune

response and its components; Antibody-mediated immune responses; Polyclonal and monoclonal antibody production and application; The basic concept of aptamers, Aptabodies and Edible antibodies.

Unit V

Defence mechanisms of shellfish: Invertebrate defence mechanisms; Quasi immune response

Unit VI

Immunoprophylaxis: Immunomodulation, probiotics; Aquaculture vaccines: History, concept, Development of vaccines; Advances in DNA vaccines, Recombinant vaccines, vectored vaccines, etc; Routes of administration; Adjuvants and ligands; Efficacy and Limitation of vaccines; Immune genes and their regulation.

VI. Practical

Serum separation; Preparation of antigen; Raising of antibodies; Antigen-antibody reactions: Agglutination tests, Precipitation tests: gel diffusion; ELISA; Antibody titration; Western blotting; Isolation of lymphocytes; Non-specific immune response: NBT assay, lysozyme assay; Prophenoloxidase in shrimp; Preparation of a simple vaccine and administration

VII. Suggested Reading

- Abbas AK. 1991. *Cellular and Molecular Immunology*. Saunders Publisher, Philadelphia
- Alt F. 2009. *Advances in Immunology*: Vol-103. Elsevier Publishers, New York
- Alt FW. 2009. *Advance in Immunology* Vol-102. Academic Press, London
- Anderson DP. 2003. *Textbook of Fish Immunology*. Narendra Publishing House, Delhi.
- Cooper EL. 1982. *Immunology and Immunization of Fish*. Pergamon Press, New York.
- Cooper EL. 1982. *General Immunology*. Pergamon Press, Oxford.
- Comparative immunology, microbiology and infectious diseases. Pergamon Press. Oxford, 2002
- Davis BD. *et al*. 1973. *Microbiology Harper and Row*, Publishers, Hagerstown.
- Delves PJ. 1994. *Cell Immunology*. BIOS Scientific Publishers Limited, Oxford.
- Delves PJ. 2017. *Roitts Essential-Immunology*. Wiley Blackwell, UK.
- Eales LJ. 2003. *Immunology for Life Scientists*. John Wiley and Sons, U.S.A.
- Elgert KD. 2009. *Immunology*. John Wiley and Sons, New York.
- Fikrig SM. 1982. *Handbook of Immunology for Students and House Staff*. Verlag Chemic International, Florida
- *Fish and Shellfish Immunology* Elsevier Science, London, 1993.
- Folds JD. 1999. *Clinical Immunology*. ASM Press, U.S.A
- *Fundamental Immunology*. Williams and Wilkins, Philadelphia, 2008
- Gupta P. 2008. *Immunology and Microbiology*. Pointer Publishers, Jaipur.
- Herzenberg LA and Weir DM. 1996. *Immunochemistry and Molecular Immunology* Vol-1. Blackwell Science, Ltd., USA.
- Kaufmann SHE. 2005. *Immunology*. ASM Press, Washington
- Lerner KL. 2003. *World of Microbiology and Immunology*: Vol-I (A-L). Thomson Gale, New York.
- Lerner KL. 2003. *World of Microbiology and Immunology*: Vol-II (M-Z). Thomson Gale, New York.
- Luttmann W. 2006. *Immunology*. Elsevier Publication, London
- Male D. 2006. *Immunology*. Elsevier Publishers, London
- Meyers RA. 2007. *Immunology*. Wiley-VCH Verlag, U.S.A.
- Paul WE. 2008. *Fundamental Immunology*. Wolters Kluwer, USA.
- Richard C. 2015. *Immunology* A Short Course. Wiley Blackwell, UK.
- Sharma DK. 2015. *Immunology*. New India Publishing Agency, New Delhi.

- Stolen JS. 1986. *Fish Immunology*. Elsevier, Amsterdam.
- Swain P and Sahoo PK. 2006. *Fish and Shellfish Immunology* NPH, Delhi.
- Tizard IR. 2009. *Veterinary Immunology: An Introduction*. Elsevier Publishers, Noida.
- Weir DM *et al*. 1996. *Weir's Handbook of Experimental Immunology*. Vol 1. Blackwell Science, Oxford.

I. Course Title : Principles of Fish Pharmacology and Therapeutics

II. Course Code : AAH 507

III. Credit Hours : 1+1

IV. Aim of the course

To learn the principles and protocols of therapeutics in aquaculture, their absorption and elimination. It offers greater knowledge of drugs for the prevention and/or treatment of diseases, and the economic husbandry of fish. It also inculcates the graduates on the legislative framework of chemotherapy for responsible use of aqua-drugs and responsible aquaculture.

V. Theory

Unit I

Therapeutics in aquaculture: Common therapeutants used in aquaculture; Their mode of action, Dose and dosage, Methods of application; Phytotherapy, Phage-therapy, Nanoparticle-based drugs, Antimicrobial peptides, etc.

Unit II

Pharmacology principles: Pharmacokinetics and pharmaco-dynamics; Residual effect and withdrawal period of various chemotherapeutants.

Unit III

Application: Pharmacovigilance; Immunopharmacology; Pharmacogenetics; OECD guidelines.

Unit IV

Impacts of aquadrugs: Drug toxicity and poisoning, Antimicrobial resistance; Antibiotic resistance and its impact on the environment and human health; Legislative framework of chemotherapy in aquaculture; Drug regulation acts and other legal aspects.

VI. Practical

On-farm practical sampling sessions; Case studies; Dose determination; Application of therapeutants; Different methods of delivery of therapeutants in aquaculture; Demonstration of phytotherapy; Determination of MIC of drugs; Determination of MCC of drugs. Extraction of compounds from plants, Methods to identify the active compounds (HPLC).

VII. Suggested Reading

- Adams HR. 2001. *Veterinary Pharmacology and Therapeutics*. Lowa State University Press, Delhi
- Bryan LE. 1989. *Handbook of Experimental Pharmacology*. Vol 91. Springer-Verlag, Berlin.
- Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Press, London.
- Herwig N. 1979. *Handbook of Drugs and Chemicals used in the Treatment of Fish Diseases*. Charles C Thomas, Springfield
- Khory RN. 1999. *Material Medica of India and their Therapeutics*. Komal Prakashan, Delhi

- Lancaster R. 1980. *Pharmacology in Clinical Practice*. William Helnemann Medical Books Ltd., London
- Moini J. 2009. *Fundamental Pharmacology*. Cengage Learning, New Delhi
- Pandey G. 2017. *Fish Pharmacology and Toxicology*. DPH, New Delhi.
- Riviere JE. *Veterinary Pharmacology and Therapeutics*. John Wiley and Sons, U.S.A

I. Course Title : Non-infectious Diseases and Disorders of Finfish and Shellfish

II. Course Code : AAH 508

III. Credit Hours : 1+1

IV. Aim of the course

To comprehend the etiology and management of different non-infectious diseases and various disorders.

V. Theory

Unit I

Importance of water and sediment quality: Impact of water and sediment parameters on finfish and shellfish health

Unit II

Nutritional imbalance: Studies on the causes, Pathogenesis, Pathology, Diagnosis and differential diagnosis of various diseases due to nutritional imbalance and anorexia; Vitamin deficiencies and mineral deficiencies and their toxicity.

Unit III

Disorders: Metabolic disorders; Skeletal deformities; White faecal syndrome (WHS) in shrimp.

Unit IV

Impact of toxicants on fish health: Algal blooms, Important mycotoxins, Icthyotoxins, Chemical toxins, and Other toxicants and their effects on fish health.

VI. Practical

Case study; Study of gross changes in different tissues inflicted due to various nutritional deficiency; Study of histopathological changes in different tissues inflicted due to various nutritional deficiency; Study of histopathological changes in different tissues inflicted due to various toxicants

VII. Suggested Reading

- *Fish Diseases and Disorders*. CABI, Wallingford, UK 2010
- Leatherland JF. 1998. *Fish Diseases and Disorders*. Vol 2. CABI Publishing, Oxon.
- Sparks A. 1972. *Invertebrate Pathology: Non-Communicable Diseases*. Academic Press, New York

I. Course Title : Epidemiology and Disease Surveillance

II. Course Code : AAH 509

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of epidemiology and surveillance of fish diseases. It aids in the collection of rapid and reliable high-quality information about aquatic animal

diseases and production. It also instils the graduates on the collection of fish disease data using inexpensive techniques that are more suitable for Indian aquaculture.

VI. Theory

Unit I

Introduction to epidemiology and concepts: Epidemiological terms; Epidemiological concepts and types; The importance of aquatic animal diseases; patterns of disease-epidemic curves; Epidemiological view of causality; Epidemiological association; Diagnosing disease, levels of diagnosis.

Unit II

Disease surveillance: Disease surveillance; Purpose and objectives of surveillance; Approaches to surveillance, Principles of active and passive surveillance; Sampling Principles and applications; Principles of data and specimen collection; Collection of information from people; Survey design and planning; Prevalence, Production and Incidence rate surveys.

Unit III

Surveillance data management: Principles and data processing, Computerized and manual data management; Epidemiological software for data analysis.

Unit IV

Strategic plan for aquatic animal health: Aquatic animal health information systems; National and regional strategic plan for aquatic animal health; National and international disease reporting: Role of NBFGR, NACA, FAO, OIE, AQUAPLAN, etc., in disease reporting; Emergency disease preparedness.

VII. Practical

Development of questionnaire; Farm survey; Collection of active and passive data on fish diseases; Data entry and data processing; Use of epidemiological software for data analysis.

VIII. Suggested Reading

- Cameron A. 2002. *Survey Toolbox for Aquatic Animal Diseases. A Practical Manual and Software Package*. ACIAR Monograph no 94, 375p
- Caugant DA. 2009. *Molecular Epidemiology of Microorganisms*. Humana Press, New York
- Gibbs EPJ. 1981. *Virus Diseases of Food Animals: A World Geography of Epidemiology and Control*. Academic Press, London
- Gregg MB. 2002. *Field Epidemiology*. Oxford University Press, Oxford.
- Rothman K.J. 2002. *Epidemiology: An Introduction*. Oxford University Press, Oxford
- Thrusfield M. 1995. *Veterinary Epidemiology*. Blackwell Science.

I. Course Title : Aquatic Wildlife Health

II. Course Code : AAH 510

III. Credit Hours : 2+0

IV. Aim of the course

To understand the health issues of aquatic wildlife and enhancing their health and protection. It helps the graduates to appreciate the impact of global climate change on the health of aquatic and marine wildlife populations and be aware of the rehabilitation and handling of dead aquatic animals.

V. Theory

Unit I

Introduction to aquatic wildlife: Introduction to aquatic wildlife: Definition, diversity: cetaceans, Crocodilians, Sea turtles, Frogs, Sea lions, Seals, Sea otters, Insects, Birds; Principles on 'one world and one health'.

Unit II

Aquatic wildlife habitats: Aquatic wildlife habitats; Ecosystem health; Aquatic ecosystem health indicators; Aquatic wildlife-related recreations; recognizing and preventing the impacts of principal stressors.

Unit III

Aquatic invasive species: Examples and role of aquatic invasive species in the transfer of exotic pathogens; prevention and spread of invasive species.

Unit IV

Aquatic wildlife diseases: Diseases of amphibians; Infections with non-hyphal parasitic chytrid fungi *Batrachochytrium detrobatidis* and *B. salamandrivorans*, and ranavirus species; Disease issues in aquatic wildlife; Monitoring of diseases in aquatic wildlife; Infectious (viral, parasitic, bacterial) and non-infectious diseases (malnutrition, toxic algae poisoning, gunshots, boat strikes, shark bites) of aquatic wildlife; Entanglement in ocean trash; Disease reporting in dead aquatic wildlife; Aquatic wildlife die-offs; Fish kills and the causes; Handling of dead aquatic animals; Clean up; Carcass disposal and disinfection procedure; zoo and aquaria medicine.

Unit V

Anthropogenic factors and contaminants on aquatic wildlife: Effect of anthropogenic factors and contaminants on aquatic wildlife; The zoonotic potential of aquatic wildlife diseases; Aquatic wildlife rehabilitations.

Unit VI

Health management issues: Health management issues in game fish, Fish ranging, etc; Health management of free-ranging aquatic wildlife populations; The impact of global climate change on the health of aquatic and marine wildlife populations.

VI.. Suggested Reading

- Biradar RS. 2010. *Aquatic Resources and Health Management*. Narendra Pub. House, Delhi.
- CIFE. 2009. *Genome and Protein-Based Techniques in Aquatic Animal Health Management*. CIFE, Mumbai.
- Humphrey J. 2005. *Aquatic Animal Quarantine and Health Certification in Asia*. Daya Publishing House, Delhi

I. Course Title : Disease Diagnostic Techniques

II. Course Code : AAH 511

III. Credit Hours : 2+1

IV. Aim of the course

To comprehend theoretical and practical aspects of different disease diagnostic techniques used in aquaculture and to take appropriate decisions on fish health management and appropriate choice of treatment.

V. Theory

Unit I

Introduction to fish disease diagnosis: Introduction to disease diagnosis; different roles and levels of diagnosis in aquaculture; The evolution of diagnostic techniques in aquaculture; A brief introduction to diagnostic features of important diseases of finfish and shellfish.

Unit II

Microbiological techniques: Safety in microbiology laboratory; Bio-safety levels and risk groups; Techniques in sterilization; Preparation of microbiological media; Culture techniques; Purification, Preservation and maintenance of bacterial and fungal cultures.

Unit III

Microscopic techniques: Bright field, Darkfield, Phase contrast, Fluorescence and electron microscopy.

Unit IV

Cell culture-based diagnostic methods: Introduction to cell culture techniques; Different cells used for virus isolation; CPE.

Unit V

Protein-based diagnostic methods: Antibody-based diagnostic methods (immunohistochemistry, ELISA, western blotting, lateral flow assay etc), Hybridoma technology and monoclonal-antibody-based diagnosis

Unit VI

Nucleic-acid based diagnostic methods: Nucleic acid amplification methods; Types of PCR: Reverse transcriptase-PCR, Real-time PCR and Other variants of PCR; *In situ* hybridization; Dot blot assay; LAMP etc.

VI. Practical

Sample collection and preparation for microscopic, microbiological, virological and histopathological analysis; Culture of microorganisms using conventional methods; Antibiotic sensitivity testing; Serological techniques in disease diagnosis: SDS-PAGE, Western blotting, ELISA, etc; Cell culture techniques; Molecular techniques in disease diagnosis, Nucleic acid extraction, estimation and different PCR-based diagnosis; Familiarisation of some of the commercially available diagnostic kits used in aquatic animal disease diagnosis.

VII. Suggested Reading

- *Infectious Disease in Aquaculture*. Woodhead Pub. Ltd., Philadelphia, 2012.
- Lucky Z. 1977. *Methods for the Diagnosis of Fish Diseases*. Amerind Publishing Co Pvt Ltd, New Delhi
- Sindermann CJ. 1977. *Disease Diagnosis and Control in North American Marine Aquaculture*. Elsevier Scientific Publishing Company, Amsterdam
- Sugama K. 1998. *Manual of Fish Diseases Diagnosis*. Nippon veterinary and animal science University, Japan.
- Walker P. 2005. *DNA-based Molecular Diagnostic Techniques*. Daya, Delhi 2005

Course Title with Credit Load
Ph.D. in Aquatic Animal Health Management

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
AAH 601	Biotechnological Tools in Fish Health Management	2+1
AAH 602	Molecular Virology of Finfish and Shellfish	1+1
AAH 603	Fish Bacterial Diseases Mechanisms	1+1
AAH 604	Pathobiology of Fish Parasitic Infection	1+1
AAH 605	Immunology and Vaccination of Fish	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
AAH 606	Cellular Pathology	1+1
AAH 607	Aquaculture Medicine	1+1
AAH 608	Techniques In Toxicology	1+1
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
AAH 691	Doctoral Seminar – I	0+1
AAH 692	Doctoral Seminar –II	0+1
	Doctoral Research	**75 Credits**
AAH 699	Doctoral Research (Semester II)	0+15
AAH 699	Doctoral Research (Semester III)	0+15
AAH 699	Doctoral Research (Semester IV)	0+15
AAH 699	Doctoral Research (Semester V)	0+15
AAH 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
PhD. Aquatic Animal Health Management

I. Course Title : Biotechnological Tools in Fish Health Management

II. Course Code : AAH 601

III. Credit Hours : 2+1

IV. Aim of the course

To understand the advanced biotechnological tools used for fish disease diagnosis. It promises to improve the health of cultured fish and shellfish, and aquaculture production.

V. Theory

Unit I

Molecular diagnostic methods: Molecular diagnostic methods; *in situ* hybridization; Nucleic acid probe-based diagnosis; choice and characteristics of the probe; Probe labelling; Hybridization: Hybridization strategies; Factors affecting the rate of hybridization; Immobilization of nucleic acid on filters; Types of hybridization; Southern, Northern, Dot/Slot blot hybridization; DNA Microarrays: DNA chips, Preparations of DNA arrays; Label and applications; Other related molecular techniques.

Unit II

Proteomic tools: Proteomic tools: Protein structure prediction and determination using NMR, MS/MS, MALDI-TOF.

Unit III

Antibody-based diagnostics: Antibody-based diagnostics; Variants of and advances in ELISA; Hybridoma technology.

Unit IV

Advanced biotechnology tools: eDNA technology; Metagenomics; Next-generation sequencing.

Unit V

Recent advances in biotechnological applications: CRISPER technology; Digital pathology; RNAi technology; Nanotechnological tool in drug and vaccine development.

Unit VI

Safety and regulatory requirements: Environmental concerns of vaccine and other biological products; Vaccination failure and adverse effects; Biosafety and regulatory requirements for fish diagnostics, diagnostic kits, vaccines, etc.

VI. Practical

Nucleic acid extraction; Real-time PCR; Protein profiling; DNA fingerprinting; DNA damage assay; Bioinformatics approaches for recombinant DNA technology; Gene cloning and transformation.

VII. Suggested Reading

- Brown TA. (Ed.). 2002. *Essential Molecular Biology*. Vols. I, II. 2nd Ed. Oxford University Press.
- CIFE. 1998. *Genetics and Biotechnological Tools in Aquaculture and Fisheries*. Mumbai CIFE
- Davbre PD. 1998. *Basic Molecular Biology: Essential Technique*. John Wiley and Sons, New York. p.208
- Lakra WS. 2004. *Fisheries Biotechnology*. Narendra Publishing House, Delhi.
- Lewin B. 2003. *Gene VIII*. Oxford University Press.
- Montet D. 2009. *Aquaculture Microbiology and Biotechnology*. Science Publisher, New Hampshire
- Sambrook J and Russel D. 2001. *Molecular Cloning*. 3rd Ed. Cold Spring Harbour Laboratory

I. Course Title : Molecular Virology of Finfish and Shellfish

II. Course Code : AAH 602

III. Credit Hours : 1+1

IV. Aim of the course

To provide the knowledge on recent advances in the field of finfish and shellfish virology and their management. It imparts a comprehensive knowledge of select viral infections of finfish and shellfish and their management.

V. Theory

Unit I

Viral phylodynamics: Host-virus interactions; viral phylo-dynamics; Phylo-dynamic variation; viral adaptation; Virus-virus interaction (VVI); Emerging viruses; The evolution of new viruses.

Unit II

Molecular virology of finfish: Molecular virology and pathogenesis of selected viruses infecting finfish with special reference to Nervous Necrosis Virus (NNV), Tilapia Lake Virus (TiLV), Cyprinid Herpes virus-2 (CyHV-2) and Iinfectious Pancreatic Necrosis virus (IPNV);

Unit III

Molecular virology of shellfish: Molecular virology and pathogenesis of viruses infecting shellfish with special reference to White Spot Syndrome Virus (WSSV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Infectious Myonecrosis Virus (IMNV) and *Macrobrachium rosenbergii* nodavirus (MrNV).

Unit IV

Viral management: Antiviral drugs and viral vaccines; Bioinformatics on vaccine design and development, Bioinformatics on viral drug design and development

VI. Practical

Cell culture media preparation; Explant culture and suspension culture; Primary cell culture and passaging; Characterization of cell lines (Viable cell counts, karyotyping, counting, staining); Preservation and revival of cells; Virus isolation using cell culture; Transfection techniques; Molecular detection and sequence analysis of finfish viruses; Molecular detection and sequence analysis of shellfish viruses; Collection and analysis of molecular information of various viruses using sequence information available on public domain

VII. Suggested Reading

- Adams JR. 1991. *Atlas of Invertebrate Viruses*. CRC Press, Boca Raton.
- Alan C. 2005. *Molecular Virology*. Academic Press 315 p.
- Andrews C. *Viruses of Vertebrates*. Trindall and Cox, Bailliere
- Burnet FM. 1968. *Enzyme, Antigen and Virus*. Cambridge University of Press, Cambridge
- Butler M. 1992. *Cell Culture*. BIOS Scientific Publishers Limited, Oxford
- Chambers TJ. 2003. *The Flaviviruses: Structure, Replication and Evolution*. Elsevier Science, London.
- Clynes M. 1998. *Animal Cell Culture Techniques* Berlin. Springer-Verlag
- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle.
- David MK, Peter MH, Diane EG, Robert AL, Malcolm AM, Bernard RStephen ES. 2007. *Fields Virology*. 5th edn. Lippincott Williams and Wilkins. 3177p.
- Dimmock N Easton A and Leppard K. 2006. *Introduction to Modern Virology*. Sixth edn Blackwell publishing. 536 p.
- Flint SJ, Enquist LW, Krug RM, Racaniello VR and Skalka AM. 2000. *Principles of Virology*. Molecular Biology, Pathogenesis and Control.
- Freshney IR. 2010. *Culture of Animal Cells: A Manual of Basic Technique* 6th edition. Wiley-Blackwell, Inc. New York. 732 p.
- Gibbs EPJ. 1981. *Virus Diseases of Food Animals: A World Geography of Epidemiology and Control*. Academic Press, London
- Hoboken NJ. 2011. *Animal Cell Culture*. John Wiley and Sons Inc., New York.
- Kibenge FSB and Godoy MG. 2016. *Aquaculture Virology*. Academic Press, Amsterdam, 568p.
- Kuchler RJ and Stroudsburg D. 1974. *Animal Cell Culture and Virology*. Hutchinson and Ross, Inc.
- Kurstak E. 1993. *Control of Virus Diseases*. Marcel Dekker, Inc., New York.
- Mothersill C and Austin B. 2000. *Aquatic Invertebrate Cell Culture*. Springer –Praxis, Chichester UK. 405 p.
- Murakami H. 1990. *Trends in Animal Cell Culture Technology*. Kodansha Ltd, Tokyo
- Polson A. 1993. *Virus Separation and Purification Methods*. Marcel Dekker Inc., New York
- Purohit SS. 1989. *Viruses, Bacteria and Mycoplasmas*. Agro Botanical Publishers, Bikaner
- Roberts RJ. 2012. *Fish Pathology*. 4th Ed. W.B. Saunders.
- Smith, K M. *Viruses*. Cambridge University Press, Cambridge.
- Wiedbrauk DL. 1995. *Molecular Methods for Virus Detection*. Academic Press, San Diego.
- Woo PTK. and Bruno DW. 2011. Fish Diseases and Disorders: Vol-3. CABI Publishers, UK.

I. Course Title : Fish Bacterial Diseases Mechanisms
II. Course Code : AAH 603
III. Credit Hours : 1+1

IV. Aim of the course

To understand the intracellular and extracellular life cycle of bacterial pathogens, disease mechanisms and mechanisms of survival in host cells.

V. Theory

Unit I

Mechanisms of survival in host cells: Intracellular and extracellular pathogens; Adherence of bacteria to host cells, Molecular mechanisms, Factors involving adherence; Invasion of host cells; Life in phagosome; Resistance to intracellular bactericidal molecules.

Unit II

Mechanisms of survival in the environment: Mechanisms of survival; Survival of bacteria under extreme climate or environment; Viable but non-culturable bacteria (VBNC); Examples of VBNC fish pathogens.

Unit III

Bacterial virulence factors: Bacterial endotoxins and enterotoxins, their molecular structures and mode of action; Host response to bacterial virulence factors, Response to intracellular and extracellular pathogens; Genes involved and regulation of their expression.

Unit IV

Host immune responses to bacterial infection: Immune responses; Cytokines, interleukins, Antibodies and other immunological molecules; Immune evasion mechanism.

VI. Practical

Study of interaction of bacteria with host cells; Estimation of adherence and invasion; Use of erythrocytes to study the interaction of bacteria with host cells; Assay of hemolytic activity; Hemagglutination and its inhibition by mannose, antibodies; Phagocytosis by macrophages and resistance to phagocytosis by pathogens; Assay virulence – LD_{50}; Virulence associated enzyme assay – protease, esterase, chitinase; Specific examples of pathogens: *Edwardsiella tarda* purification of OMPs

VII. Suggested Reading

- Austin B and Austin A. 2007. *Bacterial Fish Pathogens*. Springer Publishers, U.K.
- Bullock LG. 2014. *Diseases of Fishes*. NPH, Delhi
- Chan VL. 2006. *Bacterial Genomes and Infectious Diseases*. Humana Press, New Jersey
- Crosa JH. 1983. *Bacterial and Viral Diseases of Fish*. Washington Sea Grant Publication, Seattle.
- Hadwin G. 2017. *Diseases of Fishes. Bacterial Diseases of Fishes and Identification of Fish Pathogenic Bacteria*. Random Pub., New Delhi.
- Iglewski HB and Clark VL. 1009. *Molecular Basis of Bacterial Pathogenicity*. Academic Press
- Inglis V. 1993. *Bacterial Diseases of Fish*. Blackwell Scientific Publications, London.
- Inglis V *et al*. 2011. *Bacterial Diseases of Fish*. John Wiley and Sons, New Jersey.
- Pohland AE *et al.* (eds). 1990. *Microbial Toxins in Foods and Feeds*. Plenum Press,
- Salyers AA and Whitt DD. 1994. *Bacterial Pathogens – a Molecular Approach*. American Society for Microbiology Press
- Snieszko SF. 1971. *Diseases of Fishes*. Book 2A TFH Publications Inc, Ltd, New Jersey
- Wilson M. 2002. *Bacterial Diseases Mechanisms*. Cambridge University Press, Oxford.
- Woo PTK and Bruno DW. 2011. *Fish Diseases and Disorders* Vol-3. CABI Publishers, U.K.

I. Course title : Pathobiology of Fish Parasitic Infections

II. Course code : AAH 604

III. Credit Hours : 1+1

IV. Aim of the course

To understand the recent advances in the pathobiology of parasitic infection in fish and other aquatic organisms. It also aims at acquiring in-depth knowledge of host-parasite interaction, the role of parasites in ecosystem functioning and parasite evolution.

V. Theory

Unit I

Environmental parasitology: Macro-environmental and micro-environmental influence on parasite incidence; Relevancy of parasites as bio-indicators.

Unit II

Ecological parasitology: Role of parasites in ecosystem functioning; Manipulative parasites; Parasites as ecosystem engineers; Parasites as biological tags; The evolution of parasites; Hyperparasitism; Parasitic adaptation.

Unit III

Molecular parasitology: Host-parasite communication and cell to cell interaction; The interaction between parasites and microbiome; Molecular characterization of parasites; DNA taxonomy and barcoding of parasites.

Unit IV

Immune responses against parasites: Fish immunity and parasitic infection (Immune responses against parasites – monogenean, flagellates, ciliates, myxozoans); Immune evasion strategies of parasites; Parasite vaccines; RNA interference and parasites; Pharmacokinetics of anti-parasitic drugs.

VI. Practical

Isolation and culture of parasites; Molecular characterization and diagnosis of parasites; Use of molecular probes for identification of parasites and tracking life stages of parasites; DNA barcoding of parasites; Parasitic survey of selected fishes (case study).

VII. Suggested Reading

- Baker JR. 2004. *Advances in Parasitology*: Vol-56. Elsevier Publisher, London
- Chandler C. 1961. *Introduction to Parasitology*. John Wiley and Sons, New York
- Cox FEG. 2005. *Parasitology*. Hodder Arnold. U.S.A.
- Dogiel *et al*. 1961 *Parasitology of Fishes*. NP., London
- Garbda J. 1991. *Marine Fish Parasitology*. VCH., Weinheim
- Gupta N. 2014. *Modern Parasitology*. Narendra Publishing House, Delhi
- Klaus, R. 2005. *Marine Parasitology*. CABI Publishing, U.K.
- Lewis EE, Campbell JF and Sukhdeo MVK. 2002. *The Behavioural Ecology of Parasites*. CABI
- Marquardt WC. 2000. *Parasitology Vector Biology*. Academic Press, London.
- Marr JJ. 2003. *Molecular Medical Parasitology*. Academic Press, London.
- Poulin R and Grimes LR. 2007. *Evolutionary Ecology of Parasites*. Princeton University Press.
- Schell S. 1962. *Parasitology*. John Wiley and Sons, New York
- Schmidt GD. 2000. *Foundations of Parasitology*. McMcgraw Hill, New York.
- Sen AB. *Perspectives in Parasitology*. Vol 2. CBS Publishers and Distributors, Delhi

I. Course Title : Immunology and Vaccination of Fish
II. Course Code : AAH 605
III. Credit Hours : 2+1

IV. Aim of the course

To learn the recent advances in fish and shellfish immunology and to understand the concepts of vaccination and the latest trends in fish vaccination

V. Theory

Unit I

Finfish immune mechanisms: Molecular players in mucosal immunity; Major histocompatibility complex; Pattern recognition receptors and immune pathways; Antigen processing and presentation; T-cell activation and differentiation; B-cell activation and differentiation; Classical, alternate, Lectin pathways of complement; Their activation and regulation.

Unit II

Immune evasion: Evasion of the immune response by pathogens; Tumour evasion of the immune response

Unit III

Shellfish immune mechanisms: Immune mechanisms in crustaceans: Prophenoloxidase system; Phagocytosis; Encapsulation; Antimicrobial proteins.

Unit IV

Principles of fish vaccination: General principles of vaccination; Vaccination strategies in aquaculture; Vaccination against bacterial, Viral pathogens and parasites; the influence of environmental parameters on vaccination.

Unit V

Vaccine production and delivery: Types of vaccines, Killed, Live attenuated, Synthetic peptide, Recombinant, Anti-idiotype, DNA and RNAi based vaccines; monovalent and polyvalent vaccines; Nanoparticle-based vaccines; Vaccine production; Quality control; Vaccine composition; Superantigens; Cytokines and therapeutic uses of cytokines; Adjuvants and immunostimulants

Unit VI

Immune gene expression: Immunoglobulin genes; Regulation of immune gene expression; Use of gene-targeted knock-out in immunological research.

VI. Practical

Collection, separation and identification of fish leucocytes; Separation of mononuclear cells; Methods of vaccine preparation Vaccine quality control; Vaccine administration by different routes; Assessment of immune response to vaccination, agglutination test, ELISA, etc; Challenge studies; Designing of RNAi based vaccines; Methods for assessment of the efficacy of vaccines; Examination of hyaline, granular, semi-granular cells of shrimp; NBT assay, phagocytic index, ProPo.

VII. Suggested Reading

- Abbas AK. 1991. *Cellular and Molecular Immunology*. Saunders Publisher, Philadelphia
- Alt FW. 2009. *Advances in Immunology*. Vol. 103. Elsevier Publishers, New York
- Anderson DP. 2003. *Textbook of Fish Immunology*. Narendra Publishing House, Delhi.
- Cooper EL. 1982. *Immunology and Immunization of Fish*. Pergamon Press, New York.
- Davis, BD. *et al.* 1973. *Microbiology* Harper and Row, Publishers, Hagerstown
- Delves PJ. 2017. *Roitts Essential-Immunology*. Wiley Blackwell, UK.
- Delves PJ. 1994. *Cell Immunology*. BIOS Scientific Publishers Limited, Oxford.
- Eales LJ. 2003. *Immunology for Life Scientists*. John Wiley and Sons, U.S.A.
- Elgert KD. 2009. *Immunology*. John wiley and Sons, New York.
- Ellis, AE. 1988. *Fish Vaccination*. Academic Press, London
- Fikrig SM. 1982. *Handbook of Immunology for Students and House Staff*. Verlag Chemic International, Florida

- Folds JD. 1999. *Clinical Immunology*. ASM Press, U.S.A.
- Gaur, RK. 2011. *RNAi Technology*. CRC Press
- Gudding R, Lillehaug A, Midtlyng P J, Brown F. 1997. *Fish Vaccinology*. Karger, Basel
- Gudding R. and Lillehaug, A. 2014. *Fish Vaccination*. Wiley Blackwell, U.K.
- Gupta P. 2008. *Immunology and Microbiology*. Pointer Publishers, Jaipur.
- Herzenberg LA. and Weir DM., 1996. *Immunochemistry and Molecular Immunology* Vol-1. Blackwell Science, Ltd., USA.
- Iwama G and Nakanishi T. 1996. *The Fish Immune System. Organism, Pathogen and Environment*. Academic Press.
- Janis K. 1997. *Immunology*. 3rd Ed. WH Freeman
- Kaufmann SHE. 2005. *Immunology*. ASM Press, Washington
- Lerner KL. 2003. *World of Microbiology and Immunology*: Vol-I (A-L). Thomson Gale, New York.
- Luttmann W. 2006. *Immunology*. Elsevier Publication, London
- Male D. 2006. *Immunology*. Elsevier Publishers, London
- Meyers RA. 2007. *Immunology*. Wiley-VCH Verlag, U.S.A.
- Midtlyng PJ. 2005. *Progress in Fish Vacciniology*. Karger, Basel
- Mishra, V. 2017. *Fish Vaccination*. Delve Pub., New York.
- Mowat N (Ed.) 1999. *Quality Control of Veterinary Vaccines In Developing Countries* (FAO Animal Production And Health). Daya Publishing House.
- Paul WE. 2008. *Fundamental Immunology*. Wolters Kluwer, USA.
- Rabbani SA. 2012. *Development of Edwardsiella tarda* Vaccine Using Outer Membrane Proteins (OMP) in *Labeo rohita*. CIFE, Mumbai.
- Richard C. 2015. *Immunology A Short Course*. Wiley Blackwell, UK.
- Saltzman WM. 2006. *DNA Vaccines Methods and Protocols*. Humana Press, New Jersey
- Sharma DK. 2015. *Immunology*. New India Publishing Agency, New Delhi.
- Stolen JS., 1986. *Fish Immunology*. Elsevier, Amsterdam.
- Swain P, Sahoo PK and Ayyappan S. 2005. *Fish and Shellfish Immunology: An Introduction*. Narendra Publ. House.
- Tizard IR. 2009. *Veterinary Immunology: An Introduction*. Elsevier Publishers, Noida.
- Weir DM *et al*. 1996. *Weir's Handbook of Experimental Immunology*. Vol 1. Blackwell Science, Oxford.

I. Course Title : Cellular Pathology

II. Course Code : AAH-606

III. Credit Hours : 1+1

IV. Aim of the course

To understand the structural and functional changes in cells, tissues and organs and to gain in-depth knowledge of the cellular processes that contribute to the pathogenesis of the disease.

V. Theory

Unit I

Cell structure and function: The cell: types and structure; Parts of a cell; functions and organelles.

Unit II

Basics of cell cycle and regulation: Basics of cell cycle and regulation of cell to cell adhesion and dysregulation during disease; Mechanism of cell injury; Processes during acute and chronic injury.

Unit III

Pathology: Cellular pathological findings; Evaluating disease pathogenesis at the molecular, Cellular and tissue levels with particular reference to the diagnosis of diseases

Unit IV

Cell signalling processes: Introduction to cell signalling processes; Transcriptional and post-translational mechanisms to specific cell-signalling pathways responsible for controlling cell functions such as cell cycle, Cell differentiation, Cell death and Apoptosis.

VI. Practical

Knowledge and understanding of the pathological basis of disease and the use of techniques; Cytopathology; Flow cytometry; Confocal microscopy; Immuno-histochemistry to detect and diagnose diseases; Assays for cell survivability and apoptosis: COMET assay, MTT assay, TUNEL assay, LDH and NR.

VII. Suggested Reading

- Alan Cann. 2005. *Molecular Virology* Academic Press 315 p
- Coleman WB and Tsongalis GJ. 2009. *Molecular Pathology*. Elsevier Publisher, Boston
- Coles EH. 1986. *Veterinary Clinical Pathology*. W B Saunders Co., Philadelphia.
- Cook DJ. 2006. *Cellular Pathology*. Scion Publishers, Oxford.
- Dimmock N Easton A and Leppard K. 2006. *Introduction to Modern Virology*. Sixth edn Blackwell publishing 536 p
- Ellis AE. 1985. *Fish and Shellfish Pathology*. Academic Press, London.
- Ferguson HW. 2006. *Systematic Pathology of Fish*. Scotain Press, London.
- Freshney IR. 2010. *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications*. 6th edition. Wiley-Blackwell, New York.
- Jones TC. 1997. *Veterinary Pathology*. Williams and Wilkins, Philadelphia.
- Killeen AA. 2001. *Molecular Pathology Protocols*. Humana, U.S.A
- Knipe DM, Howley PM, Griffin DE, Lamb RA, Martin MA, Roizman B and Straus SE. 2007. *Fields Virology*. 5th edn. Lippincott Williams and Wilkins
- Lloyd RV. 2004. *Endocrine Pathology*. Humana Press, Totowa.
- Mothersill C and Austin B. 2001. *Aquatic Invertebrate Cell Culture*. Springer-Praxis, Chichester UK. 405 p.
- Perkins FO. 1990. *Pathology in Marine Science*. Academic Press Inc., San Diego.
- Roberts RJ. 2012. *Fish Pathology*. Wiley-Blackwell, Chichester
- Salle AJ. 1961. *Fundamental Principles of Pathology*. MacGraw-Hill Co, New York.
- Stockham SL. 2002. *Fundamentals of Veterinary Clinical Pathology*. Lowa State Press, Lowa

I. Course Title : Aquaculture Medicine

II. Course Code : AAH-607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role, application and impact of aquaculture drugs and chemicals

V. Theory

Unit I

Categorization of aquadrugs: Different chemicals and drugs used in aquaculture and dosages; Categories of aquadrugs: approved, unapproved and conditionally

approved aquaculture drugs, Low regulatory priority aquaculture drugs, Investigational new animal drug exemptions for aquaculture drugs and unapproved drugs

Unit II

Pharmacodynamic agents: Anaesthetics and methods of anaesthetizing fish and shellfish; Breeding induction agents; Sex control agents; The action of different drugs in finfish and shellfish.

Unit III

Medicated feeds: Feed top-dressing; binders and stabilizers; Dose and dosage; Bioaccumulation and toxicity; Use of probiotics and immunostimulants in aquaculture

Unit IV

Development of antimicrobial-resistance: Antibiotics – use and misuse including the development of antibiotic-resistant bacteria; AMR, WHONET and ATLAS; Regulatory bodies: safety regulations at national and international levels.

VI. Practical

Demonstration of anaesthetizing fish; Prophylactic application of aquadrugs; Therapeutic application of aquadrugs; Antibiotic sensitivity test; Estimation of dose; Estimation of antibiotic residues; Detection of gut colonization by probiotic bacteria.

VII. Suggested Reading

- Brown L. 1993. *Aquaculture for Veterinarians*. Oxford Pergamon press 1993. 447p
- Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Press, London
- Herwig N. 1979. *Handbook of Drugs and Chemicals used in the Treatment of Fish Diseases*. Charles C Thomas, Springfield
- Pandey G. 2017. *Fish Pharmacology and Toxicology*. DPH, New Delhi
- Radostits M. 2000. *Veterinary Medicine*. Bookpower Publisher, China
- Singh ISB . 2003. *Aquaculture Medicine*. Cochin University 2003. 336p
- Stockopf MK. 1993. *Fish Medicine*. W.B. Saunders Company, London

I. Course Title : Techniques in Toxicology

II. Course Code : AAH-608

III. Credit Hours : 1+1

IV. Aim of the course

To impart the knowledge of various toxicological methods of drugs used in aquaculture.

V. Theory

Unit I

Principles of toxicological methods: Principles of drug action and assay; regulatory phases of drug development; Dose-response curves and their analysis; Residual effects and withdrawal period of potential drugs.

Unit II

Mechanisms of action of drugs: Toxic indigenous drugs used as antimicrobials and anti-inflammatory agents; Drugs used in chemotherapy their mechanisms of action, Side effects and clinical signs

Unit III

Toxicity tests: Techniques for setting up isolated and intact preparations; Animal toxicity tests for acute, Sub-acute and chronic toxicity; Specific toxicity tests, Immunotoxicity, and carcinotoxicity; Use of cell culture for toxicity assays; Different assays for toxicity testing.

Unit IV

Naturally occurring poisons: Naturally occurring poisons: Mycotoxins, Bacterial toxins, Plant toxins, and animal toxins, Microalgal toxicity; Toxicology of mycotoxins; Types of toxicity and its measurement; Acute, sub-acute or chronic and its manifestations; acute toxicity; Mode of application, Administration, Exposure; *in vitro* tests; Dose-response relationship.

VI. Practical

Measurement of TD_{50}/TC_{50}; Measurement of LD_{50}/LC_{50}; Test for acute, sub-acute and chronic toxicity; Protocols and various specific toxicity tests; Calculation of EC_{50}; Determination of potency ratio, median effective, toxic or lethal doses; Bioassay techniques; Cell culture assay for chemical toxins; Cell culture assay for biological toxins

VII. Suggested Reading

- ASTM Standards on Aquatic Toxicology and Hazard Evaluation. ASTM, Philadelphia 1993.
- Aquatic Toxicology. American Society for Testing and Materials, Philadelphia 1980
- Cockerham LG. 1994. *Basic Environmental Toxicology*. CRC Press, Boca Raton
- Derelanko MJ. 1995. *CRC Handbook of Toxicology*. CRC Press, Boca Raton
- Duffus JH. 1996. *Fundamental Toxicology for Chemists*. The Royal Society of Chemistry, Cambridge.
- Eaton 1976. *Aquatic Toxicology*. American Society for Testing and Materials, Philadelphia
- Finkel AJ. 1983. *Industrial Toxicology*. John Wiley and Sons, London
- Hayes AW. 2008. *Principles and Methods of Toxicology*. CRC Press, U.S.A.
- Heuvel JPV. 1998. *PCR Protocols in Molecular Toxicology*. CRC Press, Boca Raton
- Hoboken NJ. 2010. *A Textbook of Modern Toxicology*. John Wiley and Sons
- Hyde W *et al*. 1977. *Analytical Toxicology Methods Manual*. IOWA State University Press, Ames.
- *Information Resources in Toxicology*. Academic Press, San Diego 2000
- Johnson EM. 1983. *Teratogenesis and Reproductive Toxicology*. Springer-Verlag, Berlin
- Kram DJ. 2001. *Toxicology Testing Handbook*. Marcel Dekker, Inc., New York.
- Malins DC. 1994. *Aquatic Toxicology*. Lewis Publishers, Boca Raton
- Matelev VV. 1971. *Water Toxicology*. Amerind Publishing Co. Pvt. Ltd. New Delhi
- Mayer H. *Aquatic Toxicology and Hazard Evaluation*. America Society for Testing and Concepts Publishing, Philippines
- Metelev VV. 1983. *Water Toxicology*. Amerind Publishing Co Pvt Ltd, New Delhi
- Mothersill C. 2003. *In-vitro Methods in Aquatic Toxicology*. Springer Verlag, UK.
- Niesink RJM. 1996. *Toxicology Principles and Applications*. CRC Press, New York.
- Ostrander GK. *Techniques in Aquatic Toxicology*. Lewis Publishers, New York.
- Pandey BN. 2011. *Fisheries and Fish Toxicology*. A P H Publishing Corporation, New Delhi
- Rand GM. 1985. *Fundamentals of Aquatic Toxicology*. Hemisphere Publishing Corporation, Washington.
- Raychaudhuri SP. 1979. *Environmental Pollution and Toxicology*. Today and Tomorrow's Printers and Publishers, New Delhi
- *The Toxicology of Fishes*. CRC Press, Boca Raton, 2008.
- *Toxicology and Risk Assessment*. Marcel Dekker, Inc., New York, 1996

- Vohora SB. 1999. *Toxicology and Environmental Health*. Department of Medical Elementary and Toxicology, New Delhi
- Ware GW. 1993. *Reviews of Environmental Contamination and Toxicology*. Springer-Verlag, New York.
- Weber LJ. 1982. *Aquatic Toxicology*. Vol 1. Raven Press, New York
- Wells PG. 1998. *Microscale Testing in Aquatic Toxicology*. CRC Press, London 1998.

List of suggested Journals

- *Journal of Fish Diseases*
- *Journal of Fish Pathology*
- *Journal of Immunology and Immunopathology*
- *African Journal of Aquatic Science*
- *American journal of pathology*
- *Applied and Environmental Microbiology*
- *Fish Pathology*
- *Histology and histopathology*
- *Asian Journal of Microbiology, Biotechnology and Environmental Sciences*
- *Cellular Immunology*
- *Clinical and Experimental Immunology*
- *Clinical and Vaccine Immunology*
- *Comparative Immunology Microbiology and Infectious Diseases*
- *Diseases of Aquatic Organisms*
- *Aquaculture research*
- *Fish and Shellfish Immunology*
- *Experimental parasitology*
- *Immunopharmacology and Immunotoxicology*
- *Indian Journal of Animal Health*
- *Indian Journal of Veterinary Pathology*
- *Journal of Aquatic Animal Health*
- *Journal of Clinical Pathology*
- *Journal of Environmental Pathology, Toxicology and Oncology*
- *Tropical Animal Health and Production*
- *Vaccine*
- *Veterinary Clinical Pathology*
- *Veterinary Immunology and Immunopathology*
- *Veterinary Microbiology*
- *Veterinary Pathology*

List of suggested e-Resources

- Aquatic Animal Health Management- FAO
- Biosecurity and Aquatic Animal Health Management
- Aquatic animal health - Network of Aquaculture Centers in Asia-Pacific https://enaca.org
- New vistas in aquatic animal health management http://ciba.res.in/Books
- Aquaculture and aquatic animal health management issues www.oie.int
- Advances in aquatic animal health management https://www.omicsonline.org
- Approaches to managing aquatic animal health in Australia-NCBI https://www.ncbi.nlm.nih.gov
- https://thefishsite.com/articles/health-national-strategies-for-aquatic-animal-health-management
- Journal of fish disease https://onlinelibrary.wiley.com › journal
- Free Classic Pathology Books www.freepsychotherapybooks.org/
- Fish Pathology https://onlinelibrary.wiley.com › doi › book
- Fish Pathology Edition 4 by Ronald J. Roberts https://www.barnesandnoble.com › fish-pathology-ronald-j-roberts

- Fish Vaccines By Alexandra Adams https://www.springer.com › book
- Vaccines for Use in Finfish Aquaculture - Acta Scientific https://www.actascientific.com
- Progress, challenges and opportunities in fish vaccine development. https://www.ncbi.nlm.nih.gov
- A Guide to Bacterial Identification - PREMIER Biosoftwww.premierbiosoft.com › tech_notes › bac-id
- The application of epidemiology in aquatic animal health – NCBI https://www.ncbi.nlm.nih.gov › pmc › articles › PMC3182899
- Maintenance of Fish Health in Aquaculture: Review of Epidemiological Approaches for Prevention and Control of Infectious Disease of Fish https://www.hindawi.com ›
- School on Aquatic Animal Epidemiology and Disease Surveillance https://enaca.org
- Common diagnostic and clinical techniques for fish – NCBI https://www.ncbi.nlm.nih.gov › pubmed
- Fish and Shellfish Immunology: An Introduction - Google Books https://books.google.com › books › about › Fish_and_Shellfish_Immunology
- Fish and Shellfish Immunology: An Introduction www.nphindia.com ›
- Significant and emerging parasitic diseases of finfish https://pdfs.semanticscholar.org ›
- Cellular Pathology Technique | ScienceDirecthttps://www.sciencedirect.com › book › cellular-pathology-technique
- Techniques in Aquatic Toxicology, Volume 2 - CRC Press Book https://www.crcpress.com ›
- Fish models in behavioural toxicology: Automated techniques, updates and perspectives. semanticscholar.org
- Physiological Methods in Fish Toxicology: Laboratory and Field Studies springer.com
- Clinical and Experimental Immunology - Wiley Online Library https://onlinelibrary.wiley.com › journal
- Immunopharmacology and Immunotoxicology https://www.tandfonline.com
- Veterinary Immunology and Immunopathology | ScienceDirect.com https://www.sciencedirect.com

Suggested Broad Areas for Master's and Doctoral Research

- Development of diagnostics for important finfish and shellfish pathogens
- Development of monoclonal antibodies for important finfish and shellfish pathogens
- Development of vaccines for important finfish and shellfish pathogens
- Molecular characterisation of important finfish and shellfish pathogens
- Pathogenesis of finfish and shellfish viruses
- Development of antiviral drugs
- Survival strategies of intracellular and extracellular fish bacterial pathogens
- Molecular mechanism of virulent factors of fish bacterial pathogens
- Microbial management in finfish and shellfish hatchery/nursery and grow-out aquaculture
- Genes involved in the virulence of finfish and shellfish pathogens and regulation of their expression
- Mucosal immunity in finfish and shellfish
- Influence of external factors on finfish and shellfish vaccination
- Development of nanoparticle-based vaccines for finfish and shellfish aquaculture
- Designing and development of RNAi based vaccine.
- Safety and efficacy of aqua drugs/ diagnostics/ vaccines
- Molecular characteristics of finfish and shellfish parasites
- Molecular taxonomy of finfish and shellfish parasites
- Development of management strategies for finfish and shellfish parasitic diseases
- Interaction between finfish and shellfish parasites and microbes
- Immune responses of fish against parasites
- Pharmacokinetics of antibiotics / antiparasitic drugs in fish finfish and shellfish
- Cellular factors that contribute to the pathogenesis of diseases
- Evaluation of disease pathogenesis at the molecular/ cellular/ tissue levels

- Probiotics in finfish and shellfish aquaculture
- Immunostimulants in finfish and shellfish aquaculture
- Impact of AMR bacteria in finfish and shellfish aquaculture
- Residual effect and withdrawal period of potential aquadrugs
- Toxicity related to aquadrugs
- Application of bioinformatics in drug designing
- Application of bioinformatics in aquatic animal health management
- Development of primary cell culture for fish/ shrimp viruses
- Epidemiology, pathogenicity, diagnosis and management of fish/shrimp diseases
- Host-parasite relationship
- Management strategies for fish/ shellfish parasitic diseases
- Pathophysiology of finfish and shellfish diseases
- Immune responses of fish to bacterial/ viral/ fungal/ parasitic infections
- Health management measures in the open water aquaculture system
- Health management measures in recirculatory aquaculture system (RAS)
- Health management measures in biofloc culture system
- Economic loss due to finfish and shellfish diseases in aquaculture
- Surveillance of new and emerging finfish and shellfish diseases
- Management of transboundary aquatic animal diseases
- Risks associated with the import of finfish and shellfish
- Risks associated with the interaction of farmed and wild aquatic animals
- Development of BMP for commercially important aquaculture species
- Finfish and shellfish hatchery diseases and their management
- Non-infectious diseases and disorders in finfish and shellfish and their management
- Nutritional imbalance and disorders in finfish and shellfish and their management
- Nutritional diseases of finfish and shellfish and their management
- Metabolic disorders of cultured finfish and shellfish exposed to pollutants
- Development of alternative therapeutants for aquaculture
- Application of phytotherapy in finfish and shellfish aquaculture
- Potential impacts of chemicals used in aquac ulture on the environment
- Epidemiology and surveillance of aquatic animal diseases
- Aquatic wildlife diseases and their management
- Aquatic invasive species and their impacts in aquaculture and transmission of diseases
- Effect of anthropogenic factors and contaminants on aquatic wildlife health
- Health management issues in game fish and fish ranging
- Impact of global climate change on the health of aquatic animals

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Biotechnology

Preamble
(Fish Biotechnology)

Biotechnology is undoubtedly the most rapidly advancing stream of biology today, and more and more researchers are applying cellular/ molecular approaches to find innovative solutions to myriad concerns and issues related to aquaculture and fisheries. The world today is faced with the challenges of climate change, rising water salinity, aquatic pollution, destruction of natural breeding grounds of aquatic animals, viral and bacterial pathogens, dwindling supply of ingredients for fish feed. In this scenario, India needs to create human resource capable of designing and executing genetic improvement/ germplasm management and conservation programs, all of which rely heavily on an understanding of molecular markers and genetics. Further, biotechnology is applied to management of aquatic environment, fish disease, and nutrition; captive maturation and induced breeding. India needs to diversify and expand the number of cultivated fish and shrimp species and biotechnology is most likely to provide a breakthrough once a critical mass of researchers is created in the country to work in this sector. The world now has its first transgenic fish – AquAdvantage salmon. India's policy is not averse to transgenics for high growth and disease resistance and the country has to still develop capability and human resource in this area. Indian education institutions must move quickly to harness the power of modern tools like genomics, nanotechnology and bioinformatics through trained human resource to achieve rapid advancements in sustainable and profitable fish/shrimp productions systems.

Globally, researchers are turning to new approaches based on molecular biology, biotechnology, genomics and bioinformatics in order to address various issues and concerns related to fisheries and aquaculture. In India, the need for human resource capable of innovative research and teaching is felt acutely in this fast emerging area, particularly as the most rapid advances are being made in this field, and institutions are eager to apply modern tools to keep up with the global standards. In addition, there is plenty scope for start-ups in the area of biotechnology, and hence the current syllabus is designed to encourage students to identify entrepreneurial opportunities and also services required in the national and international biotech industry. For example Biotech entrepreneurs will be required to certify genetically improved fish/ shrimp seed, to certify specific pathogen free seed, to confirm frozen / processed fish and shrimp meat labelling for Indian exports and national consumption, to provide genomics and bioinformatics services; to run disease diagnostic labs. In addition, ICAR, SAUs and international research institutions also need human resource trained in this area to develop new technologies for improvement of domesticated germplasms and conservation of biodiversity to deal with the anticipated challenges of climate change, rising salinity and shortage of freshwater.

Researchers/ Scientists in national and international labs; Assistant Professors in Universities/ Colleges; Private Sector (Research/ Marketing/ Technical Analysts for Biotech, Bioinformatics, Genomics, DNA Sequencing, etc.Companies); Entrepreneurs.

Course Title with Credit Load
M.F.Sc. in Fish Biotechnology

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FBT 501	Fundamentals of Molecular Biology	2+1
FBT 502	Concepts of Cell Biology	2+1
FBT 503	Gene Structure and Regulation of Expression	2+1
FBT 504	Genetic Engineering	2+1
FBT 505	Bioinformatics Tools for Fisheries	1+1
FBT 506	Fish Cell Culture	2+1
FBT 507	Aquaculture Biotechnology	2+1
	Minor Courses (From the subjects closely related to a student's major subject)	**08 Credits**
FBT 508	Marine Biotechnology	1+1
FBT 509	Molecular Markers	2+1
FBT 510	Molecular Taxonomy and Phylogenetics	2+1
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**06 Credits**
	Common Courses (The following courses, one credit each will be offered)	**05 Credits**
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	1 Credit
FBT 591	Master's Seminar	0+1

Course Code	Course Title	Credit Hours
	Masters' Thesis Research	**30 Credits**
FBT 599	Master's Research (III semester)	0+15
FBT 599	Master's Research (IV semester)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fish Biotechnology

I. Course Title : Fundamentals of Molecular Biology
II. Course Code : FBT 501
III. Credit Hours : 2+1

IV. Aim of the course

- To acquaint the students about the structure and organisation of genome.
- To provide knowledge of basic molecular processes involving nucleic acids and protein synthesis and maintenance within a living cell.

V. Theory

Unit I

Structure and properties of genome: Genetic material, Content of the Genome, Structures of DNA and RNA; Stereochemistry of bases and secondary structures; Alternative forms of DNA structure; Organisation of bacterial, viral and eukaryotic genome; Physico-chemical properties of DNA (Tm, Hyper-chromaticity, Kinetic Classes, Buoyant Density etc.).

Unit II

DNA replication: Models of DNA replication in prokaryotes, Eukaryotes and viruses; Molecular events during DNA replication; The Replisome: *E. coli* and eukaryotes; Structure and function of DNA polymerases and types; Importance of Telomere and Telomerase in replication of chromosome termini.

Unit III

Transcription: Transcription in Prokaryotes – Bacterial RNA polymerase, Initiation, elongation and termination; Transcription in Eukaryotes – RNA polymerases and mechanism; Post transcriptional modifications; Structure and synthesis of rRNA and tRNA.

Unit IV

Translation: Genetic code, Codon bias, Types and structures and active centre of ribosomes, tRNA structure, Wobble hypothesis, Mechanisms of translation and post-translational modifications in prokaryotes and eukaryotes and the factors involved in various steps, Concept of polysomes and protein structure.

Unit V

DNA recombination: Homologous and site-specific recombination; Crossing over; Holliday junction; Transposition

Unit VI

Mutations: Types, mutagens. Molecular basis of mutation, Mutations induced by chemicals, radiation, transposable elements; DNA Repair: DNA repair enzymes; Types and mechanisms; Methods for detection of DNA damage.

VI. Practical

Good Laboratory Practices – Biosafety and disposal of hazardous material. Preparation of buffers and reagents. Tissue sampling techniques for isolation of DNA and RNA. Isolation of Genomic DNA by Phenol Chloroform Method. Isolation of Genomic DNA by Salting-out method. Isolation of Genomic DNA by CTAB method. Preparation of Media for cultivation of *E.coli*. Isolation of Plasmid DNA from *E.coli* by alkaline lysis method. Isolation of RNA by TRIzol method. Quality analysis of Nucleic acids by Agarose Gel Electrophoresis. Nucleic acid quantification by spectrophotometer/nanodrop. Protein Purification. Separation of proteins by SDS-PAGE. Separation of proteins by Native PAGE. Detection of mutation by Comet Assay.

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P. 2015. *Molecular Biology of the Cell* (6th edition), New York: Garland Science. 1464 pp.
- Glick RB, Pasternak JJ and Patten CL. 2010. *Molecular Biotechnology: Principles and Applications of Recombinant DNA* (4th edition). ASM Press, WA, USA, 850 pp
- Rodney Boyer. 2005. *Concepts in Biochemistry* (3rd edition). Wiley, NJ, US, 736 pp.
- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. *Lewin's Genes XII*. Jones and Bartlet Publishers, MA, USA 829 pp.
- Lodish H, Berk A, Zipursky LS, Matsudaira P, Baltimore D and James Darnell. 2016. *Molecular Cell Biology* (8th edition). W.H. Freeman and Company Publishers, London, UK, 1280 pp.
- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry* (7th Edition) W.H. Freeman, New York, 1328pp.
- Primrose SB. 1987. *Modern Biotechnology*. Blackwell Scientific Pub., London, UK, 184 pp.
- Watson JD. *et al*. 2017. *Molecular Biology of the Gene* (7 th edition). Pearson Education, London, UK, 912 pp.
- Weaver R. *Molecular Biology*. 2011. McGraw-Hill Education, 912 pp.
- Rastogi, V.B. 2010. *Fundamentals of Molecular Biology*. Ane Books Pvt Ltd, New Delhi, 462pp.
- https://www.ncbi.nlm.nih.gov/books/
- http://bioinfo.ut.ee/primer3-0.4.0/https://all-about-molecular-biology.jimdo.com/
- https://www.molbiolcell.org/
- http://www.web-books.com/MoBio/

I. Course Title : Concepts of Cell Biology

II. Course Code : FBT 502

III. Credit Hours : 2+1

IV. Aim of the course

To outline the basic structure growth and differentiation of prokaryotic and eukaryotic cell To describe the structure and function of biological membranes To discuss the various sub-cellular components and their functions so as to impart an overall understanding of cellular organisation and evolutionary changes

V. Theory

Unit I

Basics of cell biology: Basic concept and evolution of cells, Cells to tissues; Prokaryotic and eukaryotic cell architecture, Cell theory, Diversity of cell size and shape.

Unit II

Organization of cellular organelles: Organization and function of sub-cellular organelles – Cell surface, Cell membrane and types; Cytoplasm; Endoplasmic reticulum; Golgi apparatus; Lysosomes; Mitochondria; Ribosome, Nucleolus; Peroxisomes and Sub-nuclear structures.

Unit III

Membrane transport mechanism: Overview of membrane transport, Active/ passive membrane transport (Case study - Osmoregulation in freshwater and marine fishes) ion channels; carrier proteins.

Unit IV

Cell signalling: Signalling molecules, Cell surface receptors, Secondary messengers and Intracellular signal transduction.

Unit V

Cell division: Cell cycle, Mechanism of cell division, Growth factors; Cell growth and differentiation; Cytoskeletal systems: Microtubules, Microfilaments, and intermediate filaments; Cell motility; Actin-Myosin filaments; Flagella; Cilia; Cell adhesions, Cell junctions and the extra cellular matrix.

Unit VI

Protein sorting: Secretion and targeting; Vesicular traffic; Endocytosis; Exocytosis; Protein translocation and secretary pathways.

VI. Practical

E. coli growth curve. Gram's staining. Bright-field microscopy. Phase contrast microscopy. Fluorescent microscopy. Electron microscopy. Sample preparation for light microscope. Sample preparation for electron microscope. Microtomy. Isolation of organelles. Sub-cellular fractionation. Chromosome preparation. Histochemical techniques

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P. 2015. *Molecular Biology of the Cell* (6th edition), New York: Garland Science. 1464 pp.
- Cooper GM and Robert EH. The Cell: *A Molecular Approach* (6th edition)Hausman, R. E. (2013). Sunderland, Massachusetts: Sinauer Associates. 832 pp.
- Edmund W. 1900. *The Cell in Development and Inheritance* (2nd edition). The Macmillan Company, NY, 396 pp.
- Gartner LP, Hiatt JL and Strum JM. 2011. *Cell Biology and Histology*. Lippincott Williams and Wilkins. 374 pp.
- Gilbert SF and Barresi MJF. 2016. *Developmental Biology* (11th edition). Sunderland; Sianuer Associates Inc Publishers, GIL: 810 pp.
- Lodish H, Berk A, Zipursky LS, Matsudaira P, Baltimore D and James Darnell. 2016. *Molecular Cell Biology* (8th edition). W.H. Freeman and Company Publishers, London, UK, 1280 pp.
- Verma PS. 2004. *Cell Biology, Genetics, Molecular Biology: Evolution and Ecology*. 350 pp.
- ISBN-13: 978-8121924429
- https://www.ncbi.nlm.nih.gov/books/

I. Course Title : Gene Structure And Regulation of Expression

II. Course Code : FBT 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the general principles of gene organization and expression in both prokaryotic and eukaryotic organisms.To explain various levels of gene regulation and to discuss the possibilities of manipulating gene function for the good of mankind in general and fisheries in particular.

V. Theory

Unit I

Gene components: Genes, Types of genes; Gene structure: Promoters, UTRs, ORFs, exons, Introns, Termination signal, Mono- and polycistronic genes, Gene clustering; Overlapping genes (Phi X174 virus).

Unit II

Regulation of gene expression in Prokaryotes: Operon concept: Types of operons, Lactose and tryptophan operons (Lac/Trp), Their structure and mode of regulation; Induction of transcriptional factors by environmental and biological factors (SOS response), Bidirectional promoters.

Unit III

Regulation of gene expression in Eukaryotes: DNA protein interactions (concept of DNA foot printing, EMSA, zinc fingers, leucine zippers, helix turn helix, Z-DNA); Transcription factors, Promoters, Enhancers, Repressors, Insulators, Attenuators, IRES, Alternative splicing.

Unit IV

RNA in gene regulation: Antisense RNA, MicroRNA, Ribozymes, RNA interference. Expression Profiling: Micro array and Real time PCR, RNA seq.

Unit V

Epigenetics: DNA methylation, Genetic imprinting, Histone modifications, Chromatin remodeling.

Unit VI

Mutagenesis: Site-directed mutagenesis and its applications, Transposon induced mutagenesis.

I. Practical

Total RNA extraction. Quality checking of RNA by Agarose Gel Electrophoresis. cDNA synthesis by RT-PCR. Retrieval of Gene information from NCBI/ENSEMBL. BLAST analysis. *In-silico* identification and analysis of promoters, transcription factors and other regulatory elements. Primer designing. Polymerase Chain Reaction. DNA purification from agarose gel. T/A cloning. Screening of recombinant clones by blue white selection. RACE-PCR. Real time PCR for absolute quantification of genes. Real time PCR for relative quantification of genes.

II. Suggested Reading

- Boyer R. 2005. *Concepts in Biochemistry* (3rd Edition). Wiley, NJ, US, 736 pp.
- Cooper GM and Robert EH. *The Cell: A Molecular Approach* (6th edition)Hausman, R. E.

(2013). Sunderland, Massachusetts: Sinauer Associates. 832 pp.
- Gilbert SF and Barresi MJF. 2016. *Developmental Biology* (11th edition). Sunderland; Sianuer Associates Inc Publishers, GIL: 810 pp.
- ISBN-10: 0471661791.Lewin, B. 2005 *Essential Genes*. Benjamin Cummings, 672pp.
- Primrose SB. 1987. *Modern Biotechnology*. Blackwell Scientific Pub., London, UK, 184 pp.
- Rastogi VB. 2010. *Fundamentals of Molecular Biology*. Ane Books Pvt Ltd, New Delhi, 462pp.

I. Course title : Genetic Engineering

II. Course code : FBT 504

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students with the basic concepts in recombinant DNA technology. To acquaint the students to versatile tools and techniques employed in genetic engineering and its application in fisheries and aquaculture.

V. Theory

Unit I

Enzymes used in recombinant DNA technology: DNA modifying enzymes - types of restriction endonucleases (Type I, II and III), Alkaline phosphatases, Kinases, Exonucleases, Ligases, Terminal transferases.

Unit II

Vectors in genetic engineering: Plasmids (replication, copy number control and compatibility), Bacteriophages, Phagemids, Cosmids, M13 vectors, High capacity vectors (eg. BAC, YAC, PAC, HAC), Shuttle vectors; Adapters, linkers, ligation, Transformation and selection.

Unit III

Host organisms: Prokaryotic (selected *E. coli* strains) and Eukaryotic (selected yeast strains).

Unit IV

Principle and applications of PCR: Principle of DNA amplification by PCR and applications, Optimization, Prevention of mispriming; Hot Start, Touchdown, Gradient PCR; T/A cloning of amplified products; Characteristics and types of thermostable DNA polymerases.

Unit V

Cloning strategies: Cloning strategies for prokaryotic and eukaryotic constructs, Promoter systems for high expression in *E. coli*; Cloning for in vitro transcription; Expression optimization and affinity purification strategies for recombinant proteins.

Unit VI

Genomic and cDNA library: Shotgun cloning, Construction in high capacity vectors, Screening, and Applications; Chromosome walking. cDNA library: Construction and screening; and Clone characterization.

VI. Practical

In silico DNA sequence analysis for cloning. Insert and vector preparation. Ligation. Preparation of competent cells. Transformation. Selection of transformed cells.

Primer designing. Clone confirmation by colony PCR. Clone confirmation by Horizontal cell lysis. Southern blotting. Western blotting. Labeled probe preparation by nick translation. Random primer labeling of probe

VII. Suggested Reading

- Brown T. 1998. *Molecular Biology* LabFax, Volume 1: Recombinant DNA (2nd edition). Academic Press, MA, USA. 377 pp.
- Brown TA. 2010. *Gene Cloning and DNA Analysis: An Introduction* (6th edition). Wiley-Blackwell. 320 pp.
- Brown TA. 2017. *Genomes* 4 (4th edition). Garland Science, US, 544 pp.
- Green MR and Sambrook J. 2012. *Molecular Cloning: A Laboratory Manual* (4th edition: Vol 1-3.). Cold Spring Harbor, NY, USA 2028 pp.
- Primrose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics* (7th edition). Blackwell Publishing, Oxford UK., 672 pp
- Reece RJ. *Analysis of Genes and Genomes.* 2004. John Wiley and Sons, UK. 469 pp.

I. Course title : Bioinformatics Tools for Fisheries

II. Course code : FBT 505

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the students with the use of biological databases To provide practical knowledge on DNA and protein sequence retrieval and Phylogenetic analysis using softwares

V. Theory

Unit I

Basics of Bioinformatics: Overview of Bioinformatic resources, and applications. Platforms (Linux and Windows) and available software; Databases: Primary databases: nucleotide sequence databases, Protein sequence databases; Secondary databases; Structure databases; Analysis packages.

Unit II

Sequence Alignment: Dot Matrix, PAM, BLOSSUM Matrix, Sequence retrieval from online database, Simple pairwise alignment (BLAST) and Multiple sequence alignment.

Unit III

Sequence analysis: Retrieval of sequences, Sequence quality, Assembly and annotation of Sanger sequencing reads, Identification of cis acting regulatory elements, ORF finding, signal sequences in DNA and proteins, Data analysis tools for SNP and ESTs.

Unit IV

Phylogeny and evolution: Evolution of genome, Basic force of evolution, Variation and divergence of populations, Estimation of divergence time; Phylogenetic species concept, Phylogenetic trees, Clasdistics, Concept of monophyly, Paraphyly and polyphyly, Phylogenetic reconstruction using distance-based methods (UPGMA, Neighbour-Joining), Phylogenetic reconstruction using character-based methods, Maximum Parsimony, Maximum Likelihood and Bayesian Inferences, Principle, methodology, Tree comparisons and statistical tests, Parametric bootstrapping, interpretation of results and limitations.

VI. Practical

Sequence retrieval from databases. Refining the search criteria by modifying different parameters. Sequence submission to databases (NCBI GenBank/BOLD). Pairwise sequence alignment (BLAST). Multiple sequence alignment by ClustalW. Identification of Open Reading Frame (ORF). Primer designing. Restriction site identification. Plasmid map drawing. Protein structure prediction using softwares. Construction of phylogenetic tree using MEGA/MrBayes/Phylip/PAUP. Analysis of results of phylogenetic tree.

VII. Suggested Reading

- Attwood TK and Parry-Smith DJ. 2001. *Introduction to Bioinformatics*. Benjamin Cummings, SF, USA, 339 pp.
- *Bioinformatics: A biologists' Guide to Biocomputing and the Internet*. Eaton Pub Co, 188 pp
- Choudhuri S. 2014. *Bioinformatics for Beginners: Genes, Genomes, Molecular Evolution, Databases and Analytical Tools*. Elsevier Inc. 225pp.
- Liu Z. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. John Wiley and Sons, 557 pp.
- Mount DW. 2004. *Bioinformatics: Sequence and Genome Analysis*. CSHLP, NY, 692 pp. 4. Brown S. M. (2000)
- Rashidi HH and Buehler LK. 2005. *Bioinformatics Basics: Applications in Biological Science and Medicine* (2nd edition). CRC press, FL, USA, 360 pp.
- Xiong J. 2006. *Essential Bioinformatics*. Cambridge University Press, 339pp.

I. Course Title : Fish Cell Culture

II. Course Code : FBT 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on basic cell and tissue culture techniques To acquaint the students with the applications of fish cell culture

V. Theory

Unit I

Basic of fish cell culture: Introduction, History, Development and importance of fish cell culture; Structure and Organization of animal cells; Biology of cultured cells.

Unit II

Primary Cell culture: Basic requirements for fish cell culture: Equipment, Media and supplements, basic aseptic techniques.

Unit III

Cell culture techniques: Establishment and maintenance of fish cell lines; Organ and histotypic cultures; Scaling-up of cell culture; Applications of fish cell culture /cell lines, Overview of methods used for characterization of primary culture / cell lines

Unit IV

Quality control: Quality control of fish cell lines, Prevention, Assessment of contaminants; Detection and cure of contamination, *In vitro* assays for cytotoxicity and genotoxicity assessment, Stem cells; Stem cell cultures, Embryonic stem cells and their applications; Induced Pluripotent Stem Cells and its applications.

Unit V

Applications of fish cell culture: Hybridoma Technology and its applications in fisheries, Overview of three dimensional culture and tissue engineering.

Unit VI

Cryopreservation: Cryopreservation and storage of fish Cell lines, cell repositories.

VI. Practical

General instructions to be followed in cell culture laboratory. Design and layout of a cell culture laboratory. Preparation of cell culture medium and medium filtration. Preparation of primary cell culture from selected fish tissues. Sub culturing by tripsinisation. Cell counting. Maintenance of fish cell lines. Cryopreservation and revival of cells. Measurement of doubling time. Characterisation of cells using cytogenic and molecular markers. Cytotoxicity assessment. Transfection of fish cells.

VII. Suggested Reading

- Baserga R. 1989. *Cell Growth and Division: A Practical Approach*. Oxford Press, London, UK, 172 pp.
- Butler M and Dawson M. 1992. *Cell Culture Labfax*. Academic Press, MA, USA, 274 pp.
- Clynes M. 1998. *Animal Cell Culture Techniques*. Springer, NY, USA 618 pp.
- Freshney RI. 2016. *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications* (7th edition). Wiley-Blackwell, NJ, USA, 728 pp.
- Goswami M and Lakra WS. 2012. *Fish Cell and Tissue Culture: A Text Book*. Narendra Publishing House.
- Masters JRW. 2000. *Animal Cell Culture-Practical Approach*. Oxford Press, London, UK, 334 pp.

I. Course Title : Aquaculture Biotechnology

II. Course Code : FBT 507

III. Credit Hours : 2+1

IV. Aim of the course

To provide an overview of genetic manipulation techniques for improvement of aquaculture production.

To understand the application of biotechnological tools in fish breeding, feed health, processing and other issues in fisheries.

V. Theory

Unit I

Chromosome manipulation: Ploidy manipulation, Sex reversal, Androgenesis, Gynogenesis and applications, Transgenesis in fish: Methods of gene transfer in fishes, Screening, Applications of transgenic fishes, GMOs: Biosafety regulations, ethics and IPR.

Unit II

Molecular markers for aquaculture: Sources and significance of genetic variation, Biochemical and molecular markers, Development and applications of Allozymes, mtDNA markers, RFLP, RAPD, AFLP, Minisatellites, Microsatellites and SNPs; DNA barcoding of fishes, FISH-BOL.

Unit III

Reproductive biotechnology: Overview of broodstock management and seed production, Induced breeding hormones and analogues; Seed certification through molecular techniques; Applications of nanotechnology in fish breeding.

Unit IV

Microalgae culture methods: Indoor, Mass culture, Raceway system; Enrichment of micro algae with micronutrients; Fuel production from microalgae using biotechnological approaches; Pharmaceutical products from microalgae; Macroalage cultivation and propagation.

Unit V

Biotechnological tools in aquatic animal health management: Concept and techniques for the production of SPF and SPR stocks in crustacean aquaculture; Disease diagnostic techniques(PCR, RT-PCR, LAMP) and therapeutics – DNA vaccines and RNAi vaccines.

Unit VI

Biotechnological tools in fish nutrition: Probiotics, and its role in aquaculture; Microbial flocs as feed for aquatic animals; Biofilms, Biofloc, Single cell protein, Bio-encapsulated feeds; Detection of contaminants in fish feed by biotechnology tools; Nutraceuticals, Nutrigenomics.

VI. Practical

Fish Chromosomal manipulation – Androgenesis, Gynogenesis, Triploidy. Allozyme variation by PAGE, Gel imaging and scoring. RAPD and interpretation of results. PCR-RFLP and interpretation of results. AFLP and interpretation of results. Development and validation of microsatellite marker. Disease diagnosis of shrimp/ fish seeds using PCR/RT-PCR. Synthesis and characterisation of nanoparticles. Delivery of nanoparticle conjugated hormones/drugs to fish. Isolation and screening of probiotic bacteria isolated from fish. Identification and culture of spirulina. Culture of live food organisms (Artemia/Rotifer/Moina). Different methods of gene transfer. Development of biofloc.

VII. Suggested Reading

- Liu Z. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. John Wiley and Sons, 557 pp.
- Liu ZJ. 2007. *Aquaculture Genome Technologies*. Wiley-Blackwell, 584 pp.
- Dunham RA. 2004. *Aquaculture and Fisheries Biotechnology: Genetic Approaches*. CABI Publishing, Cambridge, USA. 385 pp.
- Borowitzka MA and Borowitzka LJ. 1988. *Micro-algal Biotechnology*. Cambridge University Press, London, UK, 488 pp.
- Chen F and Jiang Y. 2001. *Algae and their Biotechnological Potential*. Springer Netherlands, 306 pp.
- Gordon R and Seckbach J. 2012. *The Science of Algal Fuels*. Springer Netherlands, 506 pp.
- Lakra. W.S 2004. *Fisheries Biotechnology*. Narendra Publishing House, New Delhi, 240 pp.

I. Course Title : Marine Biotechnology

II. Course Code : FBT 508

III. Credit Hours : (1+1)

IV. Aim of the course

To know and to understand the essential facts and concepts related to marine

biotechnology. To give the students an overview of the potential marine resources and their uses.

V. Theory

Unit I

Marine bioresources: Historical background, Overview of the present status of marine biotechnology, Commercially important and potential species, Micro and macro-algae, Their culture and application in aquaculture.

Unit II

Bio-prospecting: Bio-prospecting of genes and allele mining for novel compounds, Methods of bio-prospecting from marine environment; Marine derived pharmaceuticals; Marine bio-resources, Secondary metabolites, Marine proteins and lipids; Marine actinobacterial metabolites, Potential bioactive compounds from soft and hard corals, Marine sponges etc., Marine biotoxins and their pharmacological potential.

Unit III

Marine Enzymes and Polysaccharides: Biotechnological application of Marine Enzymes- amylase, Protease, Lipase, Cellulases and Chitinase from micro algae, bacteria, fungi, actinomycetes, Marine Polysaccharides- alginic acid, agar, Fucoidan and carrageenan from marine seaweeds.

Unit IV

Environmental Biotechnology: Bio-film, Biofuel, Bio-remediation, Phytoremediation; Genetically engineered microbes for marine pollution control, Biofouling and prevention, Antifouling properties of marine organisms (algae, seagrass, marine microbes); Metagenomics; Concepts and applications.

VI. Practical

Identification of microalgae. Isolation and culture of microalgae. Identification of seaweeds. Micro-propagation of seaweeds. Isolation and culture of planktons. Isolation of aerobic microbes from sea. Isolation of anaerobic microbes from sea. Extraction of bioactive compounds from seaweeds. Extraction of bioactive compounds from microalgae. Extraction of bioactive compounds from sponges. Screening of bioactive compounds.

VII. Suggested Reading

- Fusetani N. 2000. *Drugs from the Sea*. Karger Publisher, Switzerland, 158 pp.;
- Karl DM. 1995. *Microbiology of Deep-Sea Hydrothermal Vents*. CRC Press FL, USA, 299 pp.;
- Kim S. 2015. *Springer Handbook of Marine Biotechnology*. Springer, 1517 pp.
- Omum S. 1992. *The Search for Bioactive Compounds from Microorganisms*. Springer-Verlag New York, 336 pp.

I. Course title : Molecular Markers

II. Course code : FBT 509

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with techniques used to estimate genetic variation among

individuals and populations for applications in selective breeding and conservation.

V. Theory

Unit I

Genetic variation: Sources and significance of genetic variation; Statistical methods to estimate genetic variation.

Unit II

Biochemical and molecular markers: Type I and Type II markers; Development and applications of Allozymes, mtDNA markers, RFLP, RAPD, AFLP, Minisatellites, Microsatellites and SNPs.

Unit III

Sequencing technologies and applications: Chemical sequencing, Chain termination and NGS.

Unit IV

Genome and transcriptomic sequencing: Whole genome (Nuclear and Mitochondrial) and transcriptome sequencing and their applications.

Unit V

Marker Assisted Selection (MAS): Overview of linkage maps; FISH, QTL and genomic selection, Population genomics and applications.

Unit VI

Application of Molecular Markers in Taxonomy: DNA Barcoding; Metabarcoding.

VI. Practical

Allozyme variation by PAGE. Gel imaging and scoring of allozyme. RAPD. Interpretation of RAPD Gel and data analysis. PCR-RFLP. Interpretation of PCR-RFLP Gel and data analysis. AFLP. Interpretation of AFLP Gel and data analysis. Development and validation of microsatellite marker. Genotyping of SSR markers. Genotyping of SNPs.

VII. Suggested Reading

- Liu ZJ. 2007. *Aquaculture Genome Technologies*. Blackwell Publishing Ltd. pp.551.
- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, pp.606.
- MacKenzie S and Jentoft S. 2016. *Genomics in Aquaculture*. Academic Press. pp. 304.

I. Course Title : Molecular Taxonomy and Phylogenetics

II. Course Code : FBT 510

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with techniques used to delimit species using DNA / Protein sequence data for application in molecular taxonomy and conservation.

V. Theory

Unit I

Molecular Basis of Evolution: Overview of genome structure; Sources of genetic

variation (Recombination, Mutations, Indels, Gene duplication); fast and slow-evolving sequences; Homologous, Paralogous and Orthologous genes, Concept of Neutral theory of molecular evolution.

Unit II

Evolution and Speciation: Allopatric, Sympatric and Parapatric speciation, Factors responsible for speciation Phylogenetic species concept, Phylogenetic trees, Concept of monophyly, paraphyly and polyphyly, Species delimitation, Gene trees and species trees DNA barcoding and concept, BOLD SYSTEMs and WORMS; Principle, Methodology, Application and limitations.

Unit III

Genetic distance measures: Observed and expected distances, Pair-wise distances, inter and intra specific distances;

Unit IV

Concepts in phylogeny: Phylogenetic species concept, Phylogenetic trees, Concept of monophyly, Paraphyly and polyphyly.

Unit V

Phylogenetic tree construction: Phylogenetic reconstruction using distance-based methods (UPGMA, Neighbour-Joining), Principle, Methodology, Interpretation of results and limitations.

Unit VI

Phylogenetic analyses: Phylogenetic reconstruction using character, Based methods, Maximum Parsimony, Maximum Likelihood and Bayesian Inferences, Mesquites, Genepops, Phylogenetic tree importances.

VI. Practical

DNA sequence analysis. Genomic databases. Genbank search and dataset download. Blast tools. EMBOSS tools. Sequence alignment, and editing, Data partition, Selection of the best substitution model. Use of Neighbour-Joining, Maximum Likelihood and Bayesian inference. Re-analysis and interpretation of reference data. Bioinformatic tools (MEGA, Phylip, PAUP, Mr Bayes and Fig Tree) for phylogenetic tree reconstruction.

VII. Suggested Reading

- Hall BG. 2011. *Phylogenetic Trees Made Easy: A How-To Manual* (4theds). Sinauer Associates is an imprint of Oxford University Press.
- Liu ZJ. 2007. *Aquaculture Genome Technologies.* Blackwell Publishing Ltd. pp.551.
- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, pp.606.MacKenzie, S and Jentoft, S. 2016. *Genomics in Aquaculture*. Academic Press. pp.304.
- Xiong J. 2006. *Essential Bioinformatics*. Cambridge University Press, pp.339.

Course Title with Credit Load
Ph.D. in Fish Biotechnology

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FBT 601	Genetic Engineering of Bacteria and Viruses	2+1
FBT 602	Genetic Engineering of Higher Eukaryotes	2+1
FBT 603	Functional Genomics	2+1
FBT 604	Genome Markers in Aquaculture	2+1
	Minor Courses	**06 Credits**
	(From the subjects closely related to a students major subject)	
FBT 605	Biotechnological Applications in Aquaculture	2+0
FBT 606	Nano Biotechnology	1+1
FBT 607	Bioprocess Technology	2+0
	Supporting Courses	**05 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Seminars	**2 Credits**
FBT 691	Doctoral Seminar-I	0+1
FBT 692	Doctoral Seminar-II	0+1
	Research	**75 Credits**
FBT 699	Doctoral Research (II semester)	0+15
FBT 699	Doctoral Research (III semester)	0+15
FBT 699	Doctoral Research (IV semester)	0+15
FBT 699	Doctoral Research (V semester)	0+15
FBT 699	Doctoral Research (VI semester)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fish Biotechnology

I. Course Title : Genetic Engineering of Bacteria and Viruses

II. Course Code : FBT 601

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various techniques available to produce genetically engineered microbes and their application, design of viral vectors for efficient gene delivery.

V. Theory

Unit I

Genetic engineering of bacteria: Recombinant protein expression in Bacteria, Optimization of expression; Fusion proteins, Purification of recombinant proteins – inclusion bodies, Extracellular targeting, Engineering of signal sequences, Electroporation.

Unit II

Molecular biology of fish DNA/RNA viruses: Major groups of DNA/RNA viruses; Their Cis acting genetic elements and Regulation of protein expression.

Unit III

Genetic engineering of virus: Use of animal viruses like vaccinia, Herpes, Retrovirus, Baculovirus and Adenovirus as cloning vectors, Design of viral vectors – Special features, Cis acting regulatory elements; Strategies to optimize recombinant protein production.

Unit IV

Vectors: Pros and cons of using viral vectors as gene delivery vehicles; Vectors based on bacteriophage lambda, P1 and M13, special features and their application in optimizing recombinant protein production.

Unit V

Scope and application of genetic engineering in virus: Efficient gene delivery strategies, Host-pathogen interaction, Antigenic proteins, Vaccination approaches, DNA vaccines, Diagnostics; non-antibiotic selectable markers for live vaccines and gene therapy, Methods for detection of viral infection, Estimation of viral load by Real Time PCR, etc.

Unit VI

IPR issues in Biotechnology: Patent laws; Global scenario of genetically modified organisms, Intellectual Property Rights (IPR), Patent laws at institutional, national and international level.

VI. Practical

Transformation of bacteria by electroporation, Southern and dot-blot transfer techniques; Restriction mapping of DNA; labelling of DNA probes; PAGE analysis for recombinant proteins. Preparation of primary and secondary monolayer cell culture, use of cell culture in virus cultivation and assay; Viral DNA isolation and restriction analysis; Culture and maintenance of bacteriophages; qRT-PCR. Bacterial mass culture through fermentation technique.

VII. Suggested Reading

- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. *Lewin's Genes XII.*
- Jones and Bartlet Publishers, MA, USA 829 pp. ISBN-10: 1284104494.
- Rodney Boyer. 2005. *Concepts in Biochemistry* (3rd Edition). Wiley, NJ, US, 736 pp. ISBN-10: 0471661791.
- Green MR and Sambrook J. 2012. *Molecular Cloning: A Laboratory Manual* (4th edition: Vol 1-3.). *Cold Spring Harbor*, NY, USA 2028 pp.
- Brown TA. 2017. *Genomes 4* (4th edition). Garland Science, US, 544 pp.

I. Course Title : Genetic Engineering of Higher Eukaryotes

II. Course Code : FBT 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide in-depth knowledge on the techniques available for genetic engineering of higher eukaryotes To describe strategies to optimize recombinant protein production in eukaryotic expression systems

V. Theory

Unit I

Eukaryotic expression systems: Overview of recombinant DNA technology and applications in fisheries and aquaculture, Eukaryotic expression systems; Yeast expression system – Host strains, Special features, Types of vectors (yeast episomal vectors, Integrating vectors and YACs), Yeast two hybrid system.

Unit II

Insect cell expression system: Cell expression system- Special features, Types, baculoviral expression vectors, Polyhedron promoters.

Unit III

Mammalian cell expression system: Special features, Selectable markers; Transfection: Principle, types, Selection; Transduction by viral vectors, Construct design (strong and constitutive promoters, inclusion of introns).

Unit IV

Fish cell expression system: Tissue specific promoters, Constitutive promoters and applications, Strategies for optimizing recombinant gene protein expression in eukaryotic systems; Downstream processing of recombinant proteins.

Unit V

Fish as a model organism: Gene function analysis – Gene knockouts, RNAi, etc; Site directed and transposon mediated mutagenesis, CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) knockdown technology.

Unit VI

Transgenesis: Methods of gene transfer, Integration and detection techniques, *In situ* hybridization; Strategies for gene targeting (homologous sites/cre-lox recombination system) Biosafety regulation, Case studies: AquAdvantageTM salmon and GLoFishTM; fish as bio-factories.

VI. Practical

Gene transfer experiments (electroporation, microinjection). Western blotting for confirming integration and expression of transgene. Southern blotting for confirming integration and expression of transgene. Inverse PCR - Partial RE digestion, designing of primers and interpretation of results. Construction of cDNA library. Screening of cDNA library: Probe designing. Screening of cDNA library using colony hybridization. *in-silico* designing of guide RNA for CRISPR vector.

VII. Suggested Reading

- Boyer R. 2005. *Concepts in Biochemistry* (3rd Edition). Wiley, NJ, US, 736 pp.
- Brown TA. 2010. *Gene Cloning and DNA Analysis: An Introduction* (6th edition). Wiley-Blackwell. 320 pp.
- Brown TA. 2017. *Genomes 4* (4th edition). Garland Science, US, 544 pp.
- Fernandez JM and Hoeffler JP. 1999. *Gene Expression Systems: Using Nature for the Art of Expression*. Academic Press, 480 pp.
- Green MR and Sambrook J. 2012. *Molecular Cloning: A Laboratory Manual* (4th edition: Vol 1-3.), Cold Spring Harbor, NY, USA 2028 pp.
- Hacker and David L. 2018. *Recombinant Protein Expression in Mammalian Cells: Methods and Protocols*.
- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. *Lewin's Genes XII* Jones and Bartlet Publishers, MA, USA 829 pp.
- Wang Y, Zhao S, Bai L, Fan J and Liu E. 2013. *Expression Systems and Species Used for Transgenic Animal Bioreactors*. *Biomed Research International,* 2013.

I. Course Title : Functional Genomics

II. Course Code : FBT 603

III. Credit Hours : 2+1

IV. Aim of the course

To give an introduction to application of modern techniques for functional genome analysis

V. Theory

Unit I

Basics of functional genomics: Genome size estimation; High throughput sequencing platforms for whole genome sequencing; Principles, applications, limitations, Data analysis; Gap filling and linkage groups; Gene annotation; Genome mining for various applications.

Unit II

Transcriptomics: Transcriptome sequencing by RNAseq and NGS, Data analysis, sequence assembly, Annotation, Gene ontology assignment, KEGG pathway analysis.

Unit III

Non-coding RNA: Structure, Processing and analysis of miRNA and Long noncoding RNA.

Unit IV

Global gene expression analysis: DNA Microarray, Subtractive hybridization and differential display for the identification of differentially expressed genes, Identifying candidate genes for various traits of fish species.

Unit V

Proteomics and metabolomics: Overview of proteomics and metabolomics, Bioinformatics tools used in proteomics; Protein databases and interfaces; Principles and Applications of metabolomics and system biology.

Unit VI

Functional genomics in aquaculture: Genomic resources in aquaculture species, Gene expression pattern during fish larvae development, Genomic responses to stress challenges in fish, Functional genomics in fish/shrimp disease control.

VI. Practical

Processing of high throughput sequence data for assembling contigs. Gene annotation and pathway analysis. Mining of transcriptome data for protein coding genes, differentially expressed genes. Mining of data for short and long non coding RNA and their target genes. Ensembl genome browser. DNA microarray. Software for allele mining. Ontology and identification of metabolic pathways. Investigation of aquatic animal pathogens using DNA microarray.

VII. Suggested Reading

- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, 606 pp.
- Overturf K. 2009. *Molecular Research in Aquaculture*. Blackwell Publishing, 395 pp.
- Peruski LF and Peruski AH. 1997. *The Internet and New Biology: Tools for Genomic and Molecular Research*. ASM press, WA, USA, 350 pp.
- Saroglia M and Liu Z.J. 2012. *Functional Genomics in Aquaculture*. John Wiley and Sons, 416 pp.
- Schlena M. 1999. *DNA Microarrays: A Practical Approach,* Oxford University Press, London, UK, 232 pp.;
- Stephen H and Livesey F. 2000. *Functional Genomics: A Practical Approach*, Oxford University Press, London, UK, 272 pp.

I. Course Title : Genome Markers in Aquaculture

II. Course Code : FBT 604

III. Credit Hours : 2+1

IV. Aim of the course

To learn development and application of genomic tools in aquaculture species

V. Theory

Unit I

Molecular markers: Molecular markers in aquaculture (Microsatellites, AFLP, SNPs etc.), and their application; Transcriptome associated markers - Type I markers.

Unit II

Genetic analysis using DNA markers: SNPs: Discovery, Array development, genotyping and Data analysis and applications.

Unit III

DNA marker maps: Radiation hybrid mapping and integrated maps, Genome analysis; Preparation of ordered cosmid libraries, BAC libraries, Shotgun libraries: Construction and characterisation.

Unit IV

DNA sequencing technologies: Conventional and automated sequencing, Metagenomics, NGS platforms – Principles and applications.

Unit V

Case studies: Genotype based sequencing, Case studies of linkage maps (Rohu, Tilapia, European seabass, Channel catfish, *Litopenaeusvannamei*).

Unit VI

Applications: QTL and Maker assisted selection in aquaculture species, Genomic selection in aquaculture breeding programmes, DNA chips, phenomics and association studies.

VI. Practical

Microsattelite development and validation. AFLP and data analysis. Construction of genomic library. Screening of library by colony hybridization. Screening of library by probe labelling techniques. Software related to linkage mapping. SNP discovery and analysis.

VII. Suggested Reading

- Avise JC. 1994. *Molecular Markers, Natural History and Evolution*, Springer, US, 516 pp.
- Caetano-anolles G and Gresshoff PM. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH, NY: 364 pp.
- Liu ZJ. 2017. *Bioinformatics in Aquaculture: Principles and Methods*. Wiley-Blackwell, 606 pp.
- MacKenzie S and Jentoft S. 2016. *Genomics in Aquaculture*. Academic Press, 304 pp.
- Overturf K. 2009. *Molecular Research in Aquaculture*. Blackwell Publishing, 395 pp.

I. Course title : Biotechnological Applications in Aquaculture

II. Course code : FBT 605

III. Credit Hours : 2+0

IV. Aim of the course

To acquire knowledge on the latest development in aquaculture biotechnology

V. Theory

Unit I

Reproductive biotechnology: Gonadal steroids, Endocrine control of oogenesis and spermatogenesis, Pituitary and gonadotropins; Fish recombinant gonadotropins – Structure, Synthesis, Evolution, Regulation of gonadotropins and promoters; Pheromones – Types, Evolution, Role in breeding and population management.

Unit II

Neofemale technology: Differential growth pattern in prawns, Androgenic gland ablation, Mating design, Advantages and challenges; Artificial insemination in crustaceans – Definition, Types of thelycum, Insemination methods, Purpose and difficulties.

Unit III

Surrogate broodstock technology: Mechanism of gonad development, Germ cell transplantation (GCT), Primordial germ cells (PGCs), Spermatogonial stem cells (SSCs), GCs transplantation techniques for various developmental stages of fishes; Problems and Future developments.

Unit IV

Biosecurity and Bioremediation: Specific Pathogen Free (SPF) shrimp, Quarantine, Mating design, Nucleus Breeding Centre (NBC), Broodstock Multiplication Centre (BMC) and advantages of SPF stocks; Biosecurity in SPF shrimp hatcheries, Biotechnological approaches for fish pond management through bioremediation; Meta barcoding and its application in aquaculture.

Unit V

Nutrigenomics: Nutrient-gene interactions; Nutraceuticals; Nanotechnology for nutrient delivery in fish; Biotechnologically improved plant protein feed ingredients to replace fish meal in aqua feed.

Unit VI

Seaweed micropropagation: Methods of seaweed cultivation, Propagation methods (Vegetative and Reproduction), Clonal propagation and selection of strains with superior traits; Seaweed tissue and callus culture; Growth regulators and callus induction; Production of micropropagules from callus culture; Cell suspension cultures from seaweed callus; Bioprocess engineering of tissue culture of seaweeds and future prospects.

VI. Suggested Reading

- Allan G and Burnell G. 2013. *Advances in Aquaculture Hatchery Technology*. Woodhead Publishing. 625pp.
- Alday-Sanz, Brock J, Flegel TW, McIntosh RW, Bondad-Reantaso MG, Salazar M and Subasinghe R. 2018. *Facts, Truths and Myths about SPF Shrimp in Aquaculture*. *Reviews in Aquaculture*.
- Bernier N, Kraak GVD, Farrell AP and Brauner CJ. 2009. *Fish Physiology: Fish Neuroendocrinology*. Elsevier. 529 pp.
- Jena AK, Biswas P and Saha H. 2017. *Advanced Farming Systems in Aquaculture: Strategies to Enhance the Production*. Innovative Farming, 2(1): 84-89.
- Mishra SP. 2015. *Plant Tissue Culture*. Ane's student edition. 2nd Edition. 288pp.
- Reddy CRK, Jha B, Fujita Y and Ohno M. 2008. *Seaweed Micropropagation Techniques and their Potentials: An Overview*. *Journal of Applied Phycology* 20(5): 159-167.
- Thomas PC, Rath SC and Mahapatra KD. 2017. *Breeding and Seed Production of Finfish and Shellfish*. DayaPublsihing house. 402.
- Yanong RPE and Erlacher-Reid C. 2012. *Biosecurity in Aquaculture,* Part 1: An Overview. SRAC Publication No. 4707.

I. Course Yitle : Nano Biotechnology

II. Course Code : FBT 606

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint students with the practical knowledge on synthesis and characterisation of nanoparticles.

To explain the importance and applications of nano-biotechnology in fisheries and aquaculture.

V. Theory

Unit I

Introduction to nano biotechnology: Overview of nanoscale materials and nanostructures, Applications in fisheries and aquaculture.

Unit II

Synthesis of different types of nanomaterials: Chemical, Physical and Biological methods, Functionalization of nanoparticles for biological applications.

Unit III

Characterization of nanostructures: Scanning probe microscopy; Electron microscopy; NMR; AFM.

Unit IV

Applications: Biomolecules as nanostructures and their application in nanotechnology viz., Biosensor, Separation of cell and cell organelles, Gene therapy and chromosome/genome mapping, Nanoparticle based genotyping, Nano delivery of bio molecules, Nano-fertilizers, Nanotechnology in Packaging, Nanobarcode Technology, Biobarcode Assay; Nanotoxicity; Environmental behaviour of nanoparticles, Green nanotechnology, Ethical and IPR Issues in Nanotechnology.

VI. Practical

Chemical synthesis of nanoparticles. Green synthesis of nanoparticles. Characterization of nanoparticles by zetasizer. Characterization of nanoparticles by SEM. Nano-conjugation of DNA/protein. Confirmation of nano-conjugation by gel retardation assay. Nanodelivery of various biomolecules. Toxicity assessment of nanoparticles. Patent search on nanotechnology. Field trip to Nanotechnology institutes/labs.

VII. Suggested Reading

- Booker R and Boysen E. 2005. *Nanotechnology*, John Wiley and sons, 371 pp.
- Niemeyer CM and Mirkin CA. 2004. *Nanobiotechnology: Concepts, Applications and Perspectives*, Wiley VCH, Weinheim, 468pp.
- Pradeep T. 2007. NANO: *The Essentials: Understanding Nanoscience and Nanotechnology* McGraw Hill Education, New Delhi.
- Kulkarni, S.K. 2015. *Nanotechnology Principles and Practices*, 379 pp.

I. Course Title : Bioprocess Technology

II. Course Code : FBT 607

III. Credit Hours : (2+0)

IV. Aim of the course

To learn the techniques for bulk processing, production and purification of biologicals.

V. Theory

Unit I

Bioprocessing: Raw materials for bioprocessing, Comparison of chemical and Biochemical processing based on energetics and Environmental issues.

Unit II

Bioprocessing requirements: Development of inocula, Kinetics of enzymatic and

Microbial processes, Optimisation studies, Sterilization of media, Air and equipment, Modes of cell cultivation.

Unit III

Bioreactors: General principles of bioreactor design and their operation, Downstream processing, Separation and Purification techniques, Quality assurance testing; Representative examples of microbial products, Vaccines and vaccine development.

Unit IV

Methods in processing: Immobilization of cells and enzymes: Principles, Methodology and applications, Disintegration of cells, Separation of solid and liquid phases.

Unit V

Isolation and purification: Isolation and purification techniques for proteins and other products based on different physico-chemical properties, e.g., precipitation, adsorption, chromatographic separations, bio-affinity based methods

Unit VI

Post-processing: Principles of bioprocess control, bioprocess automation and Application of computers in bioprocessing, Recombinant products with representative examples.

VI. Suggested Reading

- Ratlidge C and Kristiansen B. 2006. *Basic Biotechnology*. Cambridge University Press, Cambridge, UK, 679 pp.
- Renneberg R. *et al*. 2017. *Biotechnology for Beginners*. Academic Press, MA, USA, 464 pp.
- Waites MJ *et al*. 2001. *Industrial Microbiology: An Introduction*. Wiley-Blackwell, NJ, USA, 304 pp.

List of suggested Journals

- *Molecular Biology Reports*
- *Mitochondrial DNA (DNA sequence)*
- *Gene*
- *Genomics*
- *Nature biotechnology*
- *BMC biotechnology*
- *Biotechnology letters*
- *Biotechnology and bioprocess engineering*
- *Molecular Ecology Resources (Molecular Ecology Notes)*
- *Molecular genetics and genomics*
- *Indian Journal of Biotechnology*
- *BMC genomics*
- *Current Science*
- *Biochemical Genetics*
- *PloS One*
- *Animal Biotechnology*
- *Biotechnology Journal*
- *Biotechnology and Applied Biochemistry*
- *Biotechnology and Genetic Engineering Reviews*
- *Food Technology and Biotechnology*
- *Molecular Biotechnology*
- *Biomed research international*

- *Genomics, proteomics and bioinformatics*
- *Genes and Genomics*
- *International Journal of Molecular Sciences*
- *Biotechnology Advances*
- *Computational and Structural Biotechnology Journal*
- *Applied Microbiology and Biotechnology*
- *Frontiers in Bioengineering and Biotechnology*
- *Current Trends in Biotechnology and Pharmacy*
- *Journal of Molecular Biology*
- *International Journal of Biological Macromolecules*
- *Molecular and Cellular Proteomics*
- *Journal of Cell and Molecular Biology*
- *Microbiology and Molecular Biology Reviews*
- Science Magazines: Scientific American, U.S.A.; New Scientist, U.K.; Everyman's Science (Indian Science Congress Association), etc.

List of suggested e-Resources

- https://www.ncbi.nlm.nih.gov/
- https://www.ebi.ac.uk/
- https://www.ebi.ac.uk/Tools/msa/clustalo/
- https://swissmodel.expasy.org/
- https://www.expasy.org/
- https://www.web-books.com/MoBio/
- http://cellbiol.com/
- https://www.edx.org/learn/molecular-biology
- https://www.icgeb.org/resources/library/
- http://www.biology4kids.com/files/cell_main.html
- https://www2.le.ac.uk/projects/vgec/highereducation/
- https://www.ncbi.nlm.nih.gov/tools/primer-blast/
- http://bioinfo.ut.ee/primer3-0.4.0/
- https://all-about-molecular-biology.jimdo.com/
- https://www.molbiolcell.org/
- http://www.web-books.com/MoBio/
- https://npsa-prabi.ibcp.fr/cgi-bin/npsa_automat.pl?page=/NPSA/npsa_sopma.html
- http://www.bioinformatics.nl/cgi-bin/primer3plus/primer3plus.cgi
- https://www.sciencedaily.com/terms/molecular_biology.htm
- https://plato.stanford.edu/entries/molecular-biology/#toc
- https://molbiol-tools.ca/Alignments.htm
- https://molbiol-tools.ca/Phylogeny.htm
- http://evolution.genetics.washington.edu/phylip/software.html
- https://www.addgene.org/

Suggested Broad Areas for Masters and Doctoral Research

- DNA marker development for species/hybrid identification, stock characterization, MAS/ genomic selection, etc.
- Cytogenetics: genotoxicity assessment; FISH for DNA marker localization
- Molecular interventions for captive maturation and induced breeding
- Chromosome manipulation: androgenesis, gynogenesis and triploidy, monosex populations
- Development of molecular diagnostics and vaccines
- Nanotechnology: Nanoparticle synthesis, functional derivatization for delivery of bio-active molecules, toxicity assessment and mitigation
- Genomics/transcriptomics/proteomics: high-throughput data for mining novel genes and markers for various applications including climate/environment resilient traits
- Cell line tissue culture/ stem cells for various applications

- Transgenesis/gene editing for trait improvement, producing mutants/ model organisms for drug screening
- Epigenetics: Mechanisms and gene expression modulation for various applications
- Cryopreservation for germplasm conservation
- Bio-prospecting of marine organisms for drug development
- Computational approaches in fish genomics and drug designing

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Processing Technology

Preamble
(Fish Processing Technology)

The syllabi for postgraduate programmes in Fish Processing Technology (M.F.Sc., and Ph.D.) were revised with the prime objective of coping up with the developments that have taken place in the field of fish processing sub-sector at national and international levels in recent years and to suit with the developments that would take place in the next five years. Although we have taken the base as the common syllabus revised and adopted by the ICAR BSMA in 2009, the syllabi followed at CIFE Mumbai for M.F.Sc. and Ph.D in Post-Harvest Technology was very much consulted as the syllabi was relooked with the changing scenario in the field and improved. The major changes in revision of the syllabi for the M.F.Sc and Ph.D. programmes in Fish Processing Technology from BSMA 2009 are discussed as under:

M.F.Sc. in Fish Processing Technology

- FPT 501 Low Temperature Preservation of Fish and Shell-fish: The title and content of this course was changed from the earlier course title, Technology of fish freezing and frozen storage without alteration in the credit load. The contents were updated and recent developments in technology and analytical methods included.
- FPT 502: Thermal Processing of Fish and Fishery Products - Unit wise distribution of contents rearranged and aspects on thermal process calculations included.
- FPT 503: Applied Fish Microbiology - Title changed from Techniques in Microbiology incorporating not only the techniques but also basic and applied aspects of fisheries microbiology
- FPT 504 Fish Quality Assurance and Certification – Details of HACCP added
- FPT 505: Applied Fish Biochemistry - Topics on "Pigments" and "Electrophoresis" added
- FPT 506: Value Added Fishery products - With the changes that have taken place in the field of fish processing and value addition both in domestic and export markets it was decided have this new course. However, some of the contents of FPT 508 Technology of Mince based Fish Products (1+1) and a few aspects from the course FPT 506 Cured, dehydrated and Smoked Fishery products (1+1) are included
- FPT 507 Trade Regulations, Certification and Documentation in Export of Fish and Fishery Products – This is a new course with the credit load of 1+1, considering the importance of export trade of fish and fishery products and the need to develop entrepreneurs. Topics on Import regulations, SPS-TBT agreement, Traceability issues for farm reared and wild aquatic products; dealing with returned consignments; Foreign trade regulations in India; Practical on "Preparation of BOL, LC; Preparation of documents for seafood export to different destinations; Study of documents on customs and port procedures for seafood export and import" included.
- FPT 508: Design, Maintenance of Fish Processing Plants and Instrumentation - Topics on "Plant design as pre-requisite for quality management" and "Designing of ETP systems" added. Minor changes in contents of practical also made.
- FPT 509: Microorganisms of Public Health Significance - Topics on "Algal toxins" and "Antibiotic resistance in microbes" added to the contents.
- FPT 510: Molecular Techniques in Seafood Quality Analysis - – This is a new course

with the credit load of 1+1. Considerable developments in molecular analysis have taken place over the past decade and contents of this course reflect all recent developments in seafood analysis.

- FPT 511: Packaging of Fish and Fishery Products - Topics on "Packaging requirements for transportation of live fish and shellfish", "FSSAI requirements and BIS guidelines", "Intelligent packaging; edible packaging", "Disposal and recycling of packaging materials" added
- FPT 512: Fish Byproducts and Waste Utilization – Title changed from Fish Byproducts and Utilization of Fishery Waste with addition of topics on biopeptides, chitooligo- saccharides and chitosan based nanoparticles and also the units rearranged
- FPT 513: Multivariate Analysis in Food Processing and Product Development – This is a new course with the credit load of 0+1, designed for students who take up research on product development.

Ph.D. in Fish Processing Technology

- FPT 601 Principles and Techniques in Seafood Analysis – Title changed from Biochemical Techniques in Fish Analysis (2+1) with additional topics on GCMS, GC MSMS, SEM, TEM introduced
- FPT 602 Functional Properties of Fish and Shellfish Proteins. Rephrasing of the tile carried out. Units rearranged for better coherence.
- FPT 603 Biotechnological Applications in Fish Processing, A new course with a credit load of 2+1. Recombinant DNA technology, Molecular biological and Immunological tools in bacterial detection in foods and molecular techniques in detection seafood adulteration are the novel topics introduced.
- FPT 604 Quality Management Sysems – In addition to the original contents accreditation of analytical laboratories introduced.
- FPT 605 Emerging Trends in seafood Processing, A new course introduced with the credit load of 1+1 to keep abreast of the developments in modern techniques in food processing. Types of novel processing technologies and their applications such as Supercritical Fluid extraction- SCFX, High-Pressure Processing (HPP); pulsed electrical fields (PEF) as a pasteurization technology, Ultrasound processing, Ozone/ CO_2 Processing, Hurdle Technology and Automation in Processing are the topics given focus.
- FPT 606 Nutraceuticals of Aquatic Origin – A new course with a credit load of 1+1 with units of Nutraceuticals and functional foods, Marine bioactive compounds and Delivery of nutraceuticals included
- FPT 607 Toxins and Contaminants – Topics on Antibiotic residues in seafood, micro-plastics, PAHs, Toxicity and accumulation studies added along with other changes made.
- FPT 608: Additives in fish Processing – A new course (1+1) taken from the original syllabus of M.F.Sc. programme updating contents and rearrangements of units.
- FPT 609: Sensory and Physical Analyses – A new course (2+1) with units on basics of sensory and physical analysis, Measuring responses, Physical and mechanical properties of food, and Guidelines for analysis and reporting.
- FPT 610: Environmental Impact of Fishery Industries – Contents updated and units rearranged
- FPT 611: Food Labeling – Title changed from Nutritional Aspects and Nutritional Labeling (2+1) and credit load reduced to 1+1. Contents revised with focus on legislation and labeling requirements.

- FPT 612: Water Quality Management in Seafood Processing – A new course with a credit load of 2+1 giving focus on units including Sources and types of water, Quality criteria, Quality Standards, Water budgeting for processing and treatment. Considering the Union Government's Blue Revolution initiatives in promoting fisheries sector, the syllabi for postgraduate programmes in Fish Processing Technology are framed in such a way that our graduates would be able to man higher positions in fisheries management with skill sets for effective entrepreneurship.

Course Title with Credit Load
M.F.Sc. in Fish Processing Technology

Course Code	Course Title	Course Hours
	Major Courses	**20 credits**
FPT 501	Low Temperature Preservation of Fish and Shell Fish	2+1
FPT 502	Thermal Processing of Fish and Fishery Products	2+1
FPT 503	Applied Fisheries Microbiology	2+1
FPT 504	Fish Quality Assurance, Management and Certification	2+1
FPT 505	Applied Fisheries Biochemistry	2+1
FPT 506	Value Added Fishery Products	2+1
FPT 507	Trade Regulations, Certification and Documentation in Export of Fish and Fishery Products	1+1
	Minor Courses	**8** credits
	(From the subjects closely related to a student's major subject)	
FPT 508	Design, Maintenance of Fish Processing Plants and Instrumentation	1+1
FPT 509	Microorganisms of Public Health Significance	1+1
FPT 510	Molecular Techniques In Seafood Quality Analysis	1+1
FPT 511	Packaging of Fish and Fishery Products	1+1
FPT 512	Fish Byproducts and Waste Utilization	1+1
FPT 513	Multivariate Analysis In Food Processing and Product Development	0+1
	Optional courses from other disciplines or MOOC	4
	Supporting courses	**6 credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	
	Common courses	**5 credits**
	(The following courses, one credit each will be offered)	
	• Library and Information Services	
	• Technical Writing and Communication Skills	
	• Intellectual Property and its management in Agriculture	
	• Basic concepts in Laboratory Techniques	
	• Agricultural Research, Research ethics and Rural Development Programmes	

Course Code	Course Title	Course Hours
	Seminar	**1 Credit**
FPT 591	Seminar I	0+1
	Masters Thesis Research	**30 Credits**
FPT 599	Master's Research (Semester III)	0+15
FPT 599	Master's Research (Semester IV)	0+15
	Total Credit load of M.F.Sc. Program	**70 Credits**

Course Contents
M.F.Sc in Fish Processing Technology

I. Course Title : Low Temperature Preservation of Fish and Shellfish
II. Course Code : FPT 501
III. Credit Hours : 2+1

IV. Aim of the course

Chilling and Freezing are the most common methods of fish preservation and most trade are happening at this form of preservation. A thorough knowledge on the mechanism of action of these methods is essential for any graduate student.

V. Theory

Unit I

Postmortem changes: Structural and chemical features of fish and shellfish as raw material for processing, Factors affecting quality of fresh fish, intrinsic and extrinsic factors, Handling of fish onboard, Landing centres and farm sites-different types of chilling methods, Depuration of bivalves, Assessment of post-harvest loss.

Unit II

Chilled storage and transportation of fish: Heat load calculation, Storage methods- insulated boxes and insulation thickness, Different types of ice, Physical, Chemical, Microbiological and Sensory changes during chill storage, Melanosis and its prevention, Iced storage shelf life, Cold shock, Transportation- live fish/shell fish, transportation of raw fish to local markets and processing centres, Improvements needed in transportation, Refrigerated transport systems, Classification of transport vehicles, cold chain.

Unit III

Freezing of fish and shellfish: Structure of water and ice, Influence of solutes on the structure of water and ice, Phase equilibria and freezing curves of pure water and binary solutions, freezing curves for fish, Determination of freezing points from time-temperature plots, Calculation of freezing time; Crystallization, Nucleation- homogeneous and Heterogeneous nucleation; Super cooling, Crystal growth, Eutectic point, Location of ice crystals in tissue, Changes during freezing.

Unit IV

Freezing methods: Technological aspects of freezing-methods of freezing (plate freezing, IQF, etc), Selection of a freezing method, Product processing and packaging, packing of fresh and frozen fish for consumers, Modified atmosphere packaging, Controlled packaging, Cold storage management-arrangements within a cold storage, handling and stacking systems.

Unit V

Changes in frozen storage: Physical changes, freezer burn and recrystallisation, Different types of recrystallisation, Chemical changes in lipids, Proteins and

nucleotides, Freeze denaturation and theories on denaturation, Changes in pH, Bacterial changes, Sensory changes, texture, taste, odour, effect of post-mortem condition on sensory qualities.

Unit VI

Prevention of quality loss during frozen storage: Treatments prior to freezing, Antioxidants, Cryoprotectants and other additives, Theories of cryoprotection, Glazing- importance and methods.

VI. Practical

Handling of fish, crustaceans and mollusks, Evaluation of freshness of fish, crustaceans and molluscs, freezing curve, determination of freezing point, Filleting of fish, treatments, glazing, packaging, freezing, Processing of shrimp, lobster, squid, cuttle fish, crab etc. in different styles, Depuration-treatment with chemicals, Packaging and Freezing, Chemical tests (Histamine, k value) on frozen products and Studies on physical and sensory changes for determination of shelf life.

VII. Suggested Reading

- AOAC manual
- Balachandran KK. 2001. *Post-harvest Technology of Fish and Fish Products*. Daya Publ. House.
- Clucas IJ. 1981. *Fish Handling, Preservation and Processing in the Tropics*. Parts I, II. FAO.
- Fennema K, Powrie WD and Marth EH. 1973. *Low Temperature Preservation of Foods and Living Matter*. Marcel Dekker.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Hall GM. (Ed). 2011. *Fish Processing –Sustainability and New Opportunities*. Wiley-Blackwell.
- Judith A. Evans. 2008. *Frozen Food Science and Technology*, Blackwell Publishing Inc. (Malden)
- SEAFDEC manual
- Nalan Gokoglu, Pinar Yerlikaya. 2015. *Seafood Chilling, Refrigeration and Freezing: Science and Technology,* John Wiley and Sons (Chichester)
- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ.
- Venugopal V. 2006. *Seafood Processing*. Taylor and Francis.

I. Course Title : Thermal Processing of Fish and Fishery Products

II. Course Code : FPT 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide information on various aspects of thermal / heat processing.

To impart knowledge on various types of packaging techniques and materials used in thermal processing.

V. Theory

Unit I

Principles of thermal processing and classification of foods: Mechanisms of heat transfer; Unsteady state of transfer; conduction, convection, radiation; Dielectric and microwave heating, Heat penetration, cold point; Low acid, medium acid and acid foods, Absolute sterility, Statistical sterility, Commercial sterility, Pasteurization and Sterilization, sous-vide.

Unit II

Canning process: Steps involved, Process flow, Additives, Principles and process details, Canning machinery and equipment, Canning process for fish/shellfish, Value added canned products; Spoilage of canned food, physical, Chemical and microbial, Examination of cans and seams, Effect of canning on nutrient profile.

Unit III

Basis of Thermal Process: Heat resistance of bacteria and spores, Decimal reduction time, Thermal death time, "D", "Z" and "F0" values, 12 D value, Significance of survivor curve and Thermal death curve.

Unit IV

Thermal process calculations: Determination of process time and F value; Graphical, formula, Nomogram methods.

Unit V

Emerging trends in containers and heat treatment processes: HTST, UHT processing and aseptic canning, Flexible packing, Retort pouch processing of fish and fishery products principles and techniques; Combination and synergistic effects.

Unit VI

Canning plant location: Practical considerations, Canning plant facilities, Layout and design, Automation in canning lines.

VI. Practical

Operation of over pressure retort for canning, Canning operations for commercial important finfishes, Canning of shrimp and Cephalopods, Retort pouch processing of table fishes, bivalves, crustaceans, Examination of canned fishery products, Sensory evaluation of canned foods, Examination of can seams, Sterility test of canned products, Isolation of Clostridium spp, from canned foods, Heat Penetration Curve and Calculation of F0 Value, Z value, process time.

VII. Suggested Reading

- Da-Wen Sun 2005, *Thermal Food Processing: New Technologies and Quality Issues*, Taylor and Francis (Boca Raton)
- Hall GM. (Ed). 1992. *Fish Processing Technology*. Blackie.
- Hersom AC and Hulland ED. 1980. *Canned Foods*. Chemical Publ. Co.
- Holdsworth SD. 1997. *Thermal Processing of Packaged Foods,* Blackie Academic and Professional
- Larousse J and Brown BE. 1997. *Food Canning Technology*. Wiley VCH.
- Venugopal V. 2006. *Seafood Processing*. Taylor and Francis.
- Warne D. 1988. *Manual on Fish Canning*. FAO Fisheries Tech. Paper 285.
- Zeathen P. 1984. *Thermal Processing and Quality of Foods*. Elsevier.

I. Course Title : Applied Fisheries Microbiology

II. Course Code : FPT 503

III. Credit Hours : 2+1

IV. Aim of the course

To teach nature and activity of microbes in fish and fishery products, microbiological spoilage and preservation, various aspects of Industrial microbiology, importance of fermentation.

V. Theory

Unit I

Introductory microbiology: Classification, nature and activity of microbes in fish and fishery products; Microbiology of marine, Brackish and freshwater fish/ shell fish, Microbiology of spoilage and preservation.

Unit II

Intrinsic and extrinsic parameters of fish and fishery products that influence growth and survival of microorganisms

Unit III

Pathogenic organisms of public health significance in seafood: The etiology of diseases; Conditions for outbreak and prevention, Food infections by *Salmonella, Vibrio parahaemolyticus*, *V. vulnificus,* pathogenic *E. coli*, *Listeria monocytogenes, Campylobacter*; Virulence mechanisms, Their sources, Incidences, Foods involved and Prevention measures.

Unit IV

Fermentation: Batch wise and continuous; Important fermented products and methods of production; Screening of microorganisms, Detection and assay of products of fermentation, Preparation and use of fermentation media, Starter culture, Preparation and maintenance of stock cultures.

Unit V

Microbial injury, Microbial biofilms, Inactive physiological states (spores and VBNC), Unculturable and Uncultured bacteria, Identification of unculturable groups.

Unit VI

Advancement in diagnostic protocols: Molecular methods for detection of microbes in fish and fishery products

VI. Practical

Isolation and characterization of spoilage and pathogenic microorganisms, Sampling for TPC from fresh, iced and frozen fish, Selection of bacterial groups in iced fish, Isolation of fish spoilage bacteria, Enumeration of halophilic bacteria from salted fish, Fermentation by selected microbes, Assay of products formed; microbial composition of fermented fish and Conventional and molecular detection of pathogens.

VII. Suggested Reading

- Alexander N. Glazer and Hiroshi Nikaido 2007. *Microbial Biotechnology: Fundamentals of Applied Microbiology*, Cambridge University Press (Newyork)
- Chakraborthy P. 1995. *A Text Book of Microbiology*. New Central Book Agency.
- Criusted J. 1986. *Methods in Microbiology*. Academic Press.
- Doyle MP, Beuchat LR and Montville TJ. 1997. *Food Microbiology - Fundamentals and Frontiers*. American Society for Microbiology.
- Harry WSJR, Paul JV and John JL. 2000. *Microbes in Action*. Freeman and Co. II (ICMSF). Academic Press.
- KR Aneja. 2008. *Textbook of basic and applied microbiology*, "New Age International (P) Limited, Publishers" (New Delhi)
- Michael J, Pelizar JR and Chan ECS. 1998. *Microbiology*. McGraw Hill.
- Rita Narayanan 2013. *Food Microbiology: basic and applied with laboratory exercises*, New India Publishing Agency (New Delhi)

I. Course Title : Fish Quality Assurance, Management and Certification
II. Course Code : FPT 504
III. Credit Hours : 2+1

IV. Aim of the course

To teach various aspects of quality assurance systems, quality management and national / international certification system.
To teach factory sanitation and hygiene, water quality and standardsTo teach quality affecting parameters

V. Theory

Unit I

Hazards in fish and fishery product: Physical, Chemical, Biological, Quality management, Total quality concept and application in fish trade.

Unit II

Quality assessment of fish and fishery products: Physical, Chemical, Organoleptic and Microbiological quality standards.

Unit III

Inspection and quality assurance: Fish inspection in India, Traceability and authenticity; Factory sanitation and hygienization: National and international requirements, SSOP.

I. Course Title : Applied Fisheries Biochemistry
II. Course Code : FPT 505
III. Credit Hours : 2+1

IV. Aim of the course

- To impart knowledge on macro and trace constituents and nutritive value of fish.
- To create basic understanding about toxins and toxic substances and their toxic effects.
- To give a detailed insight into experimental techniques used in food analysis.

V. Theory

Unit I

Proteins: Classification; structural proteins (actin, myosin, tropomyosin, actomyosin, paramyosin), Sarcoplasmic proteins (myoalbumin, globulin, hydrolases, oxidoreductases); Connective tissue proteins (collagen); Pigments, heme proteins, hemocyanins, Antifreeze proteins, Functional properties of seafood proteins, Solubility, Emulsification, Viscosity, Water holding capacity, Gelation, Denaturation of proteins, Dissociation, Aggregation, Coagulation, Reversibility and their significance to processing and quality.

Unit II

Lipids: Composition and nutritive value, Lipid types and their variations, Fatty acid composition of fish liver and body oils, Lipid fractionation, triglycerides, Phospholipids, Polyunsaturated fatty acids and their beneficial effects on human health, Auto-oxidation of fatty acids, pro- and anti-oxidants, Oxidation indices,

lipid protein interactions, Oxidized lipids-protein interactions and their impact on quality, Rancidity, Lipases and phospholipases.

Unit III

Carbohydrates: Classification and biological significance of carbohydrates, Structure and properties of monosaccharides, Disaccharides and polysaccharides, Uses of modified starch and other carbohydrates as food additives (as thickening and binding agents), Changes in Carbohydrates during processing and relationship of carbohydrates to food stability, Gelatinization.

Unit IV

Vitamins: Water soluble and Fat soluble, Heat labile vitamins, Process effecting on vitamins, Minerals; Major, Miner and Trace elements and their health benefits.

Unit V

Seafood flavours and pigments: Flavour, Taste and Odour, Chemical basis of flavour perception, Volatile fatty acids, Influence of processing on flavour, Non-protein nitrogenous compounds; Free amino acids, Peptides, Nucleotides, Guanidines, Urea, Quaternary ammonium compounds.

Unit VI

Fundamental techniques in food analysis: Basic principles of electrophoresis, Chromatography, TLC, Paper and Liquid Chromatography, HPLC, GC and GC-MS. Principle and applications of Spectrophotometry.

VI. Practical

Protein purification based on solubility, Separation of protein based on size and charge in PAGE, Separation of amino acids by TLC and paper chromatography; Enzyme assay by spectrophotometer; Amino acid analysis by HPLC, Determination of protein carbonyls, Extraction of lipids by different methods, Fractionation of lipids by TLC, Analysis of fatty acid composition by GC, Texture profile analysis and Estimation of unsaponifiable compounds in fish oil

VII. Suggested Reading

- Alasalvar C, Miyashita K, Shahidi F and Wanasundara U. 2011. *Handbook of Seafood Quality, Safety and Health Applications*, Wiley-Blackwell (Oxford)
- Anthony TT. 1988. *Handbook of Natural Toxins. Marine Toxins and Venom*. Vol. III. Marcel Dekker.
- Balachandran KK. 2001. *Post Harvest Technology of Fish and Fish Products*. Daya Publ. House.
- Connell JJ. 1995. *Control of Fish Quality*. Fishing News Books.
- Fennema K, Powrie WD and Marth EH. 1973. *Low Temperature Preservation of Foods and Living Matter*. Marcel Dekker.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Hall GM. (Ed). 1992. *Fish Processing Technology*. Blackie.
- H. Allan Bremner 2002, *Safety and Quality Issues in Fish Processing*
- Huss 2007. *Assessment and Management of Seafood Safety and Quality*. Daya Publishing House (Delhi)
- Hui YH, Merle DP and Richard GJ. (Eds.). 2001. *Food Borne Disease Handbook. Seafood and Environmental Toxins*. Vol. IV. Marcel Dekker.
- Huss HH, Jakobsen M and Liston J. 1991. *Quality Assurance in the Fish Industry*. Elsevier.
- John DEV. 1985. *Food Safety and Toxicity*. CRC Press.
- Kreuzer R. 1971. *Fish Inspection and Quality Control*. Fishing News Books.

- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ.
- Shukla RK. 2006. *Total Quality Management Practicing Manager*. New Royal Book.
- Vincent K and Omachonu JER. 2004. Principles of Total Quality. CRC Press.

I. Course Title : Value Added Fishery Products

II. Course Code : FPT 506

III. Credit Hours : 2+1

IV. Aim of the course

To make the students understand the concepts of value addition and to explain the preparation of products from low cost fish.

V. Theory

Unit I

Significance of value addition: Protein deficiency and need for fortification of food, Digestibility and nutritive value of fish meat, Overview of value-added products; Present market trends, Scope of value addition, Types of value addition, important value-added products.

Unit II

Minced fish meat: Equipment for mince preparation, Effect of mincing on physical and chemical properties; Different types of mince-based products, Surimi.

Unit III

Surimi: Basic concepts, Different unit operations, Cryoprotectants in surimi-hypothesis and mechanisms, Packaging, freezing and storage, Quality evaluation of surimi, Kamaboko and analogue products.

Unit IV

Battered and breaded products: Ingredients for batter and breading systems and their functionalities, Freeze dried products, Shelf life and specialties of AFD products, Machinery and equipment for freeze drying.

Unit V

Ready-to-eat and ready-to-cook products: Extruded fish products; Mechanism of extrusion, Types of extruders; Single screw, Twin screw, Mechanical and chemical changes during extrusion, Parameters affecting quality of extruded product, Cook-chill products.

Unit VI

Seaweeds: Resources, global and Indian scenario, Biochemical components in Seaweeds, Edible seaweeds – Nutritive value of seaweeds, Products from seaweeds.

VI. Practical

Preparation of Surimi from low value fish; Evaluation of Surimi gel strength; Evaluation of ATPase activity of actomyosin based products; Preparation of analog products from surimi, battered and breaded products, extruded products, cook-chill products and seaweed-based product.

VII. Suggested Reading

- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Hall GM. (Ed.). 1992. *Fish Processing Technology*. Blackie.

- Hui YH, Merle DP and Richard JG. (Eds.). 2001. *Food Borne Disease Handbook. Seafood and Environmental Toxins*. Vol. IV. Marcel Dekker.
- Nambudiri DD. 2006. *Technology of Fishery Products*. Fishing Chimes.
- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ.
- T Borresen 2008, *Improving Seafood Products for the Consumer,* Woodhead Publishiong Limited (Cambridge)
- Venugopal V. 2005. "*Seafood Processing: Adding Value Through Quick Freezing Retortable Packaging, and Cook-Chilling*", Taylor and Francis (Boca Raton)
- Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products*. John Wiley and Sons.

I. Course Title : Trade Regulations, Certification and Documentation in Export of Fish and Fishery Products

II. Course Code : FPT 507

III. Credit Hours : 1+1

IV. Aim of the course

To create basic understanding about Trade Regulations, Certification and documentation in export of fish and fishery products

V. Theory

Unit I

Trade policy and Legislation on labeling and other standards: Foreign Trade Policy of Fish and Fishery Products in Indian context and world context, Labeling requirements of Fish and Fishery products stipulated by National and International Organizations.

Unit II

Regulations: Export documentation- certificates of origin, Other certificates for Shipment of specific goods, Export licenses; Import regulations, SPS-TBT agreement.

Unit III

Labeling: Legislation on labeling; Labeling requirements for Traceability, Legislation on National and International standard requirements of seafood in export trade.

Unit IV

Export Certification systems: Consignment-wise, In process Quality, Self-Certification, Food safety management system, Pre-shipment inspection, Voluntary food certification scheme, Certificate for export (CFE), Health certificate, Other certification, Traceability issues for farm reared and wild aquatic products; Dealing with returned consignments; Foreign trade regulations in India.

VI. Practical

Documentation protocol for approval of fishing vessel, processing unit and technologist in processing plants. Labeling codes for Traceability of products in Export trade; Preparation of BOL and LC. Preparation of documents for seafood export to different destinations. Study of documents on customs and port procedures for seafood export and import.

VII. Suggested Reading

- Batra GS, Kaur Narinder. 1995. *Foreign Trade and Export Policy*, Anmol Publications Pvt Ltd.

- Cherian Jacob. 1997. *Export Marketing,* Himalaya Publishing House.
- Rathore Kumkum. 1994. *Export Marketing*, Arihant Publishing House.
- Mittal AC. 1991. *Export Management in India*, Omsons Publications.
- EIC, Export of Fresh, *Frozen and Processed Fish and Fishery Products A Guide for Exporters*, Export Inspection Council.

Minor Courses

I. Course Title : Design, Maintenance of Fish Processing Plants and Instrumentation

II. Course Code : FPT 508

III. Credit Hours : 1+1

IV. Aim of the course

To expose the students to design, maintenance of fish processing plant, machinery and the instruments used in fish processing plants.

V. Theory

Unit I

Plant design: Fundamentals of processing plant design, Site selection, Design and preparation of layout of processing plants, Freezing plant, Cold storage, Canning plant, dryers, etc., Plant design as pre-requisite for quality management, Functions and construction of refrigeration system; Tests and inspection, Operation and handling, Pressure-enthalpy (P-H) diagram and basic calculation, Application of P-H diagram, Size and required power of compressor.

Unit II

Maintenance: Maintenance of refrigerating machine, Troubles and causes, Preventive maintenance of machinery and equipment of fish processing plants, IOF, Canning plant, Sausage plant, Artificial dryers, Smoking chambers, etc., Safety controls for freezing and canning plant, Boilers: classification and selection, Boiler mounting and accessories; Boiler maintenance.

Unit III

Affluent water treatment and chlorination: Effluent treatment; Legislation and standards of effluent discharge, Water pollution control measures in the food industry, Waste water treatment process; Dissolved air floatation, Sedimentation, Chemical treatment, Biological treatment, Aeration, Carbon adsorption, Granular media filtration and sludge handling.

Unit IV

Measurement techniques: Sensors, active and passive sensors, Characteristic of sensors for the measurement of temperature, Relative humidity, a_w value, gel strength; Moisture, Freshness, pH, Conductivity, DO, Redox potential, Salinity, Air velocity, Solar energy and Brine concentration.

VI. Practical

Operation and maintenance of machinery and equipment for cold storage plant, freezing plant and canning plant. Operation and maintenance of dryers and boilers. Assembly of a refrigeration unit and charging of refrigerant. Measurement of temperature inside cold storage/freezer, Measurement of temperature in fish during freezing and thawing. Measurement of solar radiation. Designing of ETP systems.

VII. Suggested Reading

- Chupakhim V and Dormenko V. 1985. *Fish Processing Equipments*. MIR Publ.
- Heid JL and Joslyn MA. 1980. *Food Processing Operations*. AVI Publ. 188.
- Shafiur Rahman, Jasim Ahmed 2012. *Handbook of Food Process Design*: vol.1 and 2, Wiley-Blackwell (Oxford).
- Slade Frank H. 1967 *Food processing Plant*, Leonard Hill Books.
- Slade FH. 1997. *Food Processing Plants*. Leonard Hill.
- Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products,* John Wiley and Sons.

I. Course Title : Microorganisms of Public Health Significance

II. Course Code : FPT 509

III. Credit Hours : 1+1

IV. Aim of the course

To teach in detail about food-borne microorganisms of human health significance, food-borne diseases and their prevention.

V. Theory

Unit I

Pathogens in seafood: Sources of pathogens in seafood, Infection and intoxication; Bacteria of public health significance in fish *I* fishery products *I* environments, Epidemiology, Clostridial and staphylococcal food poisoning, Organism responsible and their origin, Growth and toxin production, Nature of toxins, Incidence of poisoning, Foods involved.

Unit II

The etiology of diseases: Conditions for outbreak and prevention, Food infections by *Salmonella, Vibrio parahaemolyticus*, *V. vulnificus,* pathogenic *E. coli*, *Listeria monocytogenes, Campylobacter, Arcobacter*; virulence mechanisms, Their sources, Incidences, Foods involved and prevention measures.

Unit III

Toxins: Histamine poisoning, Aflatoxins, patulin, Ochratoxin and other fungal toxins found in food, Toxin producer, source, Nature of toxin, Toxicity and significance in foods.

Unit IV

Virus and parasites in fish; Algal toxins; Antibiotic resistance in microbes; Significance of AMR.

VI. Practical

Laboratory techniques to detect and identify pathogens in fish - *E. coli, Staphylococcus aureus, Streptococus faecalis, Clostridium perfringens* and *Clostridium botulinum, Salmonella, Listeria, Vibrio cholere, Vibrio parabaemolyticus* and *V. vulnificus*. Animal bioassay of bacterial toxins.

VII. Suggested Reading

- Anon. 2001. *Food Borne Disease Handbook*. 2nd Ed. Vol. IV. *Seafood and Environmental Toxins*. Marcel Dekker.
- Davis BD, Dulbecco R, Eiser HN and Ginsberg HS. 1980. *Microbiology*. Harpar and Row.
- Doyle MP, Beuchat LR and Montville TJ. 1997. *Food Microbiology - Fundamentals and*

Frontiers. American Society for Microbiology.
- Harry WSJR, Paul JV and John JL. 2000. *Microbes in Action*. Freeman and Co.
- J Hoorfar. *Rapid Detection, Characterization, and Enumeration of Foodborne Pathogens*. ASM Press.
- Michael J, Pelizar JR and Chan ECS. 1998. *Microbiology*. McGraw Hill.
- Roberts D, Hooper W, Greenwood M. 1995. *Practical Food Microbiology: Methods for the Examination of Food for Micro-organisms of Publichealth Significance*, Public Health Laboratory Service (London)
- Silliker JH, Elliof RP, Baired AC and Boyan FL. 1980. *Microbial Ecology of Foods*. Vol. II. (ICMSF). Academic Press.
- Thomas J Montville, Karl R Matthews, and Kalmia E. Kniel. *Food Microbiology: An Introduction*, Third Edition. ASM Press.
- William CF and Dennis CW. 2000. *Food Microbiology*. McGraw Hill

I. Course Title : Molecular Techniques in Seafood Quality Analysis

II. Course Code : FPT 510

III. Credit Hours : 1+1

IV. Aim of the course

To teach basic concepts and techniques in molecular biology and immunology

V. Theory

Unit I

Introduction to molecular biology: Nucleic acids, Structure, Replication, Transcription and translation, Genes, ORF, Organization of genes, Operons, Plasmids. Vectors used in cloning and their structures.

Unit II

Enzymes in molecular biology: Polymerases, Ligases, Restriction Enzymes, Topoisomerases.

Unit III

Molecular methods: Molecular methods and their principles, PCR, RT-PCR, Hybridization, Microarray, AFLP, RFLP.

Unit IV

Immunological techniques in pathogen detection: Antigen-antibody reactions, Immunoassays-ELISA, FAT; Authenticity testing

VI. Practical

Conventional DNA extraction, Application of PCR for pathogen detection, Probe labeling and Southern hybridization, Primer designing, Tm determination, Agarose and protein gel electrophoresis, Cloning of genes, transformation techniques, Bioinformatic analysis of DNA and proteins, In-silico DNA and protein analysis, Restriction digestion, primer and probe designing, Protein structure prediction and Genome comparisons.

VII. Suggested Reading

- Hoorfar. *Rapid Detection, Characterization, and Enumeration of Foodborne Pathogens*. ASM Press
- Helen Kreuzer and Adrianne Massey. *Molecular Biology and Biotechnology: A Guide for Students*, Third Edition. ASM Press.

- Keith Wilson, John Walker, 2013. *Principles and Techniques of Biochemistry and Molecular Biology,* Cambridge University Press (New York)
- Leo M.L. Nollet, Fidel Toldra, 2010. *Handbook of Seafood and Seafood Products Analysis* CRC Press Inc. (Florida)
- Peter Walker 2005, *DNA-based Molecular Diagnostic Techniques: Research Needs for Standardization and Validation of the Detection of Aquatic Animal Pathogens and Diseases*, Daya Publishing House (Delhi)
- Susan Carson, Sue Carson, Heather Miller, D. Scott Witherow, 2012. *Molecular Biology Techniques: A Classroom Laboratory Manual*, Elsevier (Amsterdam)

I. Course Title : Packaging of Fish and Fishery Products

II. Course Code : FPT 511

III. Credit Hours : 1+1

IV. Aim of the course

To learn about different packaging materials, their appropriate use and benefits.

V. Theory

Unit I

Food packaging: Purposes and procedures; Technological aspects of packaging fishery products; Packaging for transport, Shipping and Institutional supplies; Packaging materials; Basic films and laminates, Their manufacture and Identification; Resistance of packaging materials; Development of protective packaging for fishery products.

Unit II

Transportation: Packaging requirements for transportation of live fish and shellfish, Methods of testing for packaging materials for their physical properties; Containers and their testing and evaluation; Package designs; Resistance of packages to hazards in handling; Transport and storage.

Unit III

Standards: Packaging standards for domestic and international trade.

Unit IV

Labeling and printing of packaging materials: FSSAI requirements and BIS guidelines, Intelligent packaging; Edible packaging; Disposal and recycling of packaging materials.

VI. Practical

Determination of grammage of paper and board, bursting strength and burst factor, punctures resistance, water proofness, stiffness of the board, ring stiffness of paper and board, flat crush, tensile strength and elongation at break of plastic films, density of plastic films, breaking length, impact strength of plastic films, tearing strength of paper and plastic films, water vapour transmission rate, oxygen transmission rate, heat seal strength, suitability of plastic films for food contact applications and Identification of plastic films.

VII. Suggested Reading

- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Da-Wen Sun 2012. *Handbook of Frozen Food Processing and Packaging*, CRC Press (Boca Raton)

- Gopakumar K. 1993. *Fish Packaging Technology - Materials and Methods*. Concept Publ.
- Gordon L Robertson. 2005. *Food Packaging: Principles and Practices*, "Marcel Dekker, Inc." (New York)
- Gordon L Robertson. 2010. *Food Packaging and Shelf Life: A Practical Guide*, CRC Press Inc. (Florida)
- Gordon L Robertson. 2013. *Food Packaging: Principles and Practice*, CRC Press (Boca Raton)
- Jerry D'Souza, Jatin Pradhan. 2010. *Handbook of Food Processing Packaging and Labeling*, SBS Publiahers and Distributors Pvt. Ltd. (New Delhi)
- Ponnuswami V. 2012. *Nano Food Packaging: A New Post-harvest Venture*, Narendra Publishing House (Delhi)
- S Subasinghe. 1999. *Retail Packaging of Fish and Fishery Products*, InfoFish
- TK Srinivasa Gopal. 2007. *Seafood Packaging*, Central Institute of FIsheries Technology (Cochin)
- W Steven Otwell, Hordur G Kristinsson, Murat O Balaban. 2006. *Modified Atmospheric Processing and Packaging of Fish: Filtered Smokes, Carbon Monoxide, and Reduced Oxygen Packaging*" "Blackwell Publishing Inc., " (Malden).

I. Course Title : Fish By-products and Waste Utilization

II. Course Code : FPT 512

III. Credit Hours : 1+1

IV. Aim of the course

To teach concepts of utilizing seafood wastes and byproducts from fish and shellfish

V. Theory

Unit I

Fish processing wastes and utilization: Overview of fish processing wastes, by catch and its composition, Liquid and solid wastes in fish processing, Bioremediation, Anaerobic treatment, Production of animal feed, Biodiesel.

Unit II

Fish meal, silage and oils: Fish meal production (dry and wet process), Nutritional importance and Quality requirements, Specifications, Packaging and storage, Fish silage; Acid silage and Fermented silage, Advantages over fish meal, Nutritional value of silage; Fish Oil; Fish body and liver oils, Extraction, Purification, Preservation and storage, Industrial and Nutritional applications of fish oils; Production of concentrates of polyunsaturated fatty acids, Preparation of fatty alcohol and amides, Extraction of shark liver oil, squalene, shark cartilage; ambergris.

Unit III

Fish wastes and utilization: Protein recovery - collagen, gelatin, extraction of enzymes; Shellfish Waste; sources and composition, Conventional uses, Chitin, Chitosan, Glucosamine hydrochloride, Carotenoids from Fish protein hydrolysates-Production and utilization, Biochemical composition and importance in food and nutrition, Functional properties of bioactive peptides; Shellfish waste and its applications, Biogas production from fish waste.

Unit IV

Novel products from fish waste and uses: Uses of Gelatin, Collagen, Shark cartilage, Glucosamine, Carotenoids, Astaxanthin, Bioactive peptides.

VI. Practical

Extraction of collagen from fish waste, gelatin from fish waste and enzymes from fish waste. Preparation of hydrolysates from fish and shellfish wastes. Extraction of chitosan and glucosamine from shrimp shell waste, Recovery of fish oil from fish waste

VII. Suggested Reading

- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Elvevoll EO. *Fish Waste and Functional foods,* Norwegian College of Fishery Science, Department of Marine Biotechnology, Norway. edele@nfh.uit.no
- Fereidoon Shahidi. 2007. *Maximizing the Value of Marine By-Products*, CRC Press Inc. (Florida)
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR. 198
- Venugopal V. 2014. *Fish Industry Byproducts as Source of Enzymes and Their Applications in Seafood Processing, in 'Fish Processing Byproducts: Quality Assessment and Applications*', Sachindra NM, Mahendrakar NS (Eds), Studium Press LLC, USA.
- Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products*. John Wiley and Sons.

I. Course Title : Multivariate Analysis in Food Processing and Product Development

II. Course Code : FPT 513

III. Credit Hours : 0+1

IV. Aim of the course

To create practical knowledge about Multivariate Analysis in Food Processing and product development.

V. Practical

Importance of multivariate analysis in optimization of different variables to achieve desired traits in food processing, product development and sensory evaluation; Design and analysis of controlled experiments: Full factorial, Factorial, Central composite and Box-Behnken Designs. Exercises to develop suitable designs for extruded products and antioxidant extractions by using Unscrambler software; Response surface analysis: Selection of variables, design variables and response variables, selection of samples, modeling the response data using Unscrambler software, checking the predictive ability, response surface plots; Principal Component Analysis (PCA): Principal components, Bi-linear modeling of one single data matrix X, Score plot, Loading plot and Correlation Loadings; Regression: Principal component regression (PCR), Multiple linear regression (MLR), Partial Least Squares Regression (PLSR): Modeling Y from the essence of X data set, Calibration and Prediction Models.

VI. Suggested Reading

- Alvin C. Rencher. 2002. *Methods of multivariate analysis*
- Rao CR. 1993. *Multivariate Analysis: Future Directions*, "North Holland Publishing Co."
- Yiu H. Hui. 2006. *Handbook of Food Science, Technology and Engineering*.

Course Title with Credit Load
Ph.D. in Fish Processing Technology

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FPT 601	Principles and Techniques of Seafood Analysis	2+1
FPT 602	Functional Properties of Fish and Shell-fish Proteins	2+1
FPT 603	Biotechnological Applications in Fish Processing	2+1
FPT 604	Quality Management Systems	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
FPT 605	Emerging Trends in Seafood Processing	1+1
FPT 606	Nutraceuticals of Aquatic Origin	1+1
FPT 607	Toxins and Contaminants	2+1
FPT 608	Additives in Fish Processing	1+1
FPT 609	Sensory and Physical Analyses	1+1
FPT 610	Environmental Impact of Fishery Industries	2+1
FPT 611	Food Labeling	1+1
FPT 612	Water Quality Management in Seafood Processing	2+1
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
FST 601	Advanced Statistical Methods	2+1
FST 602	Software for Fisheries Data Analysis and Management	0+2
RPE 601	Research and Publication Ethics	1+1
	Total Course Work Credit load	**23**
	Seminar	**2 Credits**
FPT 691	Seminar I	0+1
FPT 692	Seminar II	0+1
	Thesis Research	**75 Credits**
FPT 699	Doctoral Research (Semester II)	0+15
FPT 699	Doctoral Research (Semester III)	0+15
FPT 699	Doctoral Research (Semester IV)	0+15

Course Code	Course Title	Credit Hours
FPT 699	Doctoral Research (Semester V)	0+15
FPT 699	Doctoral Research (Semester VI)	0+15
	Total Credit load for Ph.D. Program	**100**

Course Contents
Ph.D in Fish Processing Technology

I. Course Title : Principles and Techniques of Seafood Analysis

II. Course Code : FPT 601

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various instrumental techniques in seafood analysis.

V. Theory

Unit I

Separation of molecules: General principles of separation of micro and macro molecules, Selection of appropriate tools for analysis of fish samples, Outlines of common techniques involved in biochemical analysis.

Unit II

Filtration and centrifugation techniques: Different types of filtration, Types of filters and means of using them; Types of centrifugation (preparative and analytical), concept of Svedberg unit, Selecting appropriate rotor, Relative centrifugal force.

Unit III

Viscoelastic properties, Rheology, Tribology, TPA; IR and FTIR spectrophotometry, Spectrofluorimetry, ICP, Atomic absorption mass spectrometry, Tandem MS/MS.

Unit IV

Microscopy: Fluorescence microscopy, SEM, TEM, XRD.

Unit V

Electrophoresis: General principles, types (native, denatured PAGE, 2D) Chromatographic techniques; General principle, Types of chromatography (adsorption, partition, ion-exchange, molecular sieve, affinity, liquid and gas chromatography, thin layer chromatography).

Unit VI

Chromatography: Partition coefficient, Retention, Resolution, Capacity factor, Theoretical plate, Vandeemter curve, Gel filtration chromatography, Ion exchange chromatography, Affinity chromatography, Hydrophobic interaction chromatography, Paper chromatography, Thin layer chromatography, Reversed-phase chromatography, GC, HPLC, GCMS, LCMSMS

VI. Practical

Characterization of proteins based on solubility: sarcoplasmic, myofibrillar, and stroma; Estimation of proteins- Biuret techniques, Lowry techniques, Dye binding technique and electrophoretic techniques. Amino acid analysis by HPLC. Fatty acid analysis by GC MS, Minerals and heavy metals by Atomic Absorption

spectroscopy. Texture analysis by TPA. HPLC- determination of histamine, Demonstration of GC-MS-MS.

VII. Suggested Reading

- Ewing GW. 1997. *Analytical Instrumentation Handbook*. Marcel Dekker.
- Larsen BS and McEwen CN. 1988. *Mass Spectrometry of Biological Materials*. Marcel Dekker.
- Lakshmanan. 2010. *Modern Analytical Techniques* Central Institute of FIsheries Technology (Cochin)
- Leo ML, Nollet, Fidel Toldra. 2010. *Handbook of Seafood and Seafood Products Analysis* CRC Press Inc. (Florida)
- Luis M, Botana. 2014. *Seafood and Freshwater Toxins: Pharmacology, Physiology, and Detection,* Third Edition, CRC Press (Boca Raton)
- Otles S. 2016. *Handbook of Food Analysis Instruments*. CRC Press.
- Pare JRJ and Belanger JMR. 1997. *Instrumental Methods in Food Analysis*. Elsevier.
- Robyt JF and White BJ. 1990. *Biochemical Techniques - Theory and Practice.* Waveland Press.
- Wilson K and Walker J. 2000. *Practical Biochemistry - Principles and Techniques*. Cambridge University Press.
- Wilson RH. 1994. *Spectroscopic Techniques for Food Analysis*. VCH Publ.

I. Course Title : Functional Properties of Fish and Shell Fish Proteins

II. Course Code : FPT 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on the functional properties known to affect product property.

V. Theory

Unit I

Protein properties: Functional properties of fish and shellfish proteins and their importance in food systems, Denaturation and functionality; Changes in functional properties of proteins as affected by icing, Freezing, Drying, Salting and Heating. Modification of proteins for improving functionality- Succinylation and acetylation procedures.

Unit II

Protein structure and function: Protein folding and non-covalent forces stabilizing protein structure; Free energy and entropy, Surface hydrophobicity and its relation to functional properties.

Unit III

Solubility and water sorption of proteins: Factors affecting protein hydration, Viscosity in relation to protein hydration; Methods of estimating viscosity.

Unit IV

Gelation: Definition of gel, Mechanism of formation of gel, Factors affecting the gel formation, Evaluation of gelling capacity- Thermal, Rheological and microscopy.

Unit V

Emulsifying: Theoretical concept of emulsion capacity and stability, Emulsion instability; Creaming, Sedimentation, aggregation vs Brownian aggregation. DLVO theory, microemulsions.

Unit VI

Foaming: Foaming ability of different protein systems with case studies, Foam stability in relation to proteins structure.

VI. Practical

Evaluation of water absorption properties of fish protein, fat absorption properties of fish protein, gelling properties of fish protein, emulsification capacity of fish protein and foam stability of fish/shell fish proteins. Determination of effect of pH on fish protein, temperature on functional properties fish protein and ionic strength on functional properties fish protein. Prediction of functional properties using model compounds. Estimation of surface hydrophobicity and total hydrophobicity.

VII. Suggested Reading

- Cherry JP. 1991. *Protein Functionality in Foods.* American Chemical Society. Washington. D.C.
- Damodaran S and Paraf A. 1997. *Food Proteins and Their Applications*., Marcel Dekker,
- Hill SE, Ledward DA and Mitchell JR. 1998. *Functional Properties of Food Macromolecules.* 2nd Ed. Aspen Publ.
- Nakai S and Modler HW. 1996. *Food Proteins Properties and Characterisation*. VCH Publ.
- Phillips LG, Whitehead DM and Kinsella J. 1994. *Structure, Functional Properties of Food Proteins*. Academic Press.
- Pomeranz, Yeshajahu. 1985. *Functional Properties of Food Components,* Academic Press, "
- Venugopal V. 2006. *Seafood Processing.* Taylor and Francis.
- Zdzislaw E, Sikorski. 2006. *Chemical and Functional Properties of Food Components*, Third Edition, CRC Press Inc. (Florida)

I. Course Title : Biotechnological Applications in Fish Processing

II. Course Code : FPT 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand the recent trends in microbiology and biotechnology research that could be applied in fish processing

V. Theory

Unit I

Basic Concepts: Microbial interactions and their applications in foods; Natural preservatives, Quorum sensing and its inhibitors, Phage therapy, Basic concepts of fermentations, Bioremediation and probiotics; Concepts of biotechnological approaches to product improvement.

Unit II

Microbial genomics: Genomics of bacteria, micro RNA, Microbiome and health, Metagenomics and its applications; Application of bioinformatics.

Unit III

Recombinant DNA technology: Application in food microorganisms, Engineering of microorganisms to produce useful metabolites, Enzymes, Vaccines.

Unit IV

Molecular biological tools: RT-PCR, microarray, Hybridization techniques, Next generation sequencing techniques, biosensors.

Unit V

Immunology: Immunoglobulins, Monoclonal antibodies, Application of antigen and antibody reactions, Immune-magnetic separation, proteomics.

Unit VI

Techniques involved in seafood adulteration: AFLP, RFLP, RAPD, DNA finger printing

VI. Practical

Molecular biological assays for aquatic food borne pathogenic bacteria. Molecular Immunological assays for aquatic foodborne pathogenic bacteria. Molecular Immunological assays for aquatic foodborne pathogenic viruses. Construction of recombinant plasmid. Recombinant protein expression and purification. Transformation. Gene knockout techniques. Construction of gene library. Microbiome studies. Tools used in metagenome analysis.

VII. Suggested Reading

- AM Martin. 2009. *Fisheries Processing: Biotechnological Applications*, Chapman and Hall (Chennai).
- Byong H. Lee 2015. *Fundamentals of Food Biotechnology*. Wiley-Blackwell (Oxford)
- Jennie S Popp, Molly M Jahn, Marty D Matlock, Nathan P Kemper 2012. *Role of Biotechnology in a Sustainable Food Supply*. Cambridge University Press (Newyork).
- Parmjit S Panesar, Satwinder S Marwaha. 2014. *Biotechnology in Agriculture and Food Processing: Opportunities and Challenges*. CRC Press (Boca Raton).

I. Course Title : Quality Management Systems

II. Course Code : FPT 604

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize students with different aspects of quality management systems and evaluation techniques for seafood.

To teach Seafood Quality Assurance and Quality Management Systems.

V. Theory

Unit I

The concept of total quality management: The principles of TQM, Zero defect planning, Quality circle, Quality link, Quality culture, Statistical quality control, Quality evaluation techniques for seafood; Effect of preprocess handling, Transport and storage on quality; Quality costs and evaluation.

Unit II

Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP): Codex guidelines, Concept of HACCP in seafood safety, Risk assessment; HACCP team management role and CCPs and implementation procedure for HACCP, ISO 9000 series of standards.

Unit III

Accreditation of laboratories: Validation requirements; Method of selection, Method of validation, Methods to control accuracy and precision, Primary standards, Reference standards, Reference material (RM), Certified Reference Material (CRM) and Standard Reference Material (SRM).

Unit IV

Sampling: Uncertainty and calculation of uncertainty measurements, Sample accountability; Sampling plan; Probability sampling and non- probability sampling.

Unit V

Proficiency and check samples: Intra and inter laboratory test programme, Proficiency testing programme; Predictive modeling in quality and safety assurance of fishery products.

Unit VI

Traceability, Product Recall, Equipment and machineries calibration

VI. Practical

Developing flow charts and indented use of different frozen and pasteurized fishery products. Preparation of HACCP work sheet for identification of hazards in frozen, canned and pasteurized products. Preparation of HACCP plan form for identified hazards in frozen and canned fishery products. Developing flow charts and indented use of different canned products. Study of correction and corrective action. Detection of important toxic chemicals in seafood.

VII. Suggested reading

- Alasalvar C, Miyashita K, Shahidi F, Wanasundara U. 2011. *Handbook of Seafood Quality, Safety and Health Applications*. Wiley-Blackwell (Oxford).
- Alasalvar C. 2011. *Handbook of Seafood Quality, Safety and Health Applications*. Chichester, West Sussex, UK/; Wiley-Blackwell.
- Anon. 1992. *TQM in New Product Manufacturing*. McGraw Hill.
- Anon. 1994. *Principles of Total Quality*. St. Leuie Press.
- Botana Luis M. 2014. *Seafood and Freshwater Toxins/: Pharmacology, Physiology, and Detection*, Third Edition. Third edit.
- H Allan Bremner. 2002. *Safety and quality issues in fish processing*
- Huss HH. 2003. *Assessment and Management of Seafood Safety and Quality*. FAO Tech. Paper No. 444.
- Huss. 2007. *Assessment and Management of Seafood Safety and Quality*. Daya Publishing House (Delhi)
- Kanduri L and Eckhartt RA. 2002. *Food Safety in Shrimp Processing*. Fishing News Books.
- Kreuzer R. 1971. *Fish Inspection and Quality Control*. Fishing News Books.
- Labbé Ronald G. and García, S. 2013. *Guide to Foodborne Pathogens*. Second edi.
- Shukla RK. 2006. *Total Quality Management Practicing Manager*. New Royal Book.

Minor courses

I. Course Title : Emerging Trends in Seafood Prcoessing
II. Course Code : FPT 605
III. Credit Hours : 1+1

IV. Aim of the course

To give a detailed insight into various advancements in seafood processing technologies

V. Theory

Unit I

Types of novel processing technologies and their applications: Supercritical Fluid extraction- SCFX, High-Pressure Processing (HPP); Pulsed electrical fields (PEF) as a pasteurization technology**,** Ultrasound processing, Ozone/CO_2 Processing.

Unit II

Hurdle technology: Principle and application of hurdle technology, Sous-vide technology, Other applications – Microwave processing, Accelerated Freeze Drying, Ohmic Heating.

Unit III

Trends in packaging: Active and Intelligent Packaging; Application of nanotechnology and Nano biotechnology in fisheries.

Unit IV

Automation in processing: Automation in fish process lines; Efficient process lines; Bionic noses; Machine vision; Robotics

VI. Practical

Effect of microwave cooking on proximate composition, lipid oxidation and texture profile. Formulation of different mince and surimi-based products. Preparation of battered and breaded products from prawns, fish and bivalves. Preparation of MAP products and comparison with chilled products. Super critical fluid extraction principles and procedure. Preparation of High Pressurized Product from fish

VII. Suggested Reading

- Ahmed J. 2010. *Novel Food Processing: Effects on Rheological and Functional Properties*: Boca Raton, Fla./: CRC Press, .
- Balachandran KK. 2001. *Post-Harvest Technology of Fish and Fish Products*. Daya Publ.
- Gopakumar K. (Ed.). 2002. *Text Book of Fish Processing Technology*. ICAR.
- Fereidoon Shahidi, Yvonne M. Jones, David Kitts. 2014. *"Seafood Safety, Processing, and Biotechnology*" Taylor and Francis (Boca Raton)
- Hall GM. 2011. *Fish Processing*. Chichester, West Sussex, U.K./; Wiley-Blackwell Pub.
- Hall GM. (Ed.). 1992. *Fish Processing Technology*. Blackie.
- Jacob JP. 2013. *A Handbook on Food Packaging*. New Delhi: Daya Publishing House.

- Joseph P. Kerry. 2012. *Advances in Meat, Poultry and Seafood Packaging* Woodhead Publishiong Limited (Cambridge)
- Nambudiri DD. 2006. *Technology of Fishery Products*. Fishing Chimes.
- Robertson Gordon L. 2010. *Food Packaging and Shelf Life*. Boca Raton, FL/: CRC Press/ Taylor and Francis Group .
- Sen DP. 2005. *Advances in Fish Processing Technology*. Allied Publ. Wheaton FW and Lawson TB. 1985. *Processing Aquatic Food Products*. John Wiley and Sons.

I. Course Title : Nutraceuticals of Aquatic Origin

II. Course Code : FPT 606

III. Credit Hours : 1+1

IV. Aim of the course

To teach about compounds of nutraceutical importance from the sea

V. Theory

Unit I

Nutraceuticals: An overview; Nutritional and functional value of marine proteins, Lipids and health benefits of omega-3 fatty acids.

Unit II

Functional foods: Functional components from fish processing waste: Extraction and applications of collagen, Collagen peptides, Gelatin and gelatin hydrolysates, Chitosan and glucosamine hydrochloride, Squalene and its clinical significance, carotenoids and their utility.

Unit III

Marine bioactive compounds: Antimicrobial, Cytotoxic substances; Antiviral and antitumor compositions; Secondary metabolites of corals with therapeutic value; Antioxidants from marine sources and antioxidant capacity assays-Ferric Reducing Antioxidant Power Assay, â-carotene bleaching assay, ABTS and DPPH assays.

Unit IV

Delivery of nutraceuticals: Fortification and encapsulation with marine nutraceuticals, Encapsulating methods (spray drying, freeze drying and liposome entrapment), Macromolecules of marine origin used as biopackaging, Edible films and coatings and drug delivery systems.

VI. Practical

Extraction of gelatin and collagen from fish waste. Extraction of fish protein hydrolysate and evaluation of their functional properties. Preparation of Chitin and chitosan from shrimp shell waste. Emulsification of fish oil with different emulsifiers. Preparation of omega-3 fatty acid by urea crystallization method. Encapsulation of omega-3 fatty acids by spray drying and freeze drying. Extraction of carotenoids and determination of their antioxidant capacity by Ferric Reducing Antioxidant Power, β-carotene bleaching and ABTS and DPPH assays. Determination of antimicrobial assays.

VII. Suggested Reading

- Barrow CJ. 2008. *Marine Nutraceuticals and Functional Foods*. Boca Raton/: CRC Press.
- Colin Barrow, Fereidoon Shahidi. 2007. *Marine Nutraceuticals and Functional*

Foods. CRC Press Inc. (Florida)
- John Shi. 2007. *Functional Food Ingredients and Nutraceuticals*, CRC Press Inc. (Florida)
- Jose L Martinez. 2007. *Supercritical Fluid Extraction of Nutraceuticals and Bioactive Compounds*. CRC Press (Boca Raton)
- Kim SK. ed., 2013. *Marine Proteins and Peptides: Biological Activities and Applications*. John Wiley and Sons.
- McNeil Archer D, Giavasis, L, Harvey L. 2013. *Microbial Production of Food Ingredients, Enzymes and Nutraceuticals* Woodhead Publishing Limited (Oxford)
- Se-Kwon Kim. 2013. *Marine Nutraceuticals: Prospects and Perspectives*, CRC Press (Boca Raton)
- Venugopal Vazhiyl 2011. *Marine Polysaccharides/: Food applications*. Boca Raton/ : Taylor and Francis.
- Venugopal V. 2009. *Marine Products for Healthcare: Functional and Bioactive Nutraceutical Compounds from the Ocean*. CRC Press Inc. (Florida)

I. Course title : Toxins and Contaminants

II. Course code : FPT 607

III. Credit Hours : 2+1

IV. Aim of the course

To understand various types of toxins and contaminants in seafood, their impact on human health, and the analytical methods to estimate toxins and contaminants in foods.

V. Theory

Unit I

Food borne pathogens: Status of food borne diseases, Epidemiology; Public health significance of food borne toxins, Pathogens.

Unit II

Marine bio-toxin: Ciguatoxin, Paralytic shellfish toxins, Diarrhoetic shell fish toxins, Scomberotoxins, Brevi toxins, etc., Symptoms, treatment, Pharmacology and detection;.

Unit III

Bacterial toxins: Types, Structure, Mechanisms; Food allergens.

Unit IV

Chemical contaminants of the aquatic environment: Heavy metals (Hg, Cd, Pb, Cr, Ni, As etc.), Pesticides.

Unit V

Antibiotic residues in fish, Microplastics, PAHs; Toxicity and accumulation.

Unit VI

Analytical methods: For different types of marine toxins and tolerance limits, Stability, Bioassays, Pharmacology assays, Immunoassays, Instrumental methods, Persistent pollutants, Toxicity evaluation, Measurement of LC_{50} and factors affecting LC_{50}, Animal tissue analysis.

VI. Practical

Detection of bacterial toxins by assay. Analysis of heavy metals, pesticides and antibiotic residues by ELISA method Estimation of LC50 vale of important pesticides. Quantification of antibiotic residue by LCMSMS.

VII. Suggested Reading

- Anon. 1988. *Handbook of Natural Toxins*. Vol. III. Marine Toxins and Venom. Marcel Dekker.
- Anon. 1988. *Handbook of Natural Toxins*. Vol. IV. Bacterial Toxins. Marcel Dekker.
- Anon. 2001. *Food borne Disease Handbook*. 2nd Ed. Vol. IV. Seafood and Environmental Toxins. Marcel Dekker.
- Edward PR. 1984. *Seafood Toxins*. American Chemical Society, Washington, D.C.
- Luis M Botana. 2000. *Seafood and Freshwater Toxins: Pharmacology, Physiology and Detection*, "Marcel Dekker, Inc." (New York)
- Moss J, Iglewski B, Vaughan M and Ju AT. 1995. *Bacterial Toxins and Virulence Factors in Disease*. Vol. VIII. Marcel Dekker.
- Nobuhiro Fusetani, William Kem. 2009. *Marine Toxins as Research Tools*, Springer (Dordrecht)
- Zadunaisky J. 1984. *Toxins, Drugs, and Pollutants in Marine Animals* Springer Verlag.

I. Course Title : Additives in Fish Processing

II. Course Code : FPT 608

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize with the use of different additives, their effects, levels and detection

V. Theory

Unit I

Food additives in fish processing: Importance of food additives, Classification of additives- Antioxidants, preservatives, Emulsifiers and stabilizers, Food colors, Flavours, Sequestrants, Anticaking agents, Acids-buffers-bases, Humectants, Firming and Crisping agents, Sweeteners, Enzymes, Nutritive additives, Flour and Bread additives, Cryoprotectants.

Unit II

Food additives and hypersensitivity: Risks and benefits of food additives, Health considerations and safety evaluation; Toxicity, and toxico-kinetics, Genotoxicity, Reproductive toxicity, Sub-acute toxicity, Sub-chronic toxicity, Chronic toxicity, Carcinogenicity, Allergenic effect, Allowable daily intake.

Unit III

Proteins as food additives: Natural antimicrobials- Bacteriocins, Natural antioxidants, Changes in properties of food due to different food additives.

Unit IV

Legal issues in additives: Laws related to additives, Methods of demonstrating safety, GRAS (Generally Recognized as Safe) additives, Problem of adulteration and solution.

VI. Practical

Analysis of processed seafood for TPP residues, citric acid, meta bi-sulphate residues. Analysis of food for presence of undesirable residues of food additives Antibiotics, Antioxidants, Antifungal agents and Colouring agents.

VII. Suggested Reading

- Ashrust PR. 1999. *Food Flavourings*. 3rd Ed. Aspen Publ.
- Belitz HD and Grosch W. 1999. *Food Chemistry*. 2nd Ed. Springer.
- H A Modi. 2012. *Food additives*. Aavishkar Publishers Distributors (Jaipur)
- Hutching JB. 1999. *Food Colour and Appearance*. 2nd Ed. Aspen Publ.
- Michael J. Scotter. 2015. *Colour Additives for Foods and Beverage*. Woodhead Publishing Limited (Oxford).
- NIIR Board. *Food colours, flavours and additives technology hand book*. National Institute of Industrial Research (Delhi)
- Semih Otles. 2012. *Methods of Analysis of Food Components and Additives*.CRC Press (Boca Raton)
- Teranishi R, Buttery RG and Shahidi F. 1989. *Flavour Chemistry – Trends and Developments*. American Chemical Society, Washington D.C.

I. Course Title : Sensory and Physical Analyses

II. Course Code : FPT 609

III. Credit Hours : 2+1

IV. Aim of the course

To obtain expertise in sensory and physical analyses of food products

V. Theory

Unit I

Basics of Sensory and Physical analysis: Development of sensory testing, Human subjects as instruments, Conducting a sensory study, Sensory attributes and their perception.

Unit II

Requirements of Sensory evaluation: Controls for test room, Product and panel, Factors influencing sensory verdicts.

Unit III

Measuring responses: Difference tests, Triangle test, Duo-trio and other tests, attribute difference tests, Concepts of RSM.

Unit IV

Physical and Mechanical properties of foods: Colour, Dielectric properties, Rheology, Viscosity of fluid foods, Viscoelastic behaviour, Texture measurements.

Unit V

Determining thresholds, Selection and training of panel members.

Unit VI

Guidelines for analysis and Reporting: Descriptive analysis techniques, Spectrum descriptive analysis method, Affective tests, Statistical methods and procedures, Guidelines for choice of techniques, Guidelines for reporting results.

VI. Practical

Assessment of taste panelists. Use of different decision-making aids. Determining threshold for different additives, colour and dielectric properties of fish muscle. Evaluation of rheology properties of gel prepared from fish protein. Estimation of Viscosity of fluid foods. Determination of Viscoelastic behavior fish-based products. Texture profile analysis of fish products.

VII. Suggested Reading

- David Kilcast. 2013. *Instrumental Assessment of Food Sensory Quality: a Practical Guide*, Woodhead Publishing (New Delhi)
- Gail Vance Civille, B Thomas Carr. 2015. *Sensory evaluation techniques*, CRC Press (Boca Raton)
- Harry T Lawless. 2012. *Laboratory exercises for sensory evaluation*, Springer (Dordrecht)
- Henryk Jelen. 2011. *Food Flavors: Chemical, Sensory and Technological Properties*. CRC Press (Boca Raton).
- Lawless Harry T. 1991. *Sensory science theory and applications in foods*. Marcel Dekkar, Inc.,
- Michael O'Mahony. 2014. *Sensory evaluation of food: statistical methods and procedures*."Marcel Dekker, Inc." (New York).

I. Course Title : Environmental Impact of Fishery Industries

II. Course Code : FPT 610

III. Credit Hours : 1+1

IV. Aim of the course

To provide theoretical and practical exposure on Environmental Management Systems in fisheries industry

V. Theory

Unit I

Environmental management systems: Environmental issues (ozone depletion, global warming, etc.), Pollution, Long term ecosystem degradation, Environmental aspects of fisheries industries, Their assessment, Impact and control.

Unit II

Sources of environmental concerns (physical, chemical and microbiological); Environmental review of fisheries industry.

Unit III

Techniques for the identification of environmental aspects; Remediation of environmental pollution, IS/ISO 14000 and its relevance to environmental management system in fisheries industry; Background, policy and planning, Implementation, Checking and review.

Unit IV

Legal issues: International and European laws for environmental protection; National environmental laws.

VI. Practical

Composition analysis of fish processing solid and liquid wastes. Treatment effect on solid waste. Treatment effect on liquid waste. Resident time analysis for processing waste at the site of disposal. Estimation of nutritional composition of dried sludge. Effect of probiotic on effluent treatment system.

VII. Suggested Reading

- Anon. 2000. *Manual of Chemical Methods*. 2nd Ed. Bureau of Indian Standards: IS/ISO 14000: 1996 on Environmental Management System US-EPA.
- Avogadro A, Ragaini RC. 1994. *Technologies for Environmental Cleanup: Toxic and Hazardous Waste Management*. Kluwar Academic Publishers

- Cesceri LS. 1998. *Standard Methods for Examination of Water and Waste Water*. APHA.
- Hurst CJ. 2002. *Manual of Environmental Microbiology*. 2nd Ed. ASM Press.
- Ramamoorthy S. 1991. *Evaluation of Environmental Data for Regulatory and Impact Assessment*, Elsevier Science B.V.
- U Sonesson, J Berlin, F Ziegler. 2010. *Environmental Assessment and Management in the Food Industry: Life Cycle Assessment and Related Approaches*, Woodhead Publishing Limited (Oxford).
- Wise DL. 1994. *Process Engineering for Pollution Control and Waste Minimization*. Marcel Dekker.

I. Course Title : Food Labeling

II. Course Code : FPT 611

III. Credit Hours : 1+1

IV. Aim of the course

To create basic understanding about labeling of different products, guidelines and enforcement

V. Theory

Unit I

Labeling requirements: National and international; Legislation on labeling.

Unit II

Labeling and Traceability: Labeling for product traceability, Components of traceability code – nutrition facts and nutrition labeling, Specific requirements of nutrition labeling.

Unit III

Label design specification: Size, Colour, Barcoding types, Types of labeling for organic foods, GM foods, Irradiated foods, Meat and non-meat foods, Major nutrients Minor nutrients, Essential nutrients, Function of nutrients - providing energy, Tissue building.

Unit IV

Food meant for specific age groups and convalescing people, Serving size, Calculation of nutrition facts based on nutrient composition and serving size, Energy value of foods, EC number.

VI. Practical

Analysis of major and minor nutrients. Calculation of nutrition facts. Preparation of labels for typical food items. Analysis for total calorific value of fish fats, protein and carbohydrates.Estimation of PER, BV and NPU value of fish products.

VII. Suggested Reading

- Akhil Mathur. 2012. *Food Processing, Packaging, Labelling and Marketing*. Anmol Publications Pvt. Ltd. (New Delhi)
- Jerry D'Souza, Jatin Pradhan. 2010. *Handbook of Food Processing Packaging and Labeling*. SBS Publishers and Distributors Pvt. Ltd. (New Delhi)
- Jnsel P, Turna RE and Ross D. 2001. *Nutrition*. Jones and Bartlet.
- Seshadri V. 1998. *Introduction to Clinical Nutrition and Nutritional Labelling*. Marcel Dekker.
- Simpson DS. 1987. *Food Biochemistry and Nutritional Value*. Longman.

I. Course Title : Water Quality Management in Seafood Processing

II. Course Code : FPT 612

III. Credit Hours : 2+1

IV. Aim of the course

To obtain enough knowledge in all aspects of water quality and its management for processing and drinking purpose.

V. Theory

Unit I

Sources and types of water: Type I, Type II, Type III, their characteristics; Reagent grade water specifications, Sources of contamination of drinking water, Ground water contamination, Chemical threats to drinking water quality; Primary water quality criteria; Point source and non-point source of contamination.

Unit II

Water quality criteria: Physical factors (hardness, colour, odour, taste, turbidity, conductivity, pH and Eh), Chemical parameters (physico-chemical parameters in relation to water's natural structure), Microbiological parameters, Important pathogenic organisms and their sources, Salmonella, Pathogenic Staphylococcus, Fecal bacteria, Enteroviruses, Algae, other organisms.

Unit III

Undesirable substances in drinking water: Parameters concerning toxic substances; Toxic metals/metalloids, Cyanides, Pesticides and related products and polycyclic aromatic hydrocarbons; Organic compounds and their tolerances; Polychlorinated biphenyls, pentachlorophenol, 2, 4, 6 trichlorophenol, chlororesorcinol, total nitramine and haloforms in potable water.

Unit IV

Water quality standards: Indian standard, US PHS, EEC, WHO standards. Examination of water; Microbiological examination; frequency, public supply with intermediate storage and without intermediate storage; Examination for undesirable and toxic substances; Method of analysis, sampling, etc.

Unit V

Water budgeting and treatment: Budgeting of water for different processing methods; Affluent water treatment and disinfection methods: purification and treatment of water, Chlorination of water, Use of chlorine dioxide ($Cl0_2$) ozonization, UV radiation and reverse osmosis; Implications of chlorination and trihalomethane compounds in drinking water.

Unit VI

Effluent Water treatment and disinfection methods: Primary treatment, Secondary treatment, Methods of waste water treatment in seafood industries.

VI. Practical

Estimation of available chlorine, undesirable physical and chemical objects present in the fish processing water. Examination of microbiological quality of water used in fish processing industry. Estimation of BOD and COD of effluent water. Effect of ozonation and chlorinationon water quality.

VII. Suggested Reading

- Zachritz Walter H. 1991. *Wastewater Treatment: Options for Louisiana Seafood Processors*. Louisiana Sea Grant College Program.
- Walters. 1981. *Industrial Effluent Treatment,* Applied Science Publishers Ltd (London).
- Frank R Spellman. 2013. *Handbook Water and Wastewater Treatment plant Operations*. CRC Press (Boca Raton).
- Baird Rodger B. 2017. *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, USA.

List of suggested Journals

- *Journal of Food Science and Technology*
- *Journal of Food Safety*
- *Journal of Food Protection*
- *Journal of Food Science*
- *Fishery Technology*
- *Applied and Environmental Microbiology*
- *FEMS Microbiology Letters*
- *Food Science and Technology International*
- *Food Science and Technology Research*
- *Food Technology*
- *Applied Biochemistry and Biotechnology*
- *Applied Biochemistry and Microbiology*
- *Current Science*
- *Packaging Technology and Science – International Journal*
- *Journal of Aquatic Food Product Technology*
- *International Journal of Current Microbiology and Applied Sciences*
- *Food Control*
- *Journal of Environmental Biology*
- *Indian Journal of Geo Marine Sciences*
- *Food Science and Biotechnology*

List of suggested e-Resources

- http://www.fao.org/3/v3630e/v3630e03.htm
- http://www.fao.org/3/v7180e/v7180e06.htm
- https://www.ncbi.nlm.nih.gov/pubmed/6746595
- https://link.springer.com/chapter/10.1007/978-1-4613-1113-3_4
- http://www.fao.org/3/y5979e/y5979e03.htm
- https://pdfs.semanticscholar.org/424f/9b8c413044e308d28cfcfefd36899114ca67.pdf
- https://onlinelibrary.wiley.com/doi/10.1002/9781118346174.ch4
- https://www.sciencedirect.com/science/article/pii/S2214241X16300499
- https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2672.1971.tb02291.x
- http://www.fao.org/3/X5624E/x5624e08.htm
- https://www.tandfonline.com/doi/pdf/10.1080/10408399509527708
- https://www.mpeda.gov.in/MPEDA/general_description.php#
- https://www.fda.gov/food/food-imports-exports/seafood-imports-exports
- http://www.fao.org/3/x5625e0f.htm
- http://www.ifpkochi.nic.in/IFPS3.pdf
- http://agris.fao.org/agris-search/search.do?recordID=US201300091650
- http://www.scielo.br/scielo.php?script=sci_arttext and pid=S0101-20612019000500146
- http://www.genaqua.org/uploads/pdf_19.pdf
- http://drs.cift.res.in/handle/123456789/1086
- https://onlinelibrary.wiley.com/doi/10.1002/9781118346174.ch10
- http://www.fao.org/fi/staticmedia/MeetingDocuments/WorkshopAMR17/presentations/22.pdf
- http://drs.cift.res.in/handle/123456789/1514

- https://www.tandfonline.com/doi/abs/10.1080/08982119908919278
- https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118434635.ch11

Suggested Broad Areas for Master's and Doctoral Research

- Changes in muscle during freezing
- Technology to improve shelf-life of seafood
- Novel packaging and transportation methods of seafood
- Prevention of nutrient loss during frozen storage
- Molecular markers development for identifying adulteration
- Nutritional changes during frozen storage
- Development of new value-added fishery products
- Effective utilization of fish wastes
- Development of product from discarded fish
- Development low cost tools to detect pathogens in seafood
- Occurrence and virulence characteristics of emerging pathogens in seafood
- Evaluation and prevention of anthropogenic contaminants during processing seafood
- Effect of different processing methods on quality and shelf-life of fish
- Assessment of algal, fungal and biological toxins in seafood
- Effective methods for treatment of waste water from processing industries
- Water budgeting for various seafood processes
- Development of new ready to eat fish products
- Assessment and monitoring method for quality standards of processing plants
- Development of sensors for quality detection
- Designing of instruments used in fish processing plants
- Development of low cost and sustainable packaging materials
- Utilization of nanotechnology in fish processing industry
- Automation in seafood processing and quality determination
- Application of AI in seafood processing and quality evaluation

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fishing Technology and Engineering

Preamble
(Fishing Technology and Engineering)

India has 8,118 kms coastline, 2.02 million sq. km Exclusive Economic Zone, 0.530 million sq. km Continental Shelf, 1,95,210 km of Rivers and Canals and 7.892 million ha of inland water bodies which results in capture fish production of over 7.0 million metric tonnes. Fisheries sector in India has shown impressive growth with an average annual growth rate of 10.88% during the year from 2014-15 to 2018-19. Fish production reached an estimated/ level of 11.6 million tonnes in 2017. In that year, the estimated production for capture fisheries was of almost 5.4 million tonnes (3.8 million tonnes from marine and 1.6 million tonnes from inland water). There are 2.39 lakh fishing crafts (58,911 mechanized, 75,591 motorized, 104,270 Non-motorized) operating various types of fishing gears along the coast, with 7 major fishing harbours, 75 minor fishing harbours and 1,537 landing centres are functioning to cater to the needs of over 4.0 million fisher folk engaged in capture fisheries.

To provide sustained and holistic development of fisheries in the country both the state and central governments recently offers various scheme namely, Blue revolution, Scheme for empowerment of traditional fishermen in Deep Sea fishing, Fisheries and Aquaculture Infra structure Development project. Hence, it is the need of the hour to increase the quality of syllabus in Master's degree and Doctoral program in 'Fishing Technology and Engineering encompasses mainly fishing gear and craft technology for responsible and sustainable capture fisheries, Fishing harbors and fishing fleet management, advanced fish processing machineries and refrigeration systems subjects apart from newly added courses like Deep sea fishing, GIS and Remote sensing to meet the demand of the industry.

The following topics namely Aimed fishing using the modern electronic devices like echo sounder, Sonar and trawl eye, Refrigeration in deep sea fishing vessels- design and working of RSW and CSW, Power transmission in fishing vessels, Sea Laws, Deep sea fishery resources, Weather and warning, Familiarization of meteorological equipments onboard, Weather forecasting and weather prediction at sea, Basics of sound in water-Ultra sonic sound and its characteristics, Recent advances in fishing vessel navigation, Aerial Photography, Remote Sensing, Digital image processing, Image rectification and Image enhancement - Filtering - band rationing, Image classification - supervised and unsupervised classification, Remote sensing application in soil and water conservation, **GIS** - types - raster - vector, Data base management systems - Data types - spatial - non-spatial, Spatial data models, Spatial referencing, Map projections, Data input, Editing, Encoding, Raster data analysis, Vector data analysis, NOAA and IRS- Satellites for Ocean and Fisheries studies- Digital image processing and interpretation, Application of remote sensing and GIS to fisheries and aquaculture planning and development, **PFZ-**Basics and application- Validation of PFZ data- INCOIS- Data Dissemination-Fishermen knowledge in PFZ were added.

By considering the vast opportunity and requirements in the field of fishing industry Doctoral program in 'Fishing Technology and Engineering is a must and this programme mostly deals with modern fishing technology to meet the global standards. Subjects like Mechanization in Fishing, Advanced Fishing Gear Designing and Construction, Fishing

Gear Selectivity, Deep Sea Fishing, Sustainable Fishing Methods, Fishing Harbour Planning, Construction and Management, Electronic Navigation and Sea Safety for Fishing Vessels were dealt in the programme.

The above new additions and updates will scale up the knowledge of the students to face the challenges of the competitive global fishing industry.

Course Title with Credit Load
M.F.Sc. in Fishing Technology and Engineering

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FET 501	Advanced Fishing Gear Technology	2+1
FET 502	Advanced Fishing Craft Technology	2+1
FET 503	Responsible Fishing	1+1
FET 504	Refrigeration and Electrical Engineering	2+1
FET 505	Marine Engineering	1+1
FET 506	Introduction to Deep sea Fishing	1+1
FET 507	Fishing Harbour and Fleet Management	1+1
FET 508	Acoustics, Navigation and Seamanship	2+1
	Minor Courses (From the subjects closely related to a students major subject)	**8 Credits**
FET 509	Engineering Graphics	0+1
FET 510	GIS And Remote Sensing in Fisheries	2+1
FET 512	Sea Safety and Disaster Management	1+1
FET 513	Fish Processing Machinery	1+1
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common Courses (The following courses, one credit each will be offered)	**5 Credits**
	1. Library and Information Services	
	2. Technical Writing and Communication Skills	
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FET 591	Master's Seminar I	0+1
	Masters' Thesis Research	**30 Credits**
FET 599	Master's Research (Semester III)	0+15
FET 599	Master's Research (Semester IV)	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fishing Technology and Engineering

I. Course Title : Advanced Fishing Gear Technology
II. Course Code : FET 501
III. Credit Hours : 2+1

IV. Aim of the course

To teach advanced fishing gear technology, To learn design modification of existing fishing gears, To learn selectivity of various fishing gears.

V. Theory

Unit I

Fishing gear design drawings: Survey of various fishing gears; Conventional and current practice for the representation of fishing gear by FAO specifications for scale drawing; The use of computers in the scale drawing of fishing gear to determine the defects in gear, design to develop new gears.

Unit II

Fishing gear selection: Use of fishing gear materials and their comparison; Selection of fishing gear, Analysis of the parameters of specific fishing gears and the derivation of empirical relationships for use in the design process.

Unit III

Fishing gear design and construction: Factors responsible for the choice of fishing gears; Design and construction of bottom, Mid-water and surface trawl; Gill nets and tangle nets; Types of gill nets – Simple gill net, vertical lines gill net, Framed gill nets, tangle nets and their technical characteristics, Two and three walled trammel nets, Combined gill nets; Purse seines and their classification, Longlines, Pole and Lines, Trolling line, Traps – Their classification and general principles of construction.

Unit IV

Light and electricity in fishing: Attraction of fish – fishing with electricity and application in various fishing methods, Light fishing, Fish pumps; Operation and mechanization of long lining and jigging.

Unit V

Gear Selectivity: The selectivity of trawl fishing gears, Gill nets, Purse seine and longline, Design of otter boards for various types of trawl fishing; Factors to be considered in gill netting in selection of meshes for the different fishes; Aimed fishing using the modern electronic devices like echo sounder, Sonar and Net sonde.

Unit VI

Testing fishing gear: Case studies relating to towed, surrounding and static fishing gear and their energy consumption, Fishing gear testing – full scale and

model testing in flume tanks, methods of testing a fishing gear, External forces acting on fishing gears, The influence of design features on the overall economic performance of fishing gears.

VI. Practical

Exercises on scale drawing of different types of fishing gears. Use of computer software's programme in the design of trawl gears. Model net calculations, Calculations of energy requirements of different gears. Onboard experience of different fishing methods. Use of net monitoring instruments. Study of fishing gears through models of nets and field study. Making sketches. Reading of gear designs. – Trawl nets, Purse seines, Gill net and Long line. Familiarization with design drawing software. Design of otter boards and other accessories. Survey of gears and preparation of designs according to scale by taking measurements from a net.

VII. Suggested Reading

- Baranov FI. 1969. *Selected Works on Fishing Gear* Vol. I *Commercial Fishing Techniques*, Israel Programme for Scientific Translations, Jerusalem, 631p.
- Baranov FI. 1977. *Selected Works on Fishing Gear*. Keterpress Enterprises. Israel: 259 p.
- Ben-Yami M. 1994. Purse seining manual, FAO Fishing manual, 416p.
- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publishing House – Delhi: 207 p.
- Bjordal and Lokkeborg S. 1998. *Long Lining*, Fishing News Books Ltd. Farnham, 208p.
- Brandt AV. 1984. *Fish Catching Methods of the World*. Fishing news books Ltd., London, 432p.
- FAO. 1987. *Small Scale Fishing Gear*: 19 – 44pp.
- Fridman AL. 1986. *Calculations for Fishing Gear Designs*, FAO Fishing manual, Fishing News Books, Ltd., Farnham, 264p.
- John Garner. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books Ltd. England: 91p
- Kristionsson H. 1975. *Modern Fishing Gear of the World*. The White Friars Press Limited. London: 594 p.
- Shaul Hameed M and Boopendranath MR. 2000. *Modern Fishing Gear Technology*: 193p.
- Sreekrishna Y and Shenoy Latha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research. New Delhi, 342p.

I. Course Title : Advanced Fishing Craft Technology

II. Course Code : FET 502

III. Credit Hours : 2+1

IV. Aim of the course

To teach advanced aspects of fishing craft design, To learn about modification of existing craft layout, To learn about fishing craft stability.

V. Theory

Unit I

Fishing craft: Different types of fishing crafts – trawler, stern and side trawler, Purse seiner, Long liner, Gill netter, troller etc; Main differences in the method of construction and design; Consideration regarding the speed and other fishing requirements, Deck layout and deck equipments of fishing vessels based on the fishing method; Planning internal capacities of fish hold, Engine room, Crew accommodation, Fuel tanks and Freshwater tanks.

Unit II

Boat materials: Choice of the construction materials; Comparison of materials used in fishing boat construction; Bio-deterioration of wood – marine fouling and boring organisms, Preventive measures, Raw materials, properties, Merits and demerits of FRP, Steel, Aluminium and Ferro-cement, Corrosion – types, Fundamentals, measurement and preventive measures.

Unit III

Steering gear and Hull: Principles of operating steering arrangement; Remote control; Rudder – principles – types; Steering gear – Principle and operation – Mechanical and Hydraulic; Principal dimensions of boat, Importance of shape of underwater hull, Classification and description of hull forms based on shape; Form coefficients and proportionality coefficient for different types of vessels; Various ship motions at sea; Hull resistance; Behaviour of boats to waves from different sides.

Unit IV

Stability aspects of fishing vessels: Factors affecting stability; Longitudinal stability – Trim, Moment of change of trim by 1 cm; Transverse stability – List, heel, LOLL, Meta centric height and meta centric radius, GZ curve, Degree of vanishing stability, Free surface effect, Hydrostatic curves, Dynamic stability, Stability criteria, Safety measures to restore stability in fishing vessels; Inclining experiment.

Unit V

Propellers and Power: Powering of fishing boats; power transmission system in fishing vessels; Effects of wetted surfaces on speed; Types of propellers; Designing principle power requirements of various types of fishing boats, Auxiliary power, Propulsive efficiency, Use of kort nozzle.

Unit VI

Construction of fishing boat: Layout of a typical boat building yard, Various stages of construction, Description of various machines and tools used in boat building yard, Stages of wooden boat building – Sheathing of wooden hull – Steel boat construction and FRP boat construction, Inspection of fishing boat under construction, Care and maintenance of fishing boats – Factors causing damage, Hull protection methods and maintenance schedule, Inspection of damaged fishing vessels, Regulation of fishing vessels and classification of societies in various countries.

VI. Practical

Basic principles of drawing, drawing of fishing vessels – line drawing – sectional view of the boat and keel assembly – half breadth & body. Visit to boat building yards for on – the – spot study of different stages of wooden boat construction and to study the layout. Identification of various tools and machines used in boat building. Study of various stages of boat construction with the help of boat models and making their sketches. Calculation of various dimensions; Study of deck lay outs of different types of fishing vessels and preparation of sketches; Visit to dry dock

VII. Suggested Reading

- Fyson JF. (ed). 1985. *Design of Small Fishing Vessels*, Fishing News Books, Oxford.
- Marine institute. 1988. *Proceedings of the World Symposium on Fishing Gear and Fishing Vessel Design*, The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, Newfoundland, Canada, 610p.
- Pike D. 1992. *Fishing Boats and Their Equipments*. Fishing News Books. Oxford: 184p.
- Ponnambalam A. 2003. *Fishing Craft Technology*. CIFNET. Cochin: 157p.
- Ponnambalam A. 2003. *Fishing Craft Technology*. CIFNET. Cochin: 158p.
- Sanisbury JC. 1996. *Commercial Fishing Methods-an Introduction to Vessels and Gear*, Fishing News Books Ltd., Farnham, 352p.
- Shenoy Latha. 1988. *Course Manual in Fishing Technology*, CIFE, Mumbai, 95p.
- Sreekrishna Y and Shenoy Latha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research, New Delhi, 342p.
- Tan-olofTraung. 1967. *Fishing Boats of the World*. Fishing News (book) limited. London. 635p.
- Yadav YS. 2002. *Traditional Fishing Craft of the Bay of Bengal*. BOBP. Chennai: 55p.

I. Course Title : Responsible Fishing

II. Course Code : FET 503

III. Credit Hours : 1+1

IV. Aim of the course

To teach various responsible fishing techniques, To learn about damage to the environment & biodiversity by existing fishing methods, To learn about methods of reducing by catch in trawl net.

V. Theory

Unit I

CCRF: Scope and objectives of FAO Code of conduct for Responsible Fisheries, Articles of CCRF – Description of the code, Analysis of marine catch data (present & past); analysis of CCRF concept.

Unit II

By-catch: Elaboration of Article 8 – Fishing operations; By-catch and discards – Definitions, By-catch estimation methods, by-catch reduction devices, turtle excluder devices, Finfish and shrimp excluder devices. Selective fishing gear and practices: Selectivity of trawls, gill nets and lines – Environmentally friendly fishing methods and fishing gears – Energy conservation and resource enhancement.

Unit III

Fish Aggregation Devices (FADs and Artificial reefs): Objectives, Types of FADs and artificial reefs; Design and construction of FADs and artificial reefs; Energy optimization in fisheries – Methods of energy conservation in fish harvesting. Remote Sensing and PFZ: Application of Remote sensing, PFZ and GIS in fisheries.

Unit IV

IUU - Illegal, Unregulated and Unreported fishing methods; Destructive and prohibited fishing systems and practices. Effect of fishing on non-target species: Effect of bottom trawl and gill nets on benthic fauna and habitats; Conservation methods issues and implications for biodiversity.

VI. Practical

Study of design and operation of BRDs and TEDs; Preparation of document listing and prohibited fishing practices; compilation of package of practices for energy conservation; interpretation of SST and Ocean colour charts, Study of Potential Fishing Zone (PFZ) maps; problems on fishing gear selectivity; studies on impact of various fishing gears on environment and biodiversity.

VII. Suggested Reading

- Bergstrom M. 1983. *Review of Experiences with and Present knowledge about Fish Aggregating Devices*, BOBP/WP/23 Bay of Bengal programme, Madras.
- CIFNET MODULE III & IV. *Code of Conduct for Responsible Fisheries*. 61-69pp.
- FAO. 1995. *Code of Conduct for Responsible Fisheries*, FAO, Rome, 41p.
- FAO. 1996. *Fishing Operations*, FAO Training Guidelines for responsible fisheries No.1, FAO, Rome 26p.
- FAO. 2003. *Fisheries Management*. 2. The ecosystem approach to fisheries, FAO
- Michel Kaiser and Groot. *Effect of Fishing on Non-target species and Habitats* Blackwell publishing
- *Technical Guidelines for Responsible Fisheries* – No.4, Suppl.2, FAO Rome.

I. Course Title : Refrigeration and Electrical Engineering

II. Course Code : FET 504

III. Credit Hours : 2+1

IV. Aim of the course

To teach engineering aspects about refrigerators, freezers, To learn about heat-load calculation and COP, To teach electrical aspects of fishing vessel.

V. Theory

Unit I

Principles of refrigeration: Refrigeration cycle; Vapour Compression system, Vapour absorption system, Steam Jet Refrigeration System, Solar energy based refrigeration systems; Application of Refrigeration in fisheries, Refrigeration in sea food processing plant – Refrigeration in deep sea fishing vessels – design and working of RSW and CSW – Coefficient of Performance (CoP) – ton of refrigeration – Refrigerator efficiency calculations.

Unit II

Heat load and efficiency: Heat load calculations – Insulations in freezers and cold stores – Frosting and defrosting in freezers and cold stores; Refrigeration in factory Trawlers; Types of Refrigerated transport.

Unit III

Refrigerants: Types and properties, Use of different refrigerants in seafood processing industry; Brine solution and dry ice refrigeration.

Unit IV

General structure of electrical power systems: Power transmission and distribution via overhead lines and underground cables, Steam, Hydel, Gas and Nuclear power generation, Principal and application of DC Networks, Single phase AC Circuits, Three phase AC circuits, Magnetic Transformers, Induction motor, DC Motors etc.

Unit V

Electrical Measuring Instruments: DC PMMC instruments shunt and multipliers, multi-meters, Moving iron ammeters and voltmeters, Dynamometer, Wattmeter, AC watt-hour meter, Extension of instrument ranges.

Unit VI

Principles and working of electronic components: Audio, R.F. circuits; Electron tubes, Transistors; Principles of electronic circuits; Amplifiers, Oscillators, Rectifier, Tuned circuits – Transmission of reception.

VI. Practical

Practical Visit to refrigeration plants, heat load calculations. Handling and operation of refrigeration equipments – compressor, condenser, evaporator, liquid return system, gas purging, oil drain, oil charging, refrigerant charging, defrosting; Ice making and harvesting; study of various automatic control devices; expansion valves, L.P. and H.P. switches, solenoid valves. Study of various types of fish processing machineries; electrical motors, transformers, GPS, SONAR etc.

VII. Suggested Reading

- Ayyappan VP. 2002. *Elements of Electrical Technology*. CIFNET. Cochin. 96p.
- Joshy CD and Devadhason M. 2001. *Basic Electronics and Fish Finding Equipments*. CIFNET. Cochin: 42p.
- Shawyer M and Medina Pizzali AF. *The Use of Ice on Small Fishing Vessels*. FAO. Rome: 102p.
- Sternin UG, Nikonorou IV and Bumeister Yu K. 1976. *Electrical Fishing*. Keter. Publishing House Jerusalem Ltd. 258p.

I. Course Title : Marine Engineering

II. Course Code : FET 505

III. Credit Hours : 1+1

IV. Aim of the course

To teach engineering aspects of marine engines, To learn about effective utilization engine powers during fishing and propulsion, To study about system of fishing vessels.

V. Theory

Unit I

Engine characteristics: Capacity of cylinders, IHP, BHP, FHP, BMEP, Torque determinations; SFC values, IC engines – Working cycles – Indicator diagrams – Performance number – Supercharging – Engine performance curves – Duel-fuel engines, Handling of IC engine and maintenances – Engine and boiler room arrangements – Steering gears – auxiliary engines – Heat exchangers – Propeller Shaft driver steam generators.

Unit II

Efficiency of engines: Compression ratio and thermal efficiency; Volumetric efficiency; Mechanical efficiency different ratings – continuous, peak, intermittent, Feel and lubricant – Strokes – Cooling method – Running characteristics – Size weight – Power requirement; Propulsion system – Combinations of engine, power transmission and propeller.

Unit III

Function of main engine: Friction, Clutch, Hydraulic coupling, Gearbox, Thrust; Bearing, Shafting, Propeller, Auxiliary machinery systems – Requirements of a winch, windlass, line and net hauler – estimation of their driving torque and power; Operation of a hydraulic steering gear; Rudder torque.

Unit IV

Engineering structure; Floating offshore structures –Diving – Underwater vehicles, Estimation grower requirement for various types of fishing – Efficiency group of fishing techniques – Resistance group of fishing methods – Computation of engine power.

VI. Practical

Study of basic machine parts, shafts, keys, couplings, levers, joints, pulleys, belts, gears and bearings. Study of Engine parts, engine testing, dissembling and assembling a running condition marine engine; study of marine diesel engines, fuel consumption testing with load; Propeller calculations using the computers; calculations related to engine power- Power transmission in fishing vessels.

VII. Suggested Reading

- Calder N. 1992. *Marine Diesel Engines*. Waterline Books. England: 153-168pp.
- Fishery Engineering. CIFNET. Cochin, 68-211pp.
- Nina Morgan. 1990. *Marine Technology Reference Book*. Butterworth – London.
- Rethinadhas C. 2002. *Marine Engineering*. CIFNET, Kochi, 156p.
- RK Rajput. 2006. *Thermal Engineering* Laximi Publication, New Delhi
- Watson GO and Harvey RA. 1971. *Steering Gear*. Newnes – Butterworths, London: 306–328 pp.

I. Course Title : Introduction to Deep Sea Fishing

II. Course Code : FET 506

III. Credit Hours : 1+1

IV. Aim of the course

To learn international law of the sea, To learn about deep sea fishing policies, To learn deep sea techniques.

V. Theory

Unit I

Sea Laws: UNCLOS – Law of the sea, Base line -territorial waters, Contagious zones, EEZ and High Seas, Basics of Deep-sea Fishing-National deep-sea policies

Unit II

Deep sea fishery resources: Oceanic Tuna and tuna like fishes, Oceanic Squids.

Unit III

Deep sea fishing gears and accessories – Tune long lining, Gill netting and squid jigging, Deckequipments in deep sea fishing vessel, Mother boat concept and factory vessels in deep sea fishing.

Unit IV

Weather and warning: Wind, Wave, Current, Cyclones, Squally weathers, Doldrums, Weather forecasting and weather prediction at sea – Weather equipment and storm signals, Preparation and management of deep-sea fishing vessels.

VI. Practical

Familiarization of meteorological equipments onboards. Storm signals and visit to signalling stations. Visit to deep sea fishing vessels to study the layout, manpower, facilities for deep-sea navigation and fishing, instruments and fleet management. Study on deck equipments in deep sea fishing vessels. Visit to fisheries departments and MPEDA to know about the initiatives on deep-sea fishing.

VII. Suggested Reading

- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publishing House – Delhi: 207 p.
- Capt H Subramaniam. 2015. *Marine Meteorology,* Nut Shell Series, Book No.2 Vijaya publication, Bombay.
- DJ Randall and AP Farrell. 1997. *Deepsea Fishes*. Academic press, USA.
- Garner J. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House.
- *International Convention for the Safety of Life at Sea*. Universal Publishing Corporation. Mumbai: 1-334pp.
- NR Merrett and RL Haedrich. 1997. *Deepsea Demersal Fish and Fisheries*. Chapman & Hall, London.
- PS Balachandran. 2013. *Manangement of Deepsea Fisheries*. Random Publications.New Delhi.
- Sudhakararao. 2009. *Deep Sea Fisheries of India*. B.R.Publishing Corporation. New Delhi.
- U Shanker Rao. 2012. Deep sea fishing in India (From trawler to table). Biogreen books

I. Course Title : Fishing Harbour and Fleet Management

II. Course Code : FET 507

III. Credit Hours : 1+1

IV. Aim of the course

To teach fishing harbour design and construction, To learn about fishing fleet that management and manning regulations in fishing harbour.

V. Theory

Unit I

Fishing vessel: FAO classification of fishing vessels, Indigenous fishing boats of India – fishing boats of maritime states of India, Fishing boats used in the inland and brackish waters, Account of mechanized boats introduced in India.

Unit II

Rules and Management: Personnel management, Planning of fishing cruises, Fishing fleet capacity, Fleet registration, fleet insurance, Seaworthiness assessment, Tonnage measurements Statutory rules and regulations under MSA, Classified societies, Manning regulations and requirements; Regulations to prevent collisions at sea.

Unit III

Classification and functions of fishing harbour: Facilities – waterside and landside facilities, Services and utilities provided, Layout of a modern fishing harbour, Stages in the planning of fishing harbours, Dredging.

Unit IV

Economic evaluation: On fishing harbour project, Dry docks and slipway – Fishing harbour management and maintenance.

VI. Practical

Visit to dry dock; Visit to Fishing harbour, Study of boats with the help of boat models and making sketches; Visit to various vessel types of fishing vessel.

VII. Suggested Reading

- FAO. 1960. *Report to Government of India on Fishing Harbours Based on the Work of Carl GB Juke and CRB Juke*. FAO Report No. 1242 ETAP, pp.147.
- FAO. 1962. *Second Report to Government of India on Fishing Harbour Based on the Work of BW Johnson*. FAO Report No. 1538 EPTA, pp. 99.
- Ramakrishnan TK. 2007. *Ocean Engineering*. Gene – Tech Books. New Delhi: 233p.
- Sciortino SA, Barcali A and Carlesi M. 1995. *Construction and Maintenance of Artisanal Fishing Harbours and Village Landingss*. FAO. Rome: 136p.
- Sreekrishna Y and ShenoyLatha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research, New Delhi, 342p.

I. Course Title : Acoustics, Navigation and Seamanship

II. Course Code : FET 508

III. Credit Hours : 2+1

IV. Aim of the course

To learn engineering aspects of fish acoustic equipments, To learn navigation and seamanship for fishing vessel safety.

V. Theory

Unit I

Basics of acoustic fish detection: Basics of sound in water-Ultra sonic sound and its characteristics-Acoustic surveys in fish population studies- Acoustic equipments used in fishing.

Unit II

Acoustic Equipments: Advanced models of Echo sounder – Major components, specifications and uses; Sonar – specifications, types; Instruments used for evaluation of underwater gear performance, Acoustic trawl monitoring system.

Unit III

Navigation: Fishing vessel navigation – Recent advances in fishing vessel navigation – Methods of signalling in fishing vessels- Fixing of vessel position, Navigational charts- Rules of the road.

Unit IV

Electronic Equipments: Global positioning system (GPS); Vessel monitoring systems (VMS) and AIS (Automatic Identification System) Navigation – Types, Navigational equipments, RADAR, Autopilot, Chat plotter.

Unit V

Seamanship: Handling of fishing vessels under all conditions at sea- Ropes and rope works– Their types, Handling; strength and preservation; Knots and splices; Anchoring mooring; Steering; Rolling and pitching.

Unit VI

Accidents at sea: Accidents- causes- Preventive measures- Preparedness for Fishing vessels.

VI. Practical

Chart work and navigational equipment, chart reading, position fixing, direction and distance in navigation -calculations; Operation of echo sounder, Sonar, GPS, Radar identification and study of navigation and fishing lights and day signals, distress signals and navigational equipments like compass, chronometer, aneroid barometer, sextant and logs

VII. Suggested Reading

- CIFNET. 2004. *Fishery Engineering:* 212-238pp.
- FAO. 1998. *Fishing Operations. – Vessel Monitoring Systems*, FAO Technical Guidelines for Responsible Fisheries No. 1, Suppl. 1, FAO Rome.
- Joshy CD and Devadhason M. 2001. *Basic Electronics and Fish Finding Equipments*. CIFNET. Cochin: 31-42pp.
- Larkin FJ. 1998. *Basic Coastal Navigation*, 2nd edn, Sheridan House Inc., New York: 273 p.
- MacLennan DN and Simmonds EJ. 1992. *Fisheries Acoustics, Fish and Fisheries Series* 5, Chapman and Hall, London, 323 p.
- Mitson RB. Fisheries SONAR. *Fishing News* Books Ltd. England: 274p.
- Sreekrishnan Y and ShenoyLatha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research, New Delhi, 342 p.

I. Course Title : Engineering Graphics

II. Course Code : FET 509

III. Credit Hours : 0+1

IV. Aim of the course

To teach practical aspects of computer aided engineering graphic.

V. Practical

- Introduction to Engineering Graphics – Drawing instruments and their use – Different types of lines – Lettering & dimensioning – Familiarization with current India Standard Code of Practice for Engineering Drawing. Introduction to scales. Introduction to orthographic projections – Horizontal, vertical and profile planes – First angle and third angle projections – Projection of points in different coordinates – Projections of lines inclined to one of the reference planes.
- Projections of lines inclined to both the planes – True lengths of the lines and their angles of inclination with the reference planes – Traces of lines. Projection of plane laminae of geometric shapes inclined one of the reference planes – inclined to both the planes – auxiliary projections.
- Projections of polyhedral and solids of revolution – Frustum – projection of solids with axis parallel to one of the planes and parallel or perpendicular to the other plane – Projections with the axis inclined to one of the planes. Projections of solids with axis inclined to both the planes – Projection of spheres. Sections of solids by planes perpendicular to at least one of the reference planes – True shapes of sections, Developments.

VI. Suggested Reading

- Bhatt ND. *Elementary Engineering Drawing*, Charter Publishing House, Anand, 2002.

I. Course Title : GIS and Remote Sensing in Fisheries

II. Course Code : FET 510

III. Credit Hours : 2+1

IV. Aim of the course

To learn to use GIS and Remote sensing to foster the sustainable use of natural fisheries resources

V. Theory

Unit I

Aerial Photography: Basics of photography- terminologies- Photogrammetry - Stereoscopy - Principal points - Parallax and its measurement, Colours - Composite colour images.

Unit II

Remote Sensing - Electromagnetic Spectrum - Radiation laws - Interaction with atmosphere and surfaces, Spectral reflectance of earth materials and vegetation, Satellite Remote Sensing - Resolution - Scanning - Sensors, Land Observation Satellites - Visual image interpretation

Unit III

Image and Data: Digital image processing, Image rectification and Image enhancement - Filtering - Band rationing, Image classification - Supervised & unsupervised classification, Remote sensing application in soil & water conservation.

Unit IV

GIS - Types, raster, vector, Data base management systems, Data types, Spatial - non-spatial, Spatial data models, Spatial referencing, Map projections, Data input, Editing, Encoding, Raster data analysis, Vector data analysis.

Unit V

Satellite Application: NOAA and IRS- Satellites for Ocean and Fisheries studies- Digital image processing and interpretation, Application of remote sensing and GIS to fisheries and aquaculture planning and development.

Unit VI

PFZ- Basics and application- Validation of PFZ data- INCOIS- Data Dissemination- Fishermen knowledge in PFZ

VI. Practical

Study of satellite information, interpretation of satellite pictures for resource management, case studies on remote sensing and GIS applications. Development of GIS with local parameters related to fisheries- INCOIS data processing and interpretation- Collection and Validation of INCOIS PFZ data. INCOIS data dissemination methods among coastal fishermen. Survey of effectiveness and usefulness of PFZ data.

VII. Suggested Reading

- Bhatia B. 2008. *Remote Sensing and GIS*, Oxford University Press, New Delhi.
- FAO *Technical Manuals on Remote Sensing and GIS in Fisheries and Aquaculture*.
- Josef G. 2005. *Fundamentals of Remote Sensing*, Universities Press (P) Limited, Hyderabad.
- Kumar S. 2005. *Basics of Remote Sensing and GIS*, FirewellMedi, Laxmi Publications, New Delhi.

I. Course Title : Sea Safety and Disaster Management

II. Course Code : FET 512

III. Credit Hours : 1+1

IV. Aim of the course

To teach theoretical aspects of sea safety and disaster management, To learn about bad weather preparation and situation handling. Crew management during disaster.

V. Theory

Unit I

Introduction to sea safety: Safe navigation procedures for fishing vessels; Distress Signals and DAT (Distress Alert Transmitter), and communication systems like VHF, SSB and INMARSAT; Familiarization with safety devices like SART, EPIRB and GMDSS.

Unit II

Accidents: Accidents associated with marine environment-crossing surf, Bad weather, Poor visibility storms, Loss of power at sea, Loss of way, Grounding, Collisions. Injuries from fish, Animals and machinery, Man, overboard and capsizing. **Signals for fishing vessel safety:** Agencies involved in fishing vessel rescue operations, Keeping watch at sea – Preventing collusions – Heavy weather preparations -Crew management.

Unit III

Fire onboard and Firefighting equipment: Fir accidents at sea- Types and causes for fire accidents-Firefighting methods- fire extinguishers-First aid at sea; **Weather warning:** Weather warning signals and weather reporting system for fishing vessels; Bad weather preparations for fishing vessels. Stranding and beaching of fishing vessels and refloatation procedures; Measures to enhance sea safety; International conventions related to sea safety

Unit IV

Types of natural and man-made hazards in fisheries: Cyclone, Tsunami etc., Characteristics and impact of various disasters, Preparedness for disasters at sea, Mass evacuation, storm shelters and survival platforms.

VI. Practical

Study on various Distress Signals, Study on communication systems like VHF, SSB and INMARSAT; Familiarization with safety devices, study of fire fighting equipments used in fishing vessels, study of impact of various disasters, Disaster preparedness at sea. Weather warning signals. Sea safety equipments, Crew management during disaster.

VII. Suggested Reading

- Bist. 2000. *Safety and Security at Sea a Guide to Safer Voyages*. Butterworth, New Delhi.
- FAO. 1975. Code of Safety for Fisherman and Fishing Vessels. International Maritime Organization – London: 109p.
- *International Convention for the Safety of Life at Sea*. Universal Publishing Corporation. Mumbai: 1-334pp.
- Larkin FJ. 1998. *Basic Coastal Navigation*, 2nd edn, Sheridan House Inc., New York: 273p.
- Sreekrishna Y and Shenoy Latha. 2001. *Fishing Gear and Craft Technology*. Indian Council of Agricultural Research. New Delhi, 342p.
- Udayaprakasan. 1997. *Rule of the Road Signal and Buoyage*. CIFNET, Cochin: 1- 78p.

I. Course Title : Fish Processing Machinery

II. Course Code : FET 513

III. Credit Hours : 1+1

IV. Aim of the course

To teach engineering aspects of various equipments related to fish processing, To learn about design and layout of factory vessels and Processing factory designs

V. Theory

Unit I

Machines: Theory of machines; Transmission of power; Friction wheels; Toothed gears; Belt drive and drivers- Importance and need for the use of machineries in fish processing, Advancements in fish processing machineries.

Unit II

Graders and Deskinners: Conveyers-types and working, Graders-basic principles and types, Washers and Slime removing in fishes- Deskinners-types and working principles, **Descaling and filleting machines:** Descaling – machineries-types and working, Filleting machines, types and working, Gutting machines and Deheaders, Types and working, Quick freezers.

Unit III

Slicers and filleting machines: Fish slicing machines-types and working, Fish filleting machines-types and working, Deboners, Types and working, Advanced Thermal processing machineries, High pressure processing equipments, Advanced canning machineries

Unit IV

Boilers and extruders: Boilers -types and working. Extruders-types and working-Twin screw extruders, Various Packaging machines. Machineries for fish meal plants. **Maintenance:** Fish processing Equipment Maintenance- Daily, weekly, monthly and annual Maintenance. Safety aspects of machineries and workers.

VI. Practical

Study of various types fish processing machineries-washer, grader, deheader, filleting machine, retorts; calculation of power requirements and power transmission. Study of boilers and its operation, canning equipments, Twin screw extruders. RSW and CSW in fishing vessel- design and capacity calculations. Implements required for sushmi grade tuna processing onboard of the vessel. Packing machineries, Maintenance of various fish processing machineries

VII. Suggested Reading

- EIRI Engineers. 2000. *Modern Packaging Technology Engineers* India Research Institute, Delhi.
- Gopakumar K. 2002. *Text book of Fish Processing Technology*. ICAR Publication, New Delhi.
- Heldman. 1975. *Food Process Engineering,* AVI Publishing Company, Westport.
- Kondrashova. 1984. *Shipboard Refrigeration and Fish Processing Equipment*. Amerind Publishing Co. Pvt. Ltd., New Delhi.
- Novikov. 1982. *Hand Book of Fishery Technology* – Vol. I, Amerind Publishing Co. Pvt. Ltd., New Delhi.
- Slade. 1967. *Food Processing Plant*. Leonard Hill book, London.
- Stansby. 1963. *Industrial Fishery Technology* Reinhold Publishing Corpn. London.

Course Title with Credit Load
Ph.D. in Fishing Technology and Engineering

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FET 601*	Mechanization in Fishing	1+1
FET 602*	Advanced Fishing Gear Designing and Construction	2+1
FET 603*	Fishing Gear Selectivity	1+1
FET 604*	Deepsea Fishing	2+1
FET 605*	Sustainable Fishing Methods	1+1
	Minor Courses (From the subjects closely related to a students major subject)	**6 Credits**
FET 606	Fishing Harbour, Planning, Construction and Management	**2+1**
FET 607	Electronic Navigation and Sea Safety for Fishing Vessels	**2+1**
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	**5 Credits**
	Total Course Work Credits	**23 Credits**
	Doctoral Seminar	**2 Credits**
FET 691	Doctoral Seminar – I	0+1
FET 692	Doctoral Seminar –II	0+1
	Doctoral Research	**75 Credits**
FET 699	Doctoral Research (Semester II)	0+15
FET 699	Doctoral Research (Semester III)	0+15
FET 699	Doctoral Research (Semester IV)	0+15
FET 699	Doctoral Research (Semester V)	0+15
FET 699	Doctoral Research (Semester VI)	0+15
	Total PhD Program Credit Hours	**100 Credits**

*Major compulsory courses

Course Contents
Ph.D. in Fishing Technology and Engineering

I. Course Title : Mechanization in Fishing

II. Course Code : FET 601

III. Credit Hours : 1+1

IV. Aim of the course

To learn various mechanized systems used in the fishing industry, To study the power requirements of fishing vessels, To study about deck equipment's of fishing.

V. Theory

Unit I

Resources: Marine fisheries resources of India, Types and history of fish harvesting systems, History of mechanization of fishing craft in India.

Engines for fishing boat: Advances in marine engines, Selection of marine engines, Turbo engines, Installation and engine handling, Estimation of power requirements- Powering of fishing vessels, BHP, IHP, SHP, EHP, QPC. Propellers- Types, Construction, Selection, Factors involved in propeller performance, Propeller nozzle.

Unit II

Deck fittings: Mast, Derrick, Pulley, Fair leads, Gallows, Gantries, Trawl winch, Try net winch, Pumps, Triplex roller, Power block, Capstan, Purse winch, Purse davit, Guide roller, Rail roller.

Unit III

Fishing Systems: Line hauler, Net hauler, Trap hauler, Rudder, working principle, Types, Quadrant assembly, Mechanized trawl system, Mechanized purse seine system, Mechanized gillnetting system, Automatic and semi-automatic long lining system, Mechanization in trap fishing.

Unit IV

Hydraulic system: Principle, Components, Application of hydraulic systems in fishing equipments, Trawl winches, Net hauler, Line hauler, Power block etc., Maintenance of marine engine and equipments

Fish Processing Methods onboard: Design and fabrication of insulated fish holds, CSW and RSW systems, Chill Storage onboard a vessel, Fish Processing Equipments on board a vessel.

VI. Practical

Marine engine types, working, starting system, fuel system, cooling system, lubrication system, power transmission, Propellers types and working, visit to mechanized boat building yards- construction aspects of trawler, gill netter, long liner, purse seiner etc. to study the on-board deck layout and equipments. Basic calculations for hydraulic system and marine engine power ratings, IHP, BHP, SHP. Design of fish holds CSW, RSW systems and Fish Processing Equipments. Estimation and optimization of energy in fishing.

VII. Suggested Reading

- Ben-Yami.M. 1994. *Purse Seining Manual*. Fishing News Books. A division of Blackwell scientific publication Ltd.
- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publ. House.
- Devan Aranha. 2004. *Marine Diesel Engine*. Shroff publishers and distributers Pvt. Ltd, Mumbai
- Fyson JF. (Ed). 1985. *Design of Small Fishing Vessels*. Fishing News Books. Marine Institute. 1988. *Proc. World Symposium on Fishing Gear and Fishing Vessel Design*, The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, Newfoundland, Canada
- Garner J. 1988. *Modern Deep Sea Trawling Gear*. Fishing News Books.
- Leela Edwin, P Pravin, VR Madhu Saly, N Thomas, MP Ramesan, MV Baiju, Renju Ravi, PH Dhihu Das, MR Boopendranath, B Meenakumari. 2014. *Mechanised Marine Fishing Systems: India*. Central Institute of Fisheries Technology, KOCHI.
- *Module I- Fishing Technology*.2004.CIFNET, Cochin.
- Rethinadhas. 2002. *Marine Engineering*, CIFNET Publication, Cochin
- Sainsbury JC. 1996. *Commercial fishing methods- An Introduction to Vessels and Gears*. A division of Blackwell scientific publication Ltd.
- Sreekrishna Y & Shenoy L. 2001. *Fishing Gear and Craft Technology*. ICAR.
- Srivastava UK, Dharma Reddy, B Subrahmanyam, VK Gupta. 1986. *Impact of Mechanization on Small Fishermen; Analysis and Village Studies*. Concept publishing company, New Delhi.

I. Course Title : Advanced Fishing Gear Designing and Construction

II. Course Code : FET 602

III. Credit Hours : 2+1

IV. Aim of the course

To learn advanced fishing gear designing, To study the construction of various fishing gears, To learn fishing gear survey techniques.

V. Theory

Unit I

Fishing gear design: Principle of mechanism of fish catching, Fishing gear design process, Traditional and modern techniques used for net designing, Computer aided fishing gear designing.

Unit II

Net fabrication: Design drawings and specifications of fishing gears, Reading of fishing gear design; General scheme of presentation, Conventions adopted on the specific drawings trawl net, gill net, Surrounding net, Dredges, Pots, and lines, Estimation of weight of netting, Indian standard conventions adopted for netting panels, Lines and ropes, accessories, Method of representation on drawing.

Unit III

Fishing gear construction: Forms of fibre; Natural, synthetic and their properties; Construction of yarn, Twine, Rope, Advancement in fishing gear materials, Fishing gear construction – Shaping of netting, mounting of netting, Hanging, assembly of netting, Mending-Taper ratio, Hanging coefficient, Take up ratio.

Unit IV

Factors affecting fishing gear design: Design consideration of gill net, Bottom

trawl, Mid water trawl, Purse seine and long line, Trap, Cast net, Surrounding gear, Designing of square mesh cod-end, TED, BRD, Recent advancement in the construction of passive fishing gear; Gill nets, Trammel net, Traps, Non-return devices in traps and barriers, Hook and line, long line; Barriers.

Unit V

Recent advancements in the construction of active fishing gears: Trawl net, Purse seine, Cast net, Surrounding nets.

Unit VI

The influence of design features on the overall economic performance of fishing gears, Technical flaws of fishing gear designs and their impact on fuel efficiency, Modelling principle, Trawl net-based flume tank tests.

VI. Practical

Designing and construction of eco-friendly gill net, trawl net, trammel net, trap, long line, purse seine. Calculation on cutting rate, shaping, twine surface area, hanging ratio, buoyant and sinking force. Estimation of twin surface area, drag of the trawl, horizontal spread between otter board. Practice on scale drawing of different types of fishing nets, computer software application in designing of fishing gears. Construction of square mesh cod-end, Construction of Bycatch Reduction Device and Turtle Excluder Device. Estimation of quantity of netting materials for long line, gill net and trawl. Designing of model nets

VII. Suggested Reading

- Baranov FI. 1969. *Selected Works on Fishing Gear*. Vol. I. Commercial Fishing Techniques. Israel Programme for Scientific Translations, Jerusalem.
- Baranov FI. 1977. *Selected Works on Fishing Gear*. Keterpress Enterprises. Israel.
- Ben-Yami M. 1994. *Purse Seining Manual*. FAO Fishing Manual.
- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publ. House.
- Bjordal A & Lokkeborg S. 1996. *Long Lining*. Fishing News Books.
- Brandt AV. 1984. *Fish Catching Methods of the World*. Fishing News Books.FAO. 1987. Small Scale Fishing Gear.
- Fridman AL. 1986. *Calculations for Fishing Gear Designs*. FAO Fishing Manual. Fishing News Books.
- Garner J. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House
- Kristionsson H. 1975. *Modern Fishing Gear of the World*. The White Friars Press.
- Sreekrishna Y & Shenoy L. 2001. Fishing Gear and Craft Technology. ICAR.

I. Course Title : Fishing Gear Selectivity

II. Course Code : FET 603

III. Credit Hours : 1+1

IV. Aim of the course

To learn trawl net selectivity, To learn gill net selectivity, To learn fishing hook selectivity.

V. Theory

Unit I

Selectivity: Terminologies related to selectivity, Bycatch, Discard, Ghost fishing,

Catch quality, Significance of fishing gear selectivity, size selective fishing gears, species selective fishing gears.

Unit II

Selectivity of trawl: Introduction, Trawl selectivity parameters, Selection factor, L25, L50, L75, Trawl selection curve, Factors affecting the selectivity of trawls, Method of measuring selectivity of trawls, Covered cod-end method, Trouser trawl cod-end method, Twin trawl method, Alternate hauls, Parallel hauls; Limitations of trawl net selectivity-square-mesh code end- spatial temporal variation in availability of stock on selectivity – TED, BRD.

Unit III

Selectivity of gill net: Introduction, Estimation of gill net selection, Length at first capture (Lb), Mean selection length (Lc), Length of escapement (Ld) selectivity curves, Factors influencing the selectivity of gill net, Methods of measuring selectivity - Direct estimate, indirect estimate, Girth measurements, Fishing mortality, Selectivity of hook and line – introduction, estimation of hook and line selection, selectivity curves, factors influencing the selectivity of hook and line, Methods of measuring selectivity, Size selectivity of hook, Effect of Hook and Bait Size, Estimation of the size selectivity of hooks, Impact of hook shape on hook selectivity.

Unit IV

Fisheries management – Impact of selective fishing on ecosystem, Impact of selective capture of top carnivorous- Recruitment over fishing, Growth over fishing, Fishing holidays, FADs, ARS as management tools.

VI. Practical

Optimum mesh size estimation for gill net. Lb – Length at first capture, Lc – mean selection length and Ld- escapement length. Gill net selection factor. Selectivity curves for trawl. Trawl selection range and trawl net selection factor. L25, L50 and L75. Fishing hook selectivity.

VII. Suggested Reading

- Sparre P and SC Venema. 1992. *Introduction to Tropical Fish Stock Assessment*-Part 1: Manual by, FAO Fish. Tech. Pap., Rome.
- Holger Hovgard, Hanslassen. 2000. *Manual on Estimation of Selectivity for Gill Net and Long Line Gears in Abundance Surveys* by FAO technical paper 397.
- Sreekrishna Y & Shenoy L. 2001. *Fishing Gear and Craft Technology*. ICAR.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House.
- *Module I- Fishing Technology*. 2004. CIFNET, Cochin.
- Thomas SN, Leela Edwin, P Pravin, MP Remesan, P Muhamed Ashraf, MV Baiju and Madhu VR. 2012. *Fish Harvesting Systems for Resource Conservation*. CIFT, Cochin.

I. Course Title : Deepsea Fishing

II. Course Code : FET 604

III. Credit Hours : 2+1

IV. Aim of the course

Familiarization of deck equipment's on deep sea fishing vessel, Familiarization of bridge equipment's, Familiarization of engine room equipment's of deep-sea vessel.

V. Theory

Unit I

Deep sea fishing vessels: History of Deep-Sea Fishing, History of deep-sea fishing in India, Deep sea fishing initiatives, Committee on Deep sea fishing, Fishing Vessels and Deep-Sea Fishing, Types of fishing vessel, Mother vessel, Factory trawler, Thoothoor model, Design features of fishing vessels, Medium and large vessels.

Unit II

Deep sea resources: Fin Fishes, Shell fishes and other fishery resources of deep sea, Deep Sea Fishing Potential, Deep sea fishing resources of India, Exploitation of resources, FSI initiatives, Depth wise abundance.

Unit III

Fishing surveys: The Deep-Sea Prawn Fishery, Exploratory Surveys, The Trawling Grounds, Operations and the Catches, Area-wise Catch Distribution, Exploratory Surveys by FORV Sagar Sampada.

Unit IV

Details of Fishing - Catches and the Catch Rate, Species Composition, Biological Observations, Studies by Fishery Survey of India, Operations of Chartered Trawlers, Distribution and Abundance of Deep-Sea Prawns, Fishing Grounds, Catch Per Unit of Effort, Seasonality in Fishing Effort, Seasonal Variation in Catch Rate.

Unit V

Deep sea fishing gears: Fishing gears for deep sea fishing, Modification to the Gear, Area of Fishing Commercial Operations, Operations of Large Trawlers,Operations of Medium Trawlers, Estimation of Resource Potential Management Measures, Eco-friendly deep-sea fishing.

Unit VI

Govt. initiatives and sea safety: Various schemes of central and state governments to promote deep sea fishing in India and Tamilnadu, Sea safety aspects of deep-sea fishing vessels, Modern electronic equipments for deep fishing and navigation.

VI. Practical

Familiarization of deck equipment's on deep sea fishing vessel, net hauler and line hauler, Familiarization of bridge equipment's, Familiarization of engine room equipment's of deep-sea vessel. Illustration of boat, gears used in deep sea fishing. Fishing trips.

VII. Suggested Reading

- Biswas KP. 1996. *Harvesting Aquatic Resources*. Daya Publishing House – Delhi: 207 p.
- Capt. H Subramaniam. 2015. *Marine Meteorology*, Nut shell series, Book No.2 Vijaya publication, Bombay.
- DJ Randall and AP Farrell. 1997. *Deepsea fishes*. Academic press, USA.
- Garner J. 1988. *Modern Deep-Sea Trawling Gear*. Fishing News Books.
- Hameed SM & Boopendranath MR. 2000. *Modern Fishing Gear Technology*. Daya Publ. House.
- *International Convention for the Safety of Life at Sea*. Universal Publishing Corporation. Mumbai: 1-334pp.

- NR Merrett and RL Haedrich. 1997. *Deepsea Demersal Fish and Fisheries*. Chapman & Hall, London.
- PS Balachandran. 2013. *Manangement of Deepsea Fisheries*. Random Publications. New Delhi.
- Sudhakararao. 2009. Deepsea Fisheries of India. B.R.Publishing Corporation. New Delhi.
- U Shanker Rao. 2012. Deep sea fishing in India (From trawler to table). Biogreen books.

I. Course Title : Sustainable Fishing Methods

II. Course Code : FET 605

III. Credit Hours : 1+1

IV. Aim of the course

To learn various fishing methods and gears for the sustainable exploitation of aquatic resources

V. Theory

Unit I

Sustainable fishery: Definition of sustainability, Rules and regulations for sustainable fishing, FAO- code of conduct for responsible fisheries, Properties of a sustainable fishery, Present scenario and problems of sustainable fishing, Trends in global and Indian fishery, Environmental defects.

Unit II

Impacts of unsustainable fishing: Habitat degradation due to trawling, purse seining, Habitat modification, changing the ecosystem balance, Climate change, Ocean pollution, Disease and toxins, Remediation for sustainable fishery, Fisheries management, Ecosystem based fisheries, Marine protected area, Laws and treaties, Awareness campaigns, Sustainable fishing gears and devices, Designing of eco-friendly long line, Eco-friendly gillnet, Eco-friendly trawl net, Techniques reducing the risk of unsustainability, IUU fishing, Eco-friendly fishing methods and gears.

Unit III

Application of advanced methods: GIS, Remote sensing, PFZ, The Sustainability Challenges for Fisheries-Environmental challenges, Economic challenges, Social challenges, Organizational challenges.

Unit IV

Issues related to the sustainability: Environmental, Economic, Governance arrangements, Monitoring and enforcement, Legislation and policy, Endangered fish species of India, Government regulations, Present fishing policies adopted in developed nations for sustainable fishing.

VI. Practical

Visit to fishing harbour and landing centre to study technical draw basics of fishing gear with respect to their eco friendliness. Study designing of eco-friendly fishing devices, square mesh cod end, traps with escape vents, designing of longline with circular hooks. PFZ maps and table, GIS, remote sensing application in fisheries.

VII. Suggested Reading

- CIFNET MODULE III & IV. *Code of Conduct for Responsible Fisheries*. 61-69pp.
- FAO. 1995. *Code of Conduct for Responsible Fisheries*, FAO, Rome, 41p.
- Maheswari K. 2011. *Sustaining Marine Fisheries*. Sonali publication, New Delhi.

- Patel AN & Singh S. 1992. *Remote Sensing – Principles and Applications*. Scientific Publ.
- Raval NB. 2013. *Combating Marine Pollution*. Cyber tech publication, New Delhi.
- Sinha PC. 2007. *Fishing Conservation Management and Development*. SBS Publishers and distributers pvt. ltd, New Delhi
- Valavanis VD. 2002. *GIS System in Oceanography and Fisheries*. Taylor & Francis.

I. Course Title : Fishing Harbour, Planning, Construction and Management

II. Course Code : FET 606

III. Credit Hours : 2+1

IV. Aim of the course

To learn Fishing Harbour Planning, To learn Planning Construction and Management of Fishing Harbour, To learn advanced methods for preventing sea erosion.

V. Theory

Unit I

Classification and functions of fishing harbour and Fish Landing Centre: Water side and land side facilities, Site selection for fishing port, Planning and construction, Environmental impact assessment, Indian Standard codes.

Unit II

Hydrographic surveys- Vertical depth measurements, Horizontal position fixing; Specifying hydrographic surveys, Outline design and project formulation, Preliminary design, Final design, Construction phase of a port, Maintenance dredging and reclamation construction cost estimation.

Unit III

Harbour management: Structures, Size and composition, Artisanal landing, Management body, Best management practices, Port operations, Boatyard operations, Prevention of pollution.

Unit IV

Requirements for dredging - Volume estimates, Dredging techniques, Disposal of dredged sediments, Environmental impacts of dredging, Dredging of fairways, Minimum width, Minimum depth.

Unit V

Breakwater: Parameters for the construction of a breakwater; Construction methods; Floating breakwaters; Quays, Jetties, Slipways, Construction materials for fishing harbour.

Unit VI

Dry docks; Fishing harbour management and maintenance; Shore-based infrastructure, Advanced methods for preventing sea erosion, Dreading of fishing harbours.

VI. Suggested Reading

- Carl A Thoresen. 2003. *Port Designers Handbook Recommendation and Guidelines*. Thomas Telford, London.
- Chandrasekaran.S and A.K. Jain, 2017. *Ocean Structure, Construction, Materials and*

Operations. CRC Press, Taylor & Francis Group.
- Moffat and Nichol Engineers. 1983. *Construction Materials for Coastal Structures*. Virginia, USA, US Army Corps of Engineers Coastal Engineering Research Center.
- Quinn AD. 1972. *Design and Construction of Ports and Marine Structures*. McGraw-Hill, Inc., New York.
- Sciortino JA. *Fishing Harbour Planning, Construction and Management*, FAO Fisheries and aquaculture technical paper 539, FAO, Rome.
- Thomas stevenson, *Design and Construction of Harbours*, A treatise on Maritime Engineering, Cambridge University Press.
- Tsinker Gregory. 1997. *Handbook of Port and Harbor Engineering - Geotechnical and Structural Aspects*. Springer science and business media. B.V.

I. Course title : Electronic Navigation and Sea Safety for Fishing Vessels

II. Course code : FET 607

III. Credit Hours : 2+1

IV. Aim of the course

To learn electronic navigational equipment's, To learn sea safety practices followed in the fishing vessels, To learn position plotting and chart work.

V. Theory

Unit I

Electronic navigation-I: Introduction, Terminologies and definitions related to electronic navigation, Global Positioning System, Echo sounder, Speed log, Electronic chart display and information system.

Unit II

Electronic navigation-II: Automatic Identification System (AIS), Voyage data recorder, Gyro-Compass, Auto Pilot and Course Recorder, Radio Direction Finder, VHF, Marine radio.

Unit III

Signalling: Introduction, Terminologies and definitions, Flag signalling, International code of signals, Single letter and two letter signals, Morse code, Flash light signals, Arm signals

Unit IV

Safety: Conventions on sea safety, Global Maritime Distress and Safety System (GMDSS).

Unit V

Lifesaving appliances for fishing vessels: Life buoy, Life jacket, Buoyant apparatus etc., Ship handling, Equipment, Manoeuvring and Mooring operations, Preventing Collisions at sea, Accident hazards.

Unit VI

Communication during emergencies: Danger message, Distress and rescue procedure, Distress signals Fire fighting and checking and data recording of the safety instruments in boats, Emergencies at sea, Disaster management at sea for fishing vessel.

VI. Practical

Chart work; operation of navigational equipment viz., echo sounder, Sonar, GPS, Radar and communication systems like VHF, familiarization with sea safety devices like Chart Plotter, AIS, DAT, SART, EPIRB and GMDSS; navigational and fishing lights and shapes, distress signals and navigational equipment's compass, chronometer, aneroid barometer, sextant and speed logs. Visit to fishing vessel for familiarization of navigational equipment's.

VII. Suggested Reading

- Bhatia and Sinha. 2003. *Modern Electronic Navigation Aids*, Lata publications, Mumbai.
- Capt SK. Puri. 2011. *Manual of the Rule of the Road*, Marine Publication of India, New Delhi.
- Capt VK. Bhandarkar. 1976. *Seamanship*, Bhandarkar Publications, Mumbai.
- Capt H Subramaniam. 2016. *Practical Navigation,* Nutshell Series Book 1. Vijaya Publication, Mumbai.
- Capt SK Puri. 1997. *Chart work of Mariners*. Marine Publications of India, Mumbai,
- Capt FS. Howell. 1977. *Navigation Primer for Fishermen*. Fishing News Books Ltd, England.
- Graham Danton. 2014. *Theory and Practice of Seamanship*, Routledge, Abington.
- Sreekrishna Y and Shenoy L. 2001. *Fishing Gear and Craft Technology*. ICAR, New Delhi.

List of suggested Journals

- *Fishery Technology*
- *Indian Journal of Ecology*
- *Journal of Indian Ocean studies*
- *Fisheries Research -ISSN: 0165-7836*
- *Aquacultural Engineering*
- *Fish and Fisheries*
- *Fisheries Science*
- *Fisheries and Aquaculture Journal -ISSN 2150-3508*
- *Journal of Fisheries Science and Technology*
- *Developments in Aquaculture and Fisheries Science*
- *Indian Journal of Fisheries*
- *International Journal of Fisheries and Aquaculture*
- *Journal of Fisheries and Aquatic Science*
- *American Fisheries Society Portal*
- *Canadian Journal of Fisheries and Aquatic Sciences*
- *Turkish Journal of Fisheries and Aquatic Sciences*
- *Marine Ecology Progress Series*
- *Marine Policy*
- *Reviews in Fish Biology and Fisheries*
- *Fisheries Oceanography*
- *ICES Journal of Marine Science*
- *Marine Biology*
- *Reviews in Fisheries Science*
- *Ecological Modelling*
- *Fisheries*
- *Marine and Freshwater Research*
- *Fisheries Research*
- *Marine and Coastal Fisheries*
- *Fishery Bulletin*
- *Ocean & Coastal Management*
- *Journal of Fish Biology*
- *Ecology of Freshwater Fish*
- *Environmental Biology of Fishes*

- *Bulletin of Marine Science*
- *Transactions of the American Fisheries Society*
- *California Cooperative Oceanic Fisheries Investigations Reports*
- *Marine Resource Economics*
- *Fisheries Management and Ecology*
- *North American Journal of Fisheries Management*
- *Fisheries Oceanography*
- *Proceedings of the National Academy of Sciences, USA*
- *Freshwater Biology*
- *General and Comparative Endocrinology*
- *Journal of Cetacean Research and Management*
- *PLOS ONE*
- *Environmental Biology of Fishes*
- *Limnology and Oceanography*
- *Journal of Shellfish Research*
- *Molecular Ecology*
- *Ecosystems*
- *North American Journal of Fisheries Management*
- *Fisheries Bulletin*

List of suggested E-resources

- World Fish Center: www.worldfishcenter.org
- Food and Agricultural Organization of the United Nations (FAO): www.fao.org
- FishBase: www.fishbase.org
- International Union for Conservation of Nature (IUCN): http://cms.iucn.org
- OneFish: one internet portal. all fisheries research: www.onefish.org
- Bangladesh Fisheries Research Forum (BFRF): http://bfrf.org
- National Institute of Fisheries Post Harvest Technology: www.nifphatt.gov.in
- Central Institute of Fisheries Nautical and Engineering: www.cifnet.gov.in
- Fisheries Science Institutes: www.icar.org.in
- Central Marine Fisheries Research Institute: www.cmfri.org.in
- World Fishing: www.worldseafishing.com
- Central Institute of Fisheries Technology (ICAR CIFT): www.cift.res.in
- Innovative solutions for the fishing industry: www.fishing-tech.com
- World Fishing & Aquaculture: www.worldfishing.net
- Fishing Methods and Gear | Fisheries Technologies: www.nap.edu
- New technologies in Fisheries: www.oecd.org
- Fishing and Farming Methods from the Seafood Watch: www.seafoodwatch.org
- Office of Science and Technology: www.fisheries.noaa.gov
- Unsustainable fishing: www.wwf.panda.org
- The history of fishing: www.alimentarium.org

Suggested broad areas for Master's and Doctoral research

- Design upgradation of existing fishing gears for sustainable catch.
- Selectivity studies of fishing gears.
- Development of new fishing gear design and efficiency studies
- Catch Per Unit Effort(CPU) studies for different fishing gears
- Design upgradation of fishing crafts.
- Fouling effects on fishing crafts and Prevention methods.
- Problems of Wooden crafts with boring organisms.
- Efficiency of modern fishing gear materials under different conditions
- Abrasion studies for fishing gear materials
- Energy Optimization of fishing crafts
- Design and efficiency studies of Bycatch Reduction Devices
- Design and efficiency studies of Turtle Excluding Device(TED)

- Bycatch studies.
- Studies on ap[plication of remote sensing in fishing
- PFZ validation studies.
- Studies on FADs.
- Effect of fishing on non-target species
- Heat load calculations Design and layout upgradation of Processing Plants.
- Marine engine power ratings under various load conditions
- Energy efficient fishing methods
- Dry docking efficiency studies
- Anti-fouling studies in fishing vessels
- Design and functions of fishing harbours
- Modern tools for navigation/Electronic navigation
- Application of electronics in fishing
- Application eco-sounder in location fish shoals
- Low cost waste treatment systems and their Design
- Management options for ballast water
- Disaster management strategies
- Use if ICT in disaster preparedness
- Study of power requirements for different processing machinery
- Factors determining the selection of processing machinery

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fisheries Economics

Preamble
(Fisheries Economics)

Though fisheries economics is an integral part of Fisheries Science, the PG and Ph.D. programmes are offered in few campuses for strengthening sustainability, development and welfare of fisherfolk. Desired information on fish and fisheries need to be collected, inform and convince the people about the value of new and better technology packages, make further refinement to suit them and motivate them to adopt it and draw benefit from it. The research in various thrust areas of fisheries economics provides information to planners and policy makers for the fisheries development in India by offering the PG programmes and technical man power development in colleges and research institutes. The syllabus is designed to introduce doctoral and graduate students of fisheries economics to the process of scientific research in social sciences considering development taking place in allied subjects. Accordingly the syllabus is revised to take care of the changes in the data collection and processing and dissemination in developing data based fisheries management, market-led fisheries management and fisheries advisory services. New courses introduces is based on the emerging trend requirements for the graduating students. There are new and interesting contents are added in the subjects from socioeconomics to econometric tools which require continuous updation.

Course Insides

The economics principles and concepts could be applied to study the individual fisherman, households and firms' behavior in decision making, allocation of resources and understanding the fundamental relationships in the aggregate, macroeconomic activity, public policy goals and alternative policy proposals regarding inflation, economic growth, unemployment, and scarcity affecting fisheries. The purpose of the course is to give students a thorough understanding of the principles of economics that apply to the decisions of individuals-both consumers and producers-within the larger economic system. It is a subdivision of economics that studies how people, firms and households decide on how to allocate their limited resources taking fishermen as an example. The socioeconomics of fisherfolk means and ways of their welfare. Marine capture fisheries and aquaculture are important sources of food and livelihoods for fishermen. Climate change is the change of climate which is attributed directly or indirectly to fisheries activities that alters the composition of fish production and which is in addition to natural climate variability observed over comparable time periods. Fisheries is one of the important sectors which has been most exposed to vulnerability affected by climate change. The measure of livelihood status of fishermen warrants welfare schemes for their socioeconomic development. To make the students understand about the socioeconomic conditions of the fisherfolk and to assess their standard of living to draft various means of welfare schemes and its economic impact on the productivity of fisheries and livelihood and to study about the various policies and regulations to cope up with the climate change. Economic valuation provides a means for measuring and comparing the various benefits of fisheries resources and their ecosystems, and can be a powerful tool to aid and improve their wise use and management. The current limitations to valuing the services provided by inland fish and fisheries make comparison with other water resource users extremely difficult. This list can serve to demonstrate the

importance of inland fish and fisheries, a necessary first step to better incorporating them into agriculture, land-use, and water resource planning, where they are currently often underappreciated or ignored. It also aims to provide an overview of the concept and methods for payment for ecosystem services and their policy implications. This course is aimed at providing a rigorous and application-oriented treatment of different valuation techniques for measuring the value of aquatic environmental goods and services. R & D Management is the discipline of designing and leading R & D processes, managing R & D organisations and ensuring smooth transfer of new know-how and technology to other groups or departments involved in innovation. To move towards innovation in fisheries and aquaculture, priorities for policy makers can set out the basis for a comprehensive and action-oriented approach. Technology diffusion with the number of inventions that seek patent protection through national, regional or international routes in a given jurisdiction. It shows the extent to which firms and individuals seek to "protect" the relevant markets for their inventions.

The international and domestic markets play a very important role in the development of fisheries sector in the country. Apart from ensuring the nutritional and food security, it also helps in minimising the post – harvest losses, increases revenue and enhance employment opportunities. Marketing intelligence is the everyday information relevant to a company's markets, gathered and analysed specifically for the purpose of accurate and confident decision- making in determining market opportunity, market penetration strategy and market development metrics. The main purpose is to give an idea about the marketing intelligence and business analysis applied in the fisheries sector. The trade of the fish and fisheries products are an important means of income particularly in India. This course gives an insight to the various aspects of the fisheries trade at a global level. The importance of small-scale fishers and developing countries at a global level in producing and supplying fish and fishery products put them at the forefront in facing specific trade measures. At the consumer level, increasing awareness is driving demand for traceability systems and certification schemes intended to guarantee the sustainability and quality of a growing array of fish and fishery products. In order to level the playing field and provide clarity to the market, FAO supported the development of a common benchmark tool for fishery certification schemes. The main purpose is to familiarize students with basic concepts and principles of economics applied to international trade with reference to fisheries. Finance and project management provides an insight knowledge about investing in sustainable fisheries to support thriving oceans and communities. The accounting of cost input in different phases of project, complete ledgering of inventories and the financial inflow in a production system in an integral part of management. The profitability of any production system is derived by financial control in projects. Econometric is the application of statistical methods to economic data in order to give empirical content to economic relations. Econometrics uses statistical methods after adapting them to the problems of economic life. These adopted statistical methods are usually termed as econometric methods. Such methods are adjusted so that they become appropriate for the measurement of stochastic relationships. These adjustments basically attempt to specify attempts to the stochastic element which operate in real world data and enters into the determination of observed data. To make acquainted students with econometric tools applied to social sciences. This course on quantitative and econometric analysis focuses on practical applications that are relevant in fields such as economics, finance, public policy, business, and marketing

Learning upshots

To apply economic concepts and techniques to a range of specific issues in the

management of aquatic fisheries resources; to analyse markets and industries and the economic challenges facing private business, public institutions and international organizations and to know the relevant markets for fish and aquaculture products, how these markets work, and how they affect production. Most of the courses are compulsory and demands active participation from the students. Emphasis to be placed on direct student participation, in the form of literature search and data retrieval, oral presentations, record fieldwork, assignments and computer labs. The examination form varies between courses and includes: written examinations, record, presentations of report using data science and analytics. The final examination is based on the thesis and an open oral examination

Course Title with Credit Load
M.F.Sc. in Fisheries Economics

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FEC 501	Microeconomics	2+0
FEC 502	Macroeconomics	2+0
FEC 503	Socioeconomics, Vulnerability and Fisherfolk welfare	2+1
FEC 504	Fishery Regulations and Ecosystem Valuation	2+1
FEC 505	Marketing Intelligence and Business Analysis	2+1
FEC 506	International Fisheries Trade	1+1
FEC 507	Fisheries Finance, Accounting and Control	2+1
FEC 508	Introduction to Econometric Tools	1+1
	Minor Courses (From the subjects closely related to a students major subject)	**8 Credits**
FEC 510	Management of R & D Innovations and Policy	1+1
FEC 511	Economics of Fisheries Enterprises	1+1
FEC 512	Fisheries Development Planning and Policy	2+0
FEC 513	Fisheries Project Management	1+1
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common Courses (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques 5. Agricultural Research, Research ethics and Rural Development Programmes	**5 Credits**

Course Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FEC 591	Masters' Seminar	0+1
	Total Course Work Credits	**40 Credits**
	Masters' Thesis Research	**30 Credits**
FEC 599	Masters' Research (Semester III)	0+15
FEC 599	Masters' Research (Semester IV)	0+15
	Total M.F.Sc Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fisheries Economics

I. Course Title : Microeconomics
II. Course Code : FEC 501
III. Credit Hours : 2+0

IV. Aim of the course

To teach economics theories that apply to the decisions of individual consumers and producers and also firms.

V. Theory

Unit I

Consumer theory: Theory of Demand, Consumer Behaviour, Cardinal Utility theory, Indifference Curves theory, Income and Substitution effect, Derivation of demand curve, Consumer surplus, Equilibrium of the consumer, Elasticity of demand, Market demand, Constant elasticity demand function

Unit II

Production economics: Basic theory of the firm, Concepts, Production functions, Isoquants derivations and applications, optimization behaviour, Alternative models, Short run and long run cost functions; Total price effect, Substitution effect, Output effect and Profit maximization effect decomposition analysis, Analytical approaches, joint products, Concepts and constrained optimization.

Unit III

Production theory: Theory of production and costs, Production functions, Returns to scale, Long run analysis of production, Law of variable proportions, Technological progress, Equilibrium of the firm, Choice of optimal combination of factors of production, Derivation of cost function from production function, Production function of a multiproduct firm, Iso-revenue curve of the multiproduct firm, Linear production functions, Linear programming.

Unit IV

Theory of costs: Theory of costs, Cost curves, Traditional theory of costs, Modern theory of costs, Short and Long run costs, Marginal cost, Minimum Average Total Costs, Analysis of Economies of Scale, Social and Private costs.

Unit V

Factor pricing: Theory of Price in Perfectly Competitive markets, The supply curve of the firm and industry, Short run equilibrium of the firm and industry, Equilibrium of firm and industry in long run, Optimal Resource Allocation, The stability of equilibrium, Dynamic equilibrium with lagged adjustment, Futures market- Hedging/ risk assumption.

Unit VI

Welfare economics: General Equilibrium theory- Two commodity exchange-

Production and exchange, Multimarket equilibrium, General equilibrium and allocation of resources, Factor ownership and income distribution, Welfare economics, Pareto optimality, Maximization of social welfare, Welfare maximizing state.

VI. Suggested Reading

- Brickley J, Smith C and Zimmerman J. 2008. *Managerial Economics & Organizational Architecture* (4th Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- David M Kreps. 1990. *A Course in Microeconomic Theory*. Princeton University Press.
- Dewitt K.K. 2002. *Modern Economic Theory*. Sultan Chand & Co.
- Geetika GP and Choudhury PR. 2011. *Managerial Economics* (2nd Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- Haran J. 2012. *Managerial Economics*. Jaipur: Garima Publications
- Henderson JM and Quandt RE. 2000. *Microeconomic Theory: A Mathematical Approach*. McGraw-Hill.
- Jhingan ML and Stephen JK. 2012. *Managerial Economics* (2nd Ed.). Delhi: Vrinda Publications (P) Ltd.
- Jhingan ML. 2004. *Micro Economic Theory*. Vikash Publishing House Pvt. Ltd. New Delhi.
- Koutsoyiannis A. 2003. *Modern Microeconomics*. The Macmillan Press.
- Salvatore D. 2011. *Principles of Microeconomics* (5th Ed.). Oxford: Oxford University Press
- Shrivastava OS. 2013. *Modern Managerial Economics: Including Micro and Macroeconomics*. New Delhi: Anmol Publications Pvt. Ltd.
- Silberberg E & Suen W. 2001. *The Structure of Economics – A Mathematical Analysis*. McGraw-Hill.
- Varian Hal R. 1992. *Microeconomic Analysis*. W. W. Norton and Co.
- Varian Hal R. 1999. *Intermediate Microeconomics*. Affiliated East-West Press

I. Course Title : Macroeconomics

II. Course Code : FEC 502

III. Credit Hours : 2+0

IV. Aim of the course

To understand the basic concepts and principles of macroeconomics including the analytical tools used for them.

V. Theory

Unit I

Basic concepts: Nature and Scope of Macroeconomics, Methodology and Keynesian Concepts National income, Concepts and measurement (GNP, NNP, PI & DI), methods for measuring national income, Importance of NI analysis, Nominal and Real GDP, Balance of Payments (BoP), Meaning, Structure, Deficit and surplus, Disequilibrium, control measures.

Unit II

Theory of income and employment: Classical theory of Employment and Say's Law, Modern theory of Employment and Effective Demand, Consumption function, Investment and savings; Consumption function, Average propensity to consume and marginal propensity to consume, Measure of propensity to consumption, Keynes's theory of consumption and The determinants of consumption, Importance of consumption function.

Unit III

Investment and Saving: Saving function, Average propensity to save and marginal

propensity to save; Investment function, Meaning, Types of investment, Determinants of the levels of investment, Marginal efficiency of investment, Induced investment.

Unit IV

Multiplier and accelerator: Concept of Multiplier and Accelerator, Output and Employment, Rate of interest-Classical, Neo classical and Keynesian version, Theory of Multiplier, Concepts of investment multiplier, derivation of investment Multiplier, Importance of multiplier; Aggregate demand and supply; Unemployment, Meaning, types; Full employment.

Unit V

Monetary and fiscal policy: Inflation-meaning, types, Inflationary gap, Cause and effect of inflation, Control measures for inflation; Monetary policy – Meaning, Objective, instruments, Fiscal policy – Meaning, Objective, Fiscal policy for economic growth, merits and Demerits of the fiscal policy.

Unit VI

Public finance and expenditure: Public finance and Public expenditure – Concepts, types of public expenditure, Growth of public expenditure, Effects of public expenditure on production and distribution; Government expenditure (Taxation) – Government budget constraints; Tax- meaning, Classification, Characteristics of good tax system, Problems of equity in taxation.

VI. Suggested Reading

- Ahuja HL. 2007. *Macroeconomics: Theory and Policy*. S. Chand & Co.
- Collier Macmillan Dornbusch. 2006. *Macroeconomics* McGraw Hill Publication.
- Deepashree VA. 2012. *Macroeconomics* (5ht Ed). New Delhi: Ane Books Pvt. Ltd.
- Eugene A Diulio. 2006. *Macroeconomics.* 4 Ed. Schaums' Outlines.
- Gardner Ackely. 1987. *Macro-Economic: Theory and Policy*.
- Gardner Ackley. 1987 *Macro-economics: Theory and policy*. Macmillan Publishing Co., Inc., New York.
- Gregory Mankiw N. *Macroeconomics,* 2004,Worth publishers, New York
- Gupta GS. 2010. *Macroeconomics: Theory and Applications* (3rd Ed.). New Delhi: Tata McGraw Hill Education Private Limited
- Haran J. 2012. *Managerial Economics*. Jaipur: Garima Publications
- Kennedy EP. 2012. *Macroeconomic Essentials: Understanding Economics in the News* (3rd Ed.). New Delhi: PHI Learning Private Limited.
- Kennedy MMJ. 2011. *Macroeconomic Theory*. New Delhi: PHI Learning Private Limited.
- Maheshwari Y. 2012. *Managerial Economics* (3rd Ed.). New Delhi: PHI Learning Private Limited.
- Mankiw, N.G. 2004. *Macro-economics*, World Publishers, New York.
- Mankiw MG. 2012. *Principles of Macroeconomics* (6th Ed.). Delhi: Cengage Learning India Pvt. Ltd.
- Reddy MK and Saraswathi S. 2007. *Managerial Economics and Financial Accounting*. New Delhi: PHI Learning Private Limited
- Robert J Gordon. *Macroeconomics*, Addison-Wesley, New York. Shapiro, E. *Macroeconomic Analysis*. Galgotia Publications, Delhi.
- Shapiro E. *Macroeconomic Analysis*. Galgotia Publications, Delhi.
- Tailor RK. 2012. *Principles of Managerial Economics*. Jaipur: RBSA Publishers
- Thomas F Dernburg. *Macro-economic-Concepts, Theories and Policies*, McGraw Hill Book Company, London.
- Walsh EC. 2010. *Monetary: Theory and Policy* (3rd Ed.). New Delhi: PHI Learning Private Limited.

I. Course Title : Socioeconomics, Vulnerability and Fisherfolk Welfare

II. Course Code : FEC 503

III. Credit Hours : 2+1

IV. Aim of the course

To make the students understand about the socioeconomic conditions of the fisherfolk and the impact of climate change over it to assess their standard of living to draft various means of welfare schemes to them.

V. Theory

Unit I

Factors affecting socioeconomic status: An over view of socioeconomic status of fisherfolk in India, Livelihood and Income, Indebtedness, Poverty, Inequality and unemployment in fisheries, Regional disparities in wage, work and livelihood security, Equity theory; Risk and uncertainty in fisheries, Standard of living of fisherfolk, Saving, Income, Consumption, poverty, Health status.

Unit II

Socioeconomic analysis: Concepts in socioeconomics, Gender discrimination, Income inequality, Gini coefficient and Lorenz curve, Theil index, Livelihood Index, Engel's curve, Duncan Socioeconomic Index (SEI), Occupational Status Score (OSS), Household prestige (HHP) score, Recent measurement of economic development NEW (New Economic Welfare), MRW (Measurement of Economic Welfare), PQLI (Physical Quality Living Index), HDI (Human Development Index)- Green GNP Index.

Unit III

Fisheries and climate change: Fisheries and climate change, Fisheries policy, Issues for future impact and adaptation, Socio economic condition and Fisheries policy, Fisheries and sustainability, Biodiversity of climate change, Indian fisheries current scenario in climate change, climate change threat, Impact of climate change in fisheries, Dynamics of climate change, Futuristic endeavour.

Unit IV

Climate change impact analysis: Economic impact on climate changes, Climate change mitigation and adaptation, Ongoing initiatives and future strategies for fisheries sector, Methods and tools for climate change adaptation- Impacts of climate driven extreme events and disasters in fishermen communities, Social impact on climate change, Vulnerability assessment, Top down and Bottom up approaches, Socio-economic vulnerability, Criteria and indicators, Vulnerability assessment framework and methods, Exposure, Sensitivity and Adaptive Capacity, Vulnerability Index– SeVI

Unit V

Legal instruments to mitigate climate change: An overview of international legal and policy framework to address climate change developed over time and points out some of the key issues under negotiation, History of international climate change negotiations and Nations Framework Convention on Climate Change (UNFCCC), Key provisions of the UNFCCC, Its organisational structure, and different Party groups under the Convention, Kyoto Protocol and its associated bodies, as well as key commitments by Parties, An overview of main negotiation

issues, Highlights some of the key issues relevant for a future climate change regime.

Unit VI

Welfare economics: Fundamental theorems of welfare economics, Promising features of welfare economics, Welfare Schemes for fisherfolk in India, Women empowerment in Fisheries, Overview of fisherfolk welfare schemes, Fisheries Cooperatives, Corporations and NGOs in fisherfolk welfare development.

VI. Practical

Assessment of socioeconomic parameters of fisherfolk in marine fisheries sector; Assessment of socioeconomic parameters of fisherfolk in inland fisheries sector; Consumption and savings behaviour of fisherfolk; Nutrition and Health analysis of fisherfolk; Case studies on effects on climate change in world fisheries with special emphasis to Indian fisheries; Climate change impact on coastal fisheries and aquaculture in India; Case studies on sustainability of fisheries sector in India; Case studies on climate change driven disasters affecting the fishermen communities in India; Effectiveness of fisherfolk welfare schemes; Impact of welfare schemes on fisherfolk

VII. Suggested Reading

- Bahuguna P. 2011. *Rural Marketing*. New Delhi: Centrum Press
- Brander KM. 2007. *Global Fish Production and Climate Change*. Proceedings of the National Academy of Sciences, 104(50): 19709-19714.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- CMFRI-NICRA Annual Report, 2015-2016, Marine Fisheries, Report of work done at CMFRI submitted to CRIDA, pp. 27.
- De Silva SS and Doris Soto. 2009. "*Climate Change and Aquaculture: Potential Impacts, Adaptation and Mitigation." Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge*. FAO Fisheries and Aquaculture Technical Paper 530: 151-212.
- Delgado CL, Wada N, Rosegrant MW, Meijer S and Ahmed M. 2003. *Outlook for Fish to 2020: Meeting Global Demand*. Penang, International food policy research group and worldfish centre.28 pp.
- Glick P, Stein BA and Edelson NA. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. Washington, DC, National Wildlife Federation. 168 pp. (also available at https://www.nwf.org/Educational-Resources/ Scientific-Reports/ 2011/01-19-2011-Scanning-the-Conservation-Horizon).
- Gopalakrishnan A *et al*. 2016. *Climate Change Impact on Coastal Fisheries and Aquaculture* in the SAARC region: Country paper- India, 1-25.
- Higgins Benjamin. *Economic Development: Problems Principles & Policies*. Universal Book, New Delhi
- IPCC – Intergovernmental Panel on Climate Change – https://www.ipcc.ch
- IPCC 2007: Climate Change 2007: *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.
- Ishwar C Dhingra, "*The Indian Economy, Environment and Policy*", published by Sultan Chand, ed. 2006, pp. 53.56,641.
- Khader V. 2008. *Empowerment of Fisher Women*. Udaipur: Agrotech Publishing Academy
- Khan NA. 2009. *Fundamentals of Entrepreneurship*. New Delhi: Anmol Publications Pvt. Ltd.
- Kindleberger, Charles P. *Economic Development*, McGraw Hill International. Meir, Gerald M. *Leading Issues in Economic Development*.

- Kumar D. "*Climate Economics- Impact and Assessment of Climate Change*", published by Dominant Publishers, ed. 2012.
- Kumari, Sonia. Zacharia PU, Kripa V, Sreenath KR and George Grinson. 2015. *Distribution Pattern and Community Structure of Zoanthids (Zoantharia) along the Coast of Saurashtra, Gujarat, India. Journal of the Marine Biological Association of the United Kingdom*, 96(8): 1577-1584.
- McMichael AJ. 2001. *Impact of Climatic and other Environmental Changes on Food Production and Population Health in the Coming Decades*. The Proceedings of the Nutrition Society, 60 (2): 195- 201.
- NICRA- *National Initiative on Climate Resilient Agriculture* – www.icar.nicra-icar.in
- NOAA- *National Oceanic and Atmospheric Administration* – https://www.noaa.gov
- Ogier EM, Davidson J, Fidelman P, Haward, M, Hobday AJ, Holbrook N, Hoshino E & Pecl GT. 2016. *Fisheries Management Approaches as Platforms for Climate Change Adaptation:* Comparing theory and practice in Australian fisheries. Marine Policy, 71: 82–93.
- Rathakrishnan L. 2008. *Empowerment of Women Through Entrepreneurship*. New Delhi: Gyan Publishing House
- Singh K. 2012. *Rural Development: Principles, Policies and Management* (3rd Ed.). New Delhi: SAGE Publications.
- Thakur AK and Sharma P. 2009. *Micro-credit and Rural Development*. New Delhi: Deep & Deep Publications Pvt. Ltd.
- Tiwari S and Tiwari A. 2007. *Women Entrepreneurship and Economic Development*. New Delhi: Sarup & Sons
- Todaro, Michael P and Smith SC. *Economic Development*. Pearson Education.
- UNFCC- *United Nations Framework Convention on Climate Change* – https://unfcc.int

I. Course Title : Fishery Regulations and Ecosystem Valuation

II. Course Code : FEC 504

III. Credit Hours : 2+1

IV. Aim of the course

To provide an overview of the concept and methods for payment for ecosystem services and their policy implications. This course is aimed at providing a rigorous and application-oriented treatment of different valuation techniques for measuring the value of aquatic environmental goods and services.

V. Theory

Unit I

Fisheries regulations: Fisheries Regulations, Imperative needs for the regulation of marine fisheries in India, Types of fishery regulations, Possible objectives of fisheries regulations; Fisheries regulations followed in the maritime states of India.

Unit II

Aquaculture guidelines: Aquaculture; Guidelines under CRZ notification of 1991 and its Amendments, Land leasing policies, Regulations on use of chemicals and antibiotics, Features of Aquaculture Seed (Quality Control) Relevant Central/state legislative provisions of Environment, Wildlife, Water, Biodiversity: (riverine, reservoir and aquaculture), Processing in different States.

Unit III

Ecosystem valuation: Environmental and ecosystem valuation, The concept of value and valuation –Theoretical basis of valuation – Consumer surplus, Compensating variation and equivalent variation, Cost-benefit analysis of a

conservation project, Ecosystem valuation, Payment for ecosystem services, Ethical issues in valuation, choice of discount rate.

Unit IV

Methods of valuation - Revealed preference methods: Taxonomy of ecosystem values, Use value, non-use value, Direct and indirect use value, Existence value, Bequest value and option value, Revealed preference methods, Change in productivity method – Averting behavior and substitutable private, and Environmental goods, Models for bundled attribute goods, Hedonic of differentiated commodities, Discrete choice model of differentiated commodities, Hedonic property value model, Replacement cost approach, Substitute goods approach, Travel cost methods.

Unit V

Methods of valuation –Stated preference methods: Stated preference methods, Contingent behavior, contingent valuation techniques, Willingness to accept and willingness to pay, Bidding games, Choice experiment approach, Combining revealed preference and stated preference methods, Discrete choice models for stated preference data, Validity of stated preference data, Other methods, Benefit transfer.

Unit VI

Risk valuation and assessment: Morbidity and Mortality Risk Valuation, Risk assessment and the environment, Conceptual models, Health production model, Endogenous mortality risk, Measuring the value of a statistical life, Wage hedonics, Valuing health changes, Defensive expenditures and cost of illness, Economic valuation of biodiversity, Measurement of carbon sequestration benefits, Measurement of climate change impact, Agronomic vs. economic methods, Ricardian model, Just-Pope model.

VI. Practical

Contemporary global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms; Fishery regulation in India; Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques; Recreation demand models of environmental valuation – Contingent valuation techniques – Environmental Resource Accounting Techniques; Practical considerations and comparison of instruments of environmental policy; Non-Point source pollution control methodologies - economic valuation and environmental economics; Exercises on change in productivity method; Replacement cost method with examples and insights from literature; Exercises on hedonic pricing. Travel cost method – design and application with example, Stated preference approaches – Contingent valuation methods; Measuring WTP and WTA – Empirical exercises

VII. Suggested Reading

- Adamowicz, Wiktor, Peter Boxall, Michael Willioams, and Jordon Louviere. Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation. *American Journal of Agricultural Economics* 80: 64-75 (February 1998).
- ASC – *Aquaculture Stewardship Council* – https:// www.asc.aqua.org
- Bartik, Timothy J. Measuring the Benefits of Amenity Improvements in Hedonic Price Models, *Land Economics* 64(2): 172-183 (May 1988).
- Bavinck M. 2001. *Marine Resource Management: Conflict and Regulation in the Fisheries*

of the Coromandel Coast. Sage Publications.
- Berkes F. 2001. *Managing Small-scale Fisheries: Alternative Directions and Methods*. IDRC.
- Bromely W Daniel. *The Hand Book of Environmental Economics* (Madison: Black Well Publications), 1995.
- Carlson GA, Miranowski J & Zilberman D. 1998. *Agricultural and Environmental Resource Economics*. Oxford Univ. Press.
- Champ, Patricia A, Kevin J Boyle and Thomas Brown. *A Primer on Nonmarket Valuation*. Boston, Dordrecht, London: Kluwer Academic Publishers, 2003.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- Dillman, Don A. *Mail and Internet Surveys: The Tailored Design Methods*. New York: John Wiley and Sons, 2000.
- Dixon, John A, Louise Fallon Scura, Richard A Carpenter and Paul B. Sherman,"*Economic Analysis of Environmental Impacts*" (London: Earthscan Publications Ltd.), 1995.
- FAO – *Food and Agriculture Organization* – www.fao.org
- Fisher, Antony C. *Resource and Environmental Economics* (London: Cambridge University Press), 1981.
- Freeman, A. Myrick, III. *The Measurement of Environmental and Resource Values*. Second Edition. Washington, D.C.: Resources for the Future, 2003.
- Haab T and TE. McConnell (2002). *Valuing Environmental and Natural Resources: The Econometrics of Non-market Valuation*, Edward Elgar Publishers.
- Hanemann W. Michael. *Valuing the Environment Through Contingent Valuation*, *Journal of Economic Perspectives* 8(4): 19-43 (Fall 1994).
- Hannesson R., 1993. *Bioeconomic Analysis of Fisheries*. Fishing News Books Ltd.
- Hosetti BB and A Kumar "*Environmental Impact Assessment and Management*" (New Delhi: Daya Publishing House), 1998.
- http://ocw.mit.edu/courses/economics/14-42-environmental-policy-and-economics
- http://ocw.mit.edu/courses/economics/14-42-environmental-policy-and-economics-
- http://www.agecon.purdue.edu/staff/shively/courses/AGEC406/index.htm
- http://www.colorado.edu/economics/morey/4545/4545lnts.html
- http://www.economicsnetwork.ac.uk/environmental/resources
- Joy E. Hecht, "*Natural Environmental Accounting – Bridging the Gap between Ecology and Economy*" 2004.
- Myrick Freeman A, "*The Measurement of Environmental and Resource Values – Theory and Methods*" (Resource for the future press) 2003.
- Nick Hanley, Jason F. Shogran and Ben White, "*Environmental Economics in Theory and Practice*", (Delhi: Mc Millan, India), 1997.
- Pinkerton E. ed., 2011. *Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development*. UBC Press.
- Portney, Paul R. The Contingent Valuation Debate: Why Economists Should Care, *Journal of Economic Perspectives* 8(4): 3-17 (Fall 1994).
- Sathiadhas R., 1997. *Production and Marketing Management of Marine Fisheries in India*. Daya Books.
- Timothy C. Haab and Kenneth R. Mc Connell, "*Valuing Environmental and Natural Resources – The econometrics of Non-market Valuation*" (Edward Elgar Publishing Limited, UK), 2003.
- Tom Totenberg, "*Environmental and Natural Resource Economics*" (Pearson – Addision Wesley publication), 2006.
- Turner, Kerry, David prance, Ian Batsman and Johns Hopkins - *Environmental Economics: An Elementary Introduction* 1993.
- Wilson DC, Nielsen JR and Degnbol P. eds., 2003. *The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects* (Vol. 26). Springer Science & Business Media
- www.env-econ.net
- www.teebweb.org

I. Course Title : Marketing Intelligence and Business Analysis

II. Course Code : FEC 505

III. Credit Hours : 2+1

IV. Aim of the course

To give an idea about the marketing intelligence and business analysis applied in the fisheries sector.

V. Theory

Unit I

Research methodology: The role of marketing intelligence in the firm, The process of marketing research, The difference between exploratory and confirmatory research, Secondary and primary data, Qualitative and quantitative research methodologies, Sampling theory.

Unit II

Requirements in business analysis: Requirements in Business Analysis, Management, Communication, Tracing, Configuration and change management, quality assurance, Development, Elicitation including stakeholders and/or product requirements development, Specification.

Unit III

Business analytics: Business Analysis, Internal analysis, External analysis, Business need definition, Gap analysis, Solution proposal (including feasibility analysis), Solution delivery or maintenance program/project initiation- Business process definition, Business goals, Business needs, Business requirements, Limitations and assumptions.

Unit IV

Modelling and forecasting: Solution modelling, validation and verification, Solution evaluation and optimization, Assessing the solution options (proposals), Evaluating performance of the solution, Solution/business process optimization, Model Volatility with ARCH and GARCH for Time Series Forecasting.

Unit V

Marketing research: Definitions of the various methodological concepts -Various steps involved in designing a research plan, Data collection methods; Characteristics, Structure, Sources, Value, and use of Big Data, The relationship between digital analytics and inbound marketing strategies, Consumer information and measurement services, Rules for designing a questionnaire.

Unit VI

Data analysis in marketing research: Data sources for assessing consumer preferences, firm performance, and market condition and competition- analyze enterprise data, especially for purposes of segmentation, targeting, positioning, and evaluating consumer value- process of organizing, writing, framing, and refining analytics reports- delivering effective presentations, and aligning analytic results with stakeholder needs and preferences

VI. Practical

Marketing Research – ethics, standards and issues; Utilisation of Secondary Data Resources for Customer Segmentation Pricing and Elasticity; Linear Regression

Basics; Using Linear Regression to Forecast; Conjoint Analysis; Digital Marketing Metrics Customer Lifetime Value; Cluster Analysis; Finding and interpreting secondary data; Suggesting a methodology for fisheries marketing research; Tools and concepts of data visualization

VII. Suggested Reading

- Axelos, *Managing Successful Projects with PRINCE2*® 2017 Edition, Axelos, 2017 ISBN: 9780113315338
- Bens, Ingrid. *Facilitation at a Glance*! 4th Edition, Goal/QPC; 4th edition, 2016, ISBN-10: 1576811832
- Brown Tim. *Change by Design: How Design Thinking Transforms Organizations*
- Carlson C.C., Wilmot, W.W. *Innovation: The Five Disciplines for Creating What Customers Want*, New York: Crown Business, 2006, ISBN: 0307336697 Edition, ISBN 13: 978-0-13-608543-0
- eNAM – National Agricultural Market https://enam.gov.in
- Harrington H. James. *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness*, 1991 Inspires Innovation, HarperCollins, 2009, ISBN 978-0061766084
- MPEDA – *Marine Products Export Development Agency* – mpeda.gov.in
- Naresh Malhotra. *Marketing Research: an Applied Orientation*, Sixth
- NFDB- National Fisheries Development Board – nfdb.gov.in
- Pearson Prentice Hall *Analyzing the Target Market*, Part 1: Chapter 3, Marketing Research, Harvard Business Publishing BEP 117, length 18 pages

I. Course Title : International Fisheries Trade

II. Course Code : FEC 506

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize students with basic concepts and principles of economics applied to international trade with reference to fisheries.

V. Theory

Unit I

Introduction to international economics: International Economics, Concepts and scope, Nature of international trade, Difference between domestic and Foreign trade; Theories of international trade, Absolute and comparative advantage, Modern theories of international trade, Hecksher Ohlin theorem.

Unit II

Concepts in trade: Concepts of terms of trade, Free trade, Protection, Tariffs, Quantitative restrictions and other non-tariff measures; Exchange rate; Devaluation and depreciation; Balance of payments, EXIM policy of India in relation to fish and fishery products.

Unit III

Export- Import procedures: Export- Import procedures, and certification, Growth of marine product exports – MPEDA and its development programmes.

Unit IV

Institutions and trade policies: GATT and WTO, transition from GATT to WTO, WTO provision and its agreements; Agreement on Agriculture (AoA), Agreement on SPS measures and its salient features, Role of Codex Alimentarius Commission

(CAC) and Agreement in Trade Related Intellectual Property rights (TRIPs) WTO in dispute settlement.

VI. Practical

Pattern and performance of India's seafood exports; Product and market diversification; Competitiveness of Indian fish and fish products; Exports of value added seafood products; Case study of a seafood export firm; Use of SPS / TBT measure; Non-tariff barriers in fisheries trade; Dumping and anti-dumping measures in seafood trade.

VII. Suggested Reading

- Apple yard DR & Field A. J. 2001. *International Economics*. 4th Ed. McGraw Hill.
- Bradley, T. 2008. *Essential Mathematics for Economics and Business* (2nd Ed.). New Delhi: Wiley India Pvt. Ltd
- CAC – Codex Alimentarius Commission – www.fao.org
- Charles PK. 1968. *International Economics*. Richard D. Irwin.
- Cherunilam, F. 2011. *International Economics* (5th Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- Deepti. 2011. *Foreign Direct Investment: in Different Sectors of Indian Economy*. New Delhi: Deep & Deep Publications Pvt. Ltd.
- Dennis Appleyard, *Trade Theory and Practice*. Irwin Publishers
- Ethier WJ. 1995. *Modern International Economics*. Norton International Ed.
- Francis C. 1999. *International Economics*. Tata McGraw Hill. Kemp MC. 1964. Pure Theory of International Trade. Prentice Hall.
- Walterjngo and Kaaj A. 1981. International Economics. 3rd Ed. Prentice Hall.
- Francis C. 2008. *International Economics*. Tata McGraw Hill.
- GATT – *General Agreement on Tariffs and Trade* – https://www.wto.org
- Jain, S. K. 2012. *Export Import Procedures and Documentation* (6th Ed.). Girgaon, Mumbai: Himalaya Publishing House
- Krugman PR & Obstfeld M. 1991. *International Economics*: *Theory and Policy*. Harper Collins Publ.
- Krugman, R. P. and Obstfeld, M. 2013. *International Economics: Theory and Policy* (8th Ed.). New Delhi: Pearson Education.
- Mithani. J.P *International Economics* Tata Mcgraw, Hill, New Delhi
- MPEDA – Marine Products Export Development Agency – mpeda.gov.in
- Nath, H.S. 2012. *Economics of Foreign Exchange and Global Finance*. New Delhi: Cyber Tech Publications
- Pugel, A.T. 2012. *International Economics* (13th Ed.). New Delhi: Tata McGraw Hill Education Private Limited.
- Samuelson and Nordnaus. *Economics*, Tata Mcgraw, Hill, New Delhi
- Taneja, P. 2011. *Statistics for Business and Economics*. New Delhi: Rajat Publications
- Tejpal, B.K. 2012. *Business Economics: Modern Methods & Techniques*. Jaipur: Ritu Publications
- Venkatachalam, P.V. 2012. *Text Book on International Economics*. New Delhi: Cyber Tech Publications
- WTO – World Trade Organisation - https://www.wto.org

I. Course Title : Fisheries Finance, Accounting and Control

II. Course code : FEC 507

III. Credit Hours : 2+1

IV. Aim of the course

To make aware about the innovations in the fisheries finance and accounting.

V. Theory

Unit I

Principles of finance: Importance of fisheries finance; Principles of fisheries financial management, Rural credit structure, Demand and supply, Sources and forms; Estimation of credit requirement; Cost of Credit/capital; Credit appraisal. The concept of 3C's, 7P's and 3R's of credit, District Credit Plan and lending to agriculture/priority sector Micro-Financing.

Unit II

Reforms in policies and institutions: Reforms in fisheries credit policy; Innovations in fisheries financing, Micro Finance, Role of institutions in fisheries, Finance, Public and Private sector banks; Cooperatives, Micro-finance institutions (MFIs), SHGs; Financing through Co-operatives, NABARD and Commercial Banks and RRBs International Financial Institutions; Successes and failures of co-operative sector in India; Role of co-operatives under emerging economic scenario.

Unit III

Capital and cost concepts: Sources of long-term finance and cost of capital; Concepts of components of working capital, Managing working capital, Cash management, Dividend decision; Capital budgeting, Appraisal criteria; Fish business financing system in India-money and capital markets, National, regional and global financial institutions; Insurance; Risk management; Micro-credit.

Unit IV

Project formulation and appraisal: Elements of project cycle; Identification, Preparation, appraisal, Financing and implementation of projects, Project Appraisal techniques; Undiscounted measures, ranking by inspection, Pay-back period, Average annual proceeds per unit of outlay, Time value of money, Use of discounted measures, Derivation of incremental net benefit; B-C ratio, NPV and IRR, Project management Net-work Techniques – PERT and CPM.

Unit V

Accounting types: Branches of Accounting, Internal and External Users of Accounting, Financial Accounting, Meaning, Need, Concepts and Conventions; Advantages and Limitations, Accounting Standards, The Double Entry System, Its Meaning and Scope, The Journal, Cash Book, Ledger, Trial Balance, Trading Account, Profit and Loss Account, Balance Sheet, Entries and Adjustments of different heads in different Books and Accounts, Introduction of Company Accounts.

Unit VI

Accounting management: Management Accounting, Meaning, Functions, Scope, Utility Limitations and Tools of Management Accounting, Cost Accounting, Basics, Significance, Objectives, Classification of Costs, Marginal Costing. Responsibility Accounting, meaning and significance, Budgets and Budgetary Control-Types of Budgets.

VI. Practical

Rural Lending Programmes of Commercial Banks; Lead Bank Scheme-Preparation of District Credit Plan; Preparation of financial statements using farm/firm level data; Farm credit appraisal techniques and farm financial analysis through financial statements; Different case studies on fisheries cooperative societies and their

performance (marine and inland sector); Practical exercise on PERT and CPM; Ratio analysis; Valuation of project inventories; Project appraisal techniques– undiscounted and discounted measures; Company accounts format and formatting

VII. Suggested Reading

- Bhatia BS, HL Verma, Mahesh C Harg. 2001. *Encyclopaedia of Co-operative Management* (Vol. I, II, III, IV), Deep and Deep publications, New Delhi
- Chodhury, Project Management Tata McGraw Hill Publishing Company Ltd., New Delhi
- FAO. Technical Paper No.334, *Fisheries Project Formulation*, FAO, Rome.
- FAO. 1971. *Manual on Fishermen's Co-operatives*, Rome.
- Gittinger J, Price. *Economic Analysis of Agricultural Projects*, EDI Series in Economic Development, John Hopkins University Press, Baltimore and London
- NABARD – National Bank for Agriculture and Rural Development – https://www.nabard.org
- Proctor T. 2005. *Essentials of Marketing Research. Financial Times*, Prentice Hall.
- Rajagopalan R. 1997. *Rediscovering Cooperation* Vol. I, II, III, IRMA Anand.
- Ronald W Cotterill. 1998. *Competitive Strategy Analysis for Agri-marketing Co-operatives*. 5. FISHCOPFED. 1989. *Fish Co-operatives*, New Delhi.
- Shang YC. *Aquaculture Economic Analysis* – An Introduction, The World of Aquaculture Society Ltd.
- Twiner and Simister (ed.). *Project Management*, Infinity Books, New Delhi.

I. Course title : Introduction to Econometric Tools

II. Course code : FEC 508

III. Credit Hours : 1+1

IV. Aim of the course

To make students acquainted with econometric tools applied to social sciences. This course on quantitative and econometric analysis focuses on practical applications that are relevant in fields such as economics, finance, public policy, business and marketing.

V. Theory

Unit I

Nature and scope of econometrics: Definition and Scope of Econometrics; Methodology of econometrics, The nature of the econometrics Approaches, Simple regression estimation and testing procedures, Stochastic and Non-Stochastic relations, Statistical properties of least squares estimators, Confidence interval and Hypothesis testing, Goodness of fit, Reporting the results of regression Analysis; Matrix Algebra.

Unit II

Introduction to classic linear regression analysis: Two variable regression model, The basic assumptions; Application of regression model, The covariance and covariance estimator, Functional forms of regression models and methods of estimation; Cobb-Douglas Production Model, Multiple regression model, Relationship between simple and multiple regression coefficients; Auto correlation-Heteroscedasticity; Multicollinearity; Meaning and problem, Autoregressive models for univariate time series stationary data (AR), Trend (ARIMA), and Seasonal component (SARIMA).

Unit III

Regression models and forecasting techniques: Simultaneous – Equation

Models; Problems of Simultaneous equation model; Multinomial regression models Ordinal – Regression models.

Unit IV

Forecasting with regression model: Panel data regression models, Survival analysis, Parametric and non-parametric tests in Social Sciences; Adhoc procedures in Regression analysis, Estimation of Probit, Logit and Tobit Probability Models.

VI. Practical

Analysis on fitting classical linear regression models; Detection of multicollinearity; Forecasting models; Heteroscedasticity and autocorrelation for the given data sets in fisheries; Parametric and non-parametric tests; Data analysis in MS excel, SPSS and STATA; Forecasting models that can be developed for univariate time series data.

VII. Suggested Reading

- Brooks C. 2009. *RATS Handbook to Accompany: Introductory Econometrics for Finance* New York: Cambridge University Press
- Damodar Gujarati. 2006. *Basic Econometrics*. Tata McGraw-Hill Publishing Company Ltd, Delhi
- Damodar Gujarati. 2012. *Econometrics by Example*, Palgrave Macmillan, New York
- Debbie Holmes, Peter Moody & Diana Dine. 2006. *Research Methods for the Biosciences.* International Student edition, Oxford University Press.
- Deepak Chowla & Neena Sondhi.2011. *Research Methodology: Concepts and Cases*. Vikas Publishing House Pvt. Ltd, New Delhi
- Dougherty C. 2011. *Introduction to Econometrics* (4th Ed.). Oxford: Oxford University Press
- Greene HW. 2012. *Econometric Analysis* (5th Ed.). New Delhi: Pearson Education.
- Gujarati D. 2011. *Econometrics by Example*. New York: Palgrave
- Gujarati DN, Porter DC and Gunasekar S. 2012. *Basic Econometrics* (5th Ed.). New Delhi: Tata McGraw Hill Education Private Limited
- Harry H Kelejin & Wallace E Oates. 1975. *Introduction to Econometrics: Principles and Applications*, Herber International Edition, Joanna Cotler Books
- http://www.oswego.edu/
- http://www.tiesindia.net/
- https://guides.lib.monash.edu/econometrics
- https://www.amstat.org/
- https://www.rss.org.uk
- Koutsoyiannis, A. 2013. *Theory of Econometrics: An Introductory Exposition of Econometric Methods* (2nd Ed.). New York: Palgrave
- Madnani GMK. 2012. *Introduction to Econometrics: Principles and Applications* (8th Ed.).New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.
- Murray R, Spiegel & Larry J Stephers. 2000. *Theory and Problems of Statistics*, Tata McGraw-Hill edition, New Delhi
- Studenmund AH. 2015. *Using Econometrics* (6th Ed.). Chennai: Pearson
- Teresa Bradley & Paul Patton. 2008. *Essential Mathematics for Economics and Business.* John Wiley & Sons ltd. New Delhi.

I. Course Title : Management of R&D Innovations and Policy

II. Course Code : FEC 510

III. Credit Hours : 1+1

IV. Aim of the course

To give an idea about the R & D Management and fisheries policy analysis.

V. Theory

Unit I

Innovation and technology: Innovation, productivity and economic growth; Nature, process and importance of technological innovation, Role of fisheries in economic and rural development.

Unit II

Fisheries in economic development theories: Growth stage theories, Structural transportation leading sectors and dual economy models, Technology adoption, Diffusion and transfer, Theoretical models and case studies, Technology, Resources and environment.

Unit III

Fisheries research systems: Fisheries research systems, Evolution and growth, Selected case studies of major countries, Investment trends, International comparisons, Institutional details; Changing public-private roles in technology development, Institutions and fisheries development; Collective actions, property rights, Transaction cost economics.

Unit IV

Theories and policies: Need for separate/sound fisheries policy, Resource polices, Credit policies, Input and product marketing policies, Price policies, Theories of fisheries development, Conservation, Urban industrial impact and Diffusion, High-pay-off input, Science and technology policy, Regulation, Incentives; Technology and Intellectual Property Rights, selected case studies.

VI. Practical

Measurement of productivity growth; Exercise on total factor productivity; Using frontier production function; Institutional structures and national and international fisheries research systems; Ex-ante and ex-post methods of estimation of R & D impacts in fisheries.

VII. Suggested Reading

- Alston JM, Norton GW and Pardey PG. 1995. *Science Under Scarcity*. Cornell University Press, Ithaca.
- Blaug M. 1986. *Economic History and the History of Economic Thought*. Wheatsheaf Books, Brighton. Ghatak S and Ingersent K. *Agricultural Economic Development*. Select Book Service Syndicate, New Delhi.
- FAO – *Food and Agriculture Organization* – www.fao.org
- GATT – *General Agreement on Tariffs and Trade* – https://www.wto.org
- Khurana VK. 2007. *Management of Technology and Innovation*. Ane Books India, Delhi.
- Ruttan VW. 2001. *Technology, Growth and Development: An Induced Innovation Perspective*. Oxford University Press, New York.
- Schultz TW. 1964. *Transforming Traditional Agriculture*. Yale University Press, New Haven Ruttan VM. 2001. *Technology, Growth and Development*. Oxford University Press.
- WTO – World Trade Organisation - https://www.wto.org

I. Course title : Economics of Fisheries Enterprises

II. Course code : FEC 511

III. Credit Hours : 1+1

IV. Aim of the course

To make the students aware about the economics of the various culture fisheries

and the post – harvest operations.

V. Theory

Unit I

Production economics: Aquaculture in economic development, Production concepts in aquaculture Production function, Cost and return concepts in aquaculture, Optimization of use of single resource, Cost of production, Short run production cost, Long run cost, Production function analysis in various aquaculture system, Preparation of financial statements-Balance Sheet, Cash Flow Statement and Profit and Loss Account, Ratio Analysis and Assessing the performance of farm/firm.

Unit II

Planning and budgeting: Farm income and budget analysis, Planning and budgeting, Aquaculture management decisions, Resource, labour and financial management, Managing risks and uncertainties, Economics of different aquaculture systems, Socio economic issues, Causes for aquaculture problems, Government support policies for inland, Coastal and marine aquaculture systems.

Unit III

Value Chain Management concept: Value Chain Management concepts, Value addition in fish marketing, Constraints and approaches to VCM in fisheries sector, Domestic and external markets for fisheries products, Export – Infrastructure development from landing to marketing.

Unit IV

Value chain analysis: Post-harvest operations in inland and marine fisheries including deep sea fishing, methodological issues in marine capture fisheries, needed measures for the constraints in post-harvest operations.

VI. Practical

Estimation of cost and returns of different aquaculture systems in India; Production trends of aquaculture in India for the past 10 years and the projected production estimates; Production function analysis; Planning and budgeting; Financial analysis in aquaculture production systems; Case studies of various aquaculture systems in India; Visit to various shrimp hatcheries or farms; Visit to various finfish farms and ornamental units; Visit to various craft and gear manufacturing units; Cost and returns of marketing establishments including export processing firms

VII. Suggested Reading

- Asche F, Roll KH and Tveteras R. 2009. Economic inefficiency and environmental impact: An application to aquaculture production. *Journal of Environmental Economics and Management*, *58*(1), pp.93-105.
- Battese GE. 1992. Frontier production functions and technical efficiency: a survey of empirical applications in agricultural economics*Agricultural economics*, *7*(3-4), pp.185-208.
- CIBA – Central Institute of Brackish water Aquaculture – www.ciba.res.in
- CIFRI – Central Inland Fisheries Research Institute – www.cifri.ernet.in
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- Engle, Carole R et *al*. 2017. "Economics of sustainable intensification of aquaculture: evidence from shrimp farms in Vietnam and Thailand." *Journal of the World Aquaculture society*48(2), 227-239.
- Hatch U and Tai CF. 1997. A survey of aquaculture production economics and management. *Aquaculture Economics & Management*, *1*(1-2), pp.13-27.

- Jolly CM & Clonts HA. 1993. *Economics of aquaculture*. CRC Press.
- Knapp G & Rubino MC. 2016. The political economics of marine aquaculture in the United States. *Reviews in Fisheries Science & Aquaculture*, *24*(3), 213-229.
- Ngoc PTA, Meuwissen MP, Cong Tru L, Bosma RH, Verreth J & Lansink AO. 2016. Economic feasibility of recirculating aquaculture systems in pangasius farming. *Aquaculture Economics & Management*, *20*(2), 185-200.
- Ìlayide SÌ and Heady EO. 1982. *Introduction to agricultural production economics*. Ibadan University Press, University of Ibadan.
- Shang YC. 1990. *Aquaculture economic analysis: an introduction*. World Aquaculture Society.
- Subba Reddy S and Raghu Ram P. 1996. *Agricultural finance and management*. Oxford & IBH Pub. Co.

I. Course Title : Fisheries Development Planning and Policy

II. Course Code : FEC 512

III. Credit Hours : 2+0

IV. Aim of the course

To understand fisheries policy of different states and plans for development

V. Theory

Unit I

Planning: Planning Commission era, Organisation, role and functions, Planning in India, Objectives, Strategy, Allocation, Achievements and Bottlenecks, Types of planning, Stages in planning process, Planning models. Impact of development plans, International co-operation programmes, NITI AYOG; Planning under NITI AYOG; Planning and development in China and Russia; Planning and Free Market economies.

Unit II

Fisheries development schemes and policies: Fisheries Development and policy under the plans, Fisheries schemes; NFDB; NABARD schemes, State and center sector schemes and centrally sponsored schemes, Central Department of Fisheries; Agriculture policies, Need for a separate fishery policy, National Marine Fisheries Policy; Leasing policies for inland and brackish water bodies in different states, National Mariculture Policy; National Inland Fisheries and Aquaculture policy, Inputs Policy, Financing and Credit Policy, marketing and pricing policy, Export -Import Policy.

Unit III

Importance of fisheries in rural and economic development: Importance of Fisheries in rural and economic development, Centre and state level policies for fisheries, Fisheries policy issues, Fisheries sector strategy, Various resource policies, Fisheries policy and Legislation, Development of Fisheries during the Five-Year Plans, Fisheries credit and marketing policies.

Unit IV

Planning and cooperation: Fisheries planning, Economic factors influencing development and co-operation in fisheries, Fisheries management, Role of fisheries in rural development and Policy initiatives, Economic planning in fisheries, Problems of development Planning, Fishing policies and economic growth, Panning and policy analysis, Fisheries project planning.

Unit V

Fisheries legislation: Fisheries legislation in India, background, Indian Fisheries Act of 1897 and Subsequent amendments; Marine capture fisheries, Comparative study of Marine Fishery Regulation, Acts of coastal Indian States – licensing/ registration of vessels and mechanization, Declaration of closed season, Protection of endangered species, Prohibition of destructive fishing methods, Regulation of mesh size, Filing of return on fish catch and income, Features of MPEDA Act and Rules, 1972.

Unit VI

Legislative policies: Guidelines for operation of Indian deep sea fishing vessels in Indian EEZ, Maritime Zone of India (regulation of fishing by foreign vessels) Act 1981, Aquatic exotics and quarantine regulations, Marine Fisheries Policy, 2004. Coastal Aquaculture authority; Aquaculture Guidelines under CRZ notification of 1991 and its Amendments, Land leasing policies, Regulations on use of chemicals and antibiotics, Features of Central/state legislative provisions of Environmental, Wildlife, Water, Biodiversity: (riverine, reservoir and aquaculture), Processing in different States.

VI. Suggested Reading

- Bailey C and Jentoft S. 1990. *Hard Choices in Fisheries Development*. Marine policy, 14(4), pp.333-344.
- Chakaravathi RM. 1986. *Under Development and Choices in Agriculture*. Heritage Publ., New Delhi.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in
- Dewett KK. 2002. *Modern Economic Theory*. S. Chand & Co.
- Diana Tussie and David Glover. 2000. *The Developing Countries in World Trade- Policies and Bargaining Strategies*, Lynne Rienner/ IDRC, Washington.
- Dutta and Sundaram Indian economy
- FAO – Food and Agriculture Organization –www.fao.org
- Gillis M, Perkins DH, Roemer M and Snodgrass DR. 1992. *Economics of Development* (No. Ed. 3). WW Norton & Company, Inc.
- Green D and Griffith M. 2002. *Dumping on the Poor: The Common Agricultural Policy*, the WTO and International Development, CAFOD, London.
- HL Ahuja *Indian Economy*
- Higgins Benjamin. *Economic Development, Problems, Principles and Policies*. Universal Book Stall, New Delhi.
- Holden M and Garrod D. 1996. *The Common Fisheries Policy: Origin, Evaluation and Future* (No. Ed. 2). Fishing News Books Ltd.
- James D Gaisford & William A Kerr 2001. *Economic Analysis for International Trade Negotiations*, John Wiley and Sons.
- Kindleberger, Charles P. *Economic Development*. McGraw-Hill, New Delhi.
- ML Jhingan *Economics of Development and Planning*
- Meier, Gerald M. *Leading Issue in Economic Development*. Oxford University Press,Delhi.
- Michael L Weber. 2001. *From Abundance to Scarcity: A History of U.S. Marine Fisheries Policy*, Island Press, New York.
- MPEDA – Marine Products Export Development-www.mpeda.org.in
- NFDB- National Fisheries Development Board – nfdb.gov.in
- Panayotou T. 1982. *Management Concepts for Small-Scale Fisheries: Economic and Social Aspects* (p. 53). Rome: FAO.
- Runge CF. 1986. *Common Property and Collective Action in Economic Development*. World Development, 14(5), pp.623-635.
- Soley N. 1999. *Development Planning: a Perspective for the Fisheries Sector*. Centre for the

Economics and Management of Aquatic Resources, University of Portsmouth.
- Soumyen Sikder. 2001. *Contemporary Issues in Globalisation- an Introduction to Theory and Policy in India*, OUP, New Delhi
- Todaro Machael P. *Economic Development in the Third World*. Orient Longman, NewDelhi

I. Course Title : Fisheries Project Management

II. Course Code : FEC 513

III. Credit Hours : 1+1

IV. Aim of the course

To highlight the different institutions financing fisheries projects

V. Theory

Unit I

Finance and management: Sources of long term finance and cost of capital; Concepts of components of working capital, Managing working capital, Cash management, dividend decision; Capital budgeting, Appraisal criteria.

Unit II

Financing system in India: Financing system in India, Money and capital markets, national, Regional and global financial institutions; Insurance; Risk management; Micro-credit.

Unit III

Project formulation: Elements of project cycle, Identification, Preparation, Appraisal, Financing and implementation of projects, Project Appraisal techniques, Undiscounted measures, Ranking by inspection, Pay-back period, Average annual proceeds per unit of outlay, Time value of money.

Unit IV

Project Evaluation: Identification, Preparation, Appraisal, Financing and Implementation of projects, Project Appraisal technique, Undiscounted Measures, Time value of money, Use of discounted measures, B-C ratio, NPV and IRR, Agreements, Supervision, Monitoring and Evaluation phases in appraising fisheries investment projects, Net worth Techniques–PERT and CPM.

VI. Practical

Rural Lending Programmes of Commercial Banks, Lead Bank Scheme; Insight on District Credit Plan; Preparation of financial statements using farm/firm level data; Farm credit appraisal techniques and farm financial analysis through financial statements; Different case studies on fisheries cooperative societies in India; Visit to marine and inland cooperatives to analyse performance; Practical and Case studies: Ratio analysis, valuation of project inventories; Project appraisal techniques–undiscounted and discounted measures.

VI. Suggested Reading

- Chodhury, *Project Management* Tata McGraw Hill Publishing Company Ltd., New Delhi
- Dhubashi PR. 1986. *Policy and Performance - Agricultural and Rural Development in Post Independent India.* Sage Publ.
- FAO Technical Paper No.334, *Fisheries Project Formulation*, FAO, Roam.
- Gittinger JP. 1982. *Economic Analysis of Agricultural Projects***.** The Johns Hopkins Univ. Press. Gupta SC. 1987. *Development Banking for Rural Development.* Deep & Deep Publ.

- Gittinger J Price. *Economic Analysis of Agricultural Projects*, EDI Series in Economic Development, John Hopkins University Press, Baltimore and London
- Little IMD & Mirlees JA. 1974. *Project Appraisal and Planning for Developing Countries.* Oxford & IBH Publ.
- Muniraj R. 1987. *Farm Finance for Development*. Oxford & IBH Publication.
- Shang YC. *Aquaculture Economic Analysis – An Introduction*, The World of Aquaculture Society Ltd.
- Twiner and Simister (ed.). *Project Management*, Infinity Books, New Delhi.

Course Title with Credit Load
Ph.D. in Fisheries Economics

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FEC 601	Fisheries Production and Sustainability	1+1
FEC 602	Applied Econometrics	2+1
FEC 604	Fishery Resource Evaluation and Governance	1+1
FEC 605	Institutional and Legal Environment for Fish Business	2+0
FST 601	Advanced Statistical Methods	2+1
	Minor Courses (From the subjects closely related to a student's major subject)	**6 Credits**
FEC 603	Economics of Development and Planning	2+0
FEC 606	Indian Fisheries Trade and International Scenario	1+1
FST 602	Software for Fisheries Data Analysis and Management	0+2
	Supporting courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**5 Credits**
	Total Course Work Credits	**23 Credits**
	Seminar	**2 Credits**
FEC 691	Seminar-I	0+1
FEC 692	Seminar-II	0+1
	Ph.D. Research	**75 Credits**
FEC 699	Doctoral Research (Semester II)	0+15
FEC 699	Doctoral Research (Semester III)	0+15
FEC 699	Doctoral Research (Semester IV)	0+15
FEC 699	Doctoral Research (Semester V)	0+15
FEC 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fisheries Economics

I. Course Title : Fisheries Production and Sustainability
II. Course Code : FEC 601
III. Credit Hours : 1+1

IV. Aim of the course

To impart skill of fish production and sustainability in the different culture systems

V. Theory

Unit I

Introduction: Fishery resources of India, Capture and culture fisheries- Status and prospects, Production function in culture and capture fisheries of India- Inland fisheries in India, Marine fisheries in India, Mariculture, Present status and future potential.

Unit II

Production economics: Fish catch and fishing effort, Catch per unit effort, Fishing costs and returns, Estimation of economics of fisheries, Dynamic economic models of fishing, Sustainable yield, Sustainable yield curves, Open access equilibrium, Maximum economic yield, Maximum sustainable yield, Change in open access equilibrium yield, Free and open access equilibrium, Total revenue, costs and sustainable yield with respect to effort.

Unit III

Fisheries management: Fisheries Management Theories, Objectives and techniques of fisheries management, Criteria for fisheries management, Need for management, Implementation of management Measures.

Unit IV

Fisheries regulations: Objectives of fisheries regulation, Need and types of regulation in Indian Fisheries, Overfishing- Problems of overfishing, Reasons for overfishing, Measures adopted to minimize overfishing.

VI. Practical

Production status of fishery resources in India; Analysis in the production of marine fisheries in India; Analysis in the production of maritime states in east coast of India; Analysis in the production of maritime states in west coast of India; Analysis in the production of inland fisheries in India; Analysis in the production of inland states in India; Catch and effort surveys; Estimation of cost and returns of different capture fisheries methods; Estimation of cost and returns of different culture fisheries methods; Case studies on various sectors of fisheries.

VII. Suggested Reading

- Charles AT. 2008. *Sustainable Fishery Systems*. John Wiley & Sons.
- CMFRI- Central Marine Fisheries Research Institute – www.cmfri.org.in

- Evenson RE and Pingali P. 2010. *Handbook of Agricultural Economics*, vol. 4. Amsterdam, London: Elsevier
- FAO – Food and Agriculture Organization – www.fao.org
- Johl SS. 2007. *Fundamentals of Farm Business Management.* New Delhi: Kalyani Publishers
- Munro GR and Scott AD. 1985. *The economics of fisheries management*. In Handbook of natural resource and energy economics (Vol. 2, pp. 623-676). Elsevier.
- Pearce D, Barbier E and Markandya A. 2013. *Sustainable Development: Economics and Environment in the Third World*. Routledge.
- Schaefer MB. 1957. *Some Considerations of Population Dynamics and Economics in Relation to the Management of the Commercial Marine Fisheries*. Journal of the Fisheries Board of Canada, 14(5), pp.669-681.
- Sutinen JG and Andersen P. 1985. The economics of fisheries law enforcement. *Land Economics*, 61(4), pp.387-397.
- WWF- World Wide Fund for nature - htpps: //www.worldwildlife.org

I. Course Title : Applied Econometrics

II. Course Code : FEC 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge of advanced econometric tools for better understanding of economic problems.

V. Theory

Unit I

Model specifications: Econometric model specification criteria, Specification errors, Measurement errors of dependent and explanatory variables, Different model specification criteria.

Unit II

Instrumental variables: Review of classical regression model, Hypothesis testing, Estimation subject to linear restriction, Mixed estimation, Use of instrumental variables in regression analysis.

Unit III

Qualitative regression tools: Use of Dummy variables, Models for qualitative dependent variable-LPM, Multinomial logit models.

Unit IV

Simultaneous equations: Simultaneous equation systems; Basic rationale, identification problems, Single equation methods of estimation, Indirect least squares, Two stage least squares and K-class estimators, Limited information maximum likelihood, Three-stage least squares and Full information maximum likelihood; Relative merits of these methods and their small and large sample properties, SURE estimates.

Unit V

Time series analysis: Introduction to time series analysis, Trend, cycle and seasonality, Time series models, Basic ideas in fitting non-linear regression models.

Unit VI

Time series modelling: Distributed lag models, Analysis of economic time series,

Stationarity and unit root test, ARIMA, ARCH group of models and co-integration, Neural Network Models, Pooling of cross-section and time series data.

VI. Practical

Estimation of multiple regression model; Estimation of LPM; Logit and Probit models – comparing two regressions; Chow test - Indirect least squares 2SLS, SURE, 3SLS; Estimation of simultaneous equation models; unit root tests for stationarity, fitting of ARIMA and ARCH group of models; Co integration. Model selection; Hands on using econometric packages like SPSS and SAS.

VII. Suggested Reading

- Greene WH. 2002. *Econometric Analysis*. Pearson Edu.
- Gujarati, Damodar, *Econometrics*, McGraw Hill, latest edition
- http://www.oswego.edu/
- http://www.tiesindia.net/
- https://guides.lib.monash.edu/econometrics
- https://www.amstat.org/
- https://www.oecd.org
- https://www.rss.org.uk
- Johnston, J. and Dinardo, J. 2000. *Econometric Methods*. McGraw-Hill.
- Maddala, G.S. 2002. *Econometrics*. McGraw Hill.
- Spyros Makidakis, Steven Wheelwright and Hyndman, Wiley *Forecasting Methods and Applications*.

I. Course Title : Economics of Development and Planning

II. Course Code : FEC 603

III. Credit Hours : 2+0

IV. Aim of the course

To provide orientation to the concepts and measures of economic development and planning.

V. Theory

Unit I

Economic development and growth: Development Economics, Scope and Importance, Economic development and economic growth, Divergence in concept and approach, Theories of development; Indicators and Measurement of Economic Development – GNP as a measure of economic growth – Green GNP, Criteria for under development, Obstacles to economic development, Economic and Non-Economic factors of economic growth.

Unit II

Theories of development: Role of fisheries in economic development, Characteristics of developing and developed economies; Theories of development; Role of economic, Technological, Social, Cultural, Political and Environmental factors; Interdependence between fisheries and industrial development.

Unit III

Growth models: Growth models – Harrod - Domar, Neo-classical, Von Neumann; Development strategies in India; Five-year plans and fisheries, Growth analysis, Determinants of growth and their measurements.

Unit IV

Planning: Planning models, Features of planning in capitalist, Socialist, Neosocialist and Mixed economies; Types of planning, micro level, Regional, Sectoral, Agro eco regional development.

Unit V

Institutions and policies: Role of Non-Government Organizations (NGOs) and Self-Help Groups (SHGs) in agriculture and fisheries development; Characterizing fisheries growth, Changes in fishing and farming pattern, Decomposition analysis and sources of output growth; Transfer of technology, Constraints to technology adoption, Yield gap analysis and research planning; Fisheries information system, Fisheries policy analysis and reforms.

Unit VI

Food and nutritional security: Concepts of food and nutritional security, Production oriented policies, Food price policies, Food subsidies, Food safety and Food quality, Measurement of poverty, Poverty alleviation programmes.

VI. Practical

VII. Suggested Reading

- Chakaravathi RM. 1986. *Under Development and Choices in Agriculture*. Heritage Publ., New Delhi.
- Dewett KK. 2002. *Modern Economic Theory*. S. Chand & Co.
- Dutta and Sundaram. *Indian Economy*
- HL Ahuja. *Indian Economy*
- ML Jhingan. *Economics of Development and Planning*

I. Course Title : Fishery Resource Evaluation and Governance

II. Course Code : FEC 604

III. Credit Hours : 1+1

IV. Aim of the course

The students will be exposed to economic evaluation techniques in the realm of resource governance in fisheries.

V. Theory

Unit I

Ecosystem valuation: Present status of Natural environmental ecosystems in India Economic Tools Markets for the Environment, Valuing the natural ecosystems in fisheries, Cost-Benefit analysis and Environmental risk, Problems in natural Fishery Resources management, Misuse of natural resources, Accountability and transparency.

Unit II

Environmental policies and tools: A History of Environmental 'Regulation, Environment, Security, Violence: The Malthusian Legacy, Problems of "Regulating" Nature, Introduction to Policy Analysis; A policy tool approach. Property Rights and Common Property Management, Payments for environmental services.

Unit III

International Environmental Agreements: Evolution in Environmental

Governance, Governance Strategies, Governance Tools, Analytical issues in assessing participation and devolution, Participatory approaches in natural resource management and policy.

Unit IV

Environmental Impact assessment: Concept and principles of EIA; Methodologies for EIA in fisheries and aquaculture sector; Institutional (International/National/ Stale/Local) arrangements and strategies for estimation, Amelioration and compensation for impacts; Aquaculture Authority Bill and AAI, Environment related conflicts and dispute resolution; Coasian theorem and stakeholder decision making process.

VI. Practical

Environmental Policy Analysis; Developing Criteria for Evaluating Environmental Policies; Frameworks for environmental governance analysis; Common Property and Community-Based Resource Management; Case studies on environmental economics of shrimp farming (intensive/semi-intensive/extensive) and poly culture farms; Application of Extended Domestic Resource; Cost Ratio and Policy Analysis Matrix for aquaculture; Case studies on the sustainability of various capture fishery systems; Exercise on global warming and fisheries development concepts in valuing environment; Productivity change method, substitute cost method, Hedonic price method, Travel cost method, Contingent valuation methods.

VII. Suggested Reading

- Donald Kettl. *Introduction: Environmental Governance: A Report on the Next Generation of Environmental Policy*, Brookings Institute 2001.
- E.Ostrom. 2000. *Private and Common Property Rights*, http://allserv.rug.ac.be/~gdegeest/ 2000book.pdf (pp. 332-352)
- Forsyth T. 2009. *Democratizing Environmental Expertise About Forests and Climate*. In Kütting, G and Lupshutz (eds) *Environmental Governance: Power and Knowledge in a Local-Global World*. Routledge: London and NY. Pp170-185.
- Lemos MC and A Agrawal. 2006. Environmental Governance. *Annual Review of Environmental Resources*, 31: 297-325.
- Paluso NL. 2004. *Coercing Conservation*. In Conka, K & Dabelko, G.D. Green Planet Blues: *Environmental Politics from Stockholm to Johannesburg*. Westview Press. Third Edition. Pp 346-357
- Pretty and Ward. Social Capital and the Environment. *World Development* (29) 2: 209-229
- Cortner HJ and MA Moote. 1999. *Collaborative Stewardship in Action: Building a Civic Society*. *The Politics of Ecosystem Management*. Washington, D.C.: Island Press.
- Ridley M and B Low. 1993. "Can Selfishness Save the Environment" *The Atlantic Monthly* 272 (3): 76-86.
- Scott JC. 1998. *Nature and Space*. In Scott, J.C.: Seeing like a State. New Haven, Yale University Press, pp. 11-52.
- Vatn AE, Krogh F, Gundersen and P Vedeld. 2002. Environmental Taxes and Politics - The Dispute over Nitrogen taxes in Agriculture. *European Environment*, 12: 224-240.
- Vedung E. 1998. *Policy Instruments: Typologies and Theories*. In Bemelmans-Videc, ML RC Rist and E. Vedung (eds) Carrots, Sticks and Sermons. *Policy Instruments and their Evaluation*. New Brunswick, Transaction Publishers, pp. 28-53.

I. Course Title : Institutional and Legal Environment for Fish Business

II. Course Code : FEC 605

III. Credit Hours : 2+0

IV. Aim of the course

To provide an insight into the legal and institutional aspects that impact the efficiency and performance of fish business organizations.

V. Theory

Unit I

Legal system and business: The Indian legal system an overview, The Indian Contract Act (1872); Meaning, nature, and scope; Types of contracts; Essentials of a valid contract, Offer and acceptance, capacity to contract, Free consent, Performance of contract, Issues in international business transactions; International Sale of Goods, The Sales Contract, Letters of Credit, Foreign Direct Investment, Protection of intellectual property, Dispute Resolution.

Unit II

Acts and laws: Companies Act (1956); Incorporation, Commencement of business, types of companies, Management, Winding up of companies; Negotiable Instruments Act, Factory Act, Labour laws, Industrial dispute Act.

Unit III

Management systems for food quality and safety: Management systems for food quality and safety; Regulatory provisions and acts; Essential Commodities Act, APMC Act, Consumer Protection Act, RTI Act, MRTP Act, Regulations related to food safety, Hygiene and quality; National FPO (1955).

Unit IV

Acts and laws for food quality and safety: Food Safety and Standards Act (2006), and other Acts related to fish, fruits, meat, milk, grading and standardization (AGMARK) and international (sanitary and phyto-sanitary requirements, Codex, ISO, HACCP, Good Manufacturing Practices (GMP) and Good Agricultural Practices (GAP)) (BMPs in Aquaculture and Fisheries).

Unit V

Institutional environment: Role of institutions in fish business; Ministry of Food Processing Industries, Ministry of Food and Consumer Affairs, Product Boards, Export Promotion Council, Food Safety and Standards Authority, India, etc. International institutions facilitating fish business, Provisions related to FDI in agriculture and food production and distribution.

Unit VI

Corporate social responsibility: Nature and importance of ethics and moral standards; Corporations and social responsibilities, Scope and Purpose of business ethics; Ethics in business functional areas; Industrial espionage; Solving ethical problems; governance mechanism.

VI. Suggested Reading

- Bare Acts: Indian Contract Act. 1972. *The Sale of Goods Act* 1930. Essential Commodities Act, 1955, Consumer protection Act, 1986. The companies Act, 1956.
- Chow, Daniel CK and Schoenbaum TJ. 2005. *International Business Transactions: Problems,*

Cases and Material. Aspen Publishers Gulshan, S.S. and Kapoor, G.K. 2003. *Business Law including Company Law*. 10thed. New Age Publications.
- http://www.fao.org
- https://www.fisheries.noaa.gov
- https://www.iied.org
- https://www.wto.org
- Kapoor ND. 2005. *Business Law*. S. Chand & Sons. Tulsain PC. 2006. *Business Law*. Tata McGraw Hill.
- Tuteja SK. 2005. *Business Law for Managers*. S. Chand & Sons.

I. Course Title : Indian Fisheries Trade and International Scenario

II. Course Code : FEC 606

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the student with the evolution, growth and performance of Indian fisheries trade in international context.

V. Theory

Unit I

Evolution of Indian fisheries industry: Growth and evolution of Indian fisheries industry; Size, Organisation, structure, Export promotion measures in India, Duty draw back, Deemed exports –ASIDE-MDA-MAI-EPGC, Innovations and productivity in Indian fisheries industry.

Unit II

Trade theories and policies: International trade; Nature of international trade, Theories of international trade, Modern theories of international trade.

Unit III

Concepts of terms of trade: Free trade, Protection, Tariffs, Quantitative restrictions and other non-tariff measures, Globalisation and changing facets of global and Indian fisheries industry.

Unit IV

Institutional frame work: Growth of global fisheries industry, Fresh, Frozen, Cured, Canned and other types, Fisheries industry in US, Japan, European Union, Australia, Asian and African countries, Institutional frame work in India for foreign trade, Internalization of Indian fisheries trade.

VI. Practical

Pattern and Performance of India's Seafood Exports; Export Composition and destination of Indian seafood products; Product and market diversification; Competitiveness of Indian fish and fish products; Exports of value added seafood products; Case studies on non-tariff barriers in fisheries trade; Case studies on dumping and anti-dumping measures in seafood trade; Studies on world shrimp, tuna and cephalopod industries; Analysis of International price trends and volatility; WTO and trade dispute settlement.

VII. Suggested Reading

- Appleyard DR & Field AJ. 2001. *International Economics*. 4th Ed.
- FAO. Fisheries Statistics. Rome (Various years).

- FAO. Globefish Commodity Updates. Rome (Various years).
- Francis C. 2008. *International Economics*. Tata McGraw Hill.
- Henry Thompson. 2010. *International Economics*. World Scientific Publishing Co,Pte.Ltd
- Jain Khushpat S. 2012. *Export Import Procedures and Documentation*. Himalaya Publishing House
- Krugman PR & Obstfeld M. 1991. *International Economics: Theory and Policy*. Harper Collins Publ.
- McGraw Hill.Dennis A. 2001. *Trade Theory and Practice*. Irwin Publ.
- Ministry of Agriculture. *Handbook of Fisheries Statistics*. New Delhi (Various years).
- Mithani JP.1998. *International Economics*. Tata McGraw Hill.
- Oscar JB. 1999. *Export Competitiveness in South-East Asia: Policy Initiatives and Corporate Actions in Marine Products Industry*. Wheeler Publ.
- Porter G. 1998. *Fisheries Subsidies* – Over fishing and Trade. Geneva.

List of suggested Journals

- *Agricultural Economics*
- *Agricultural Economics Research Review*
- *American Journal of Agricultural Economics*
- *Applied Economic Perspectives and Policy (Review of Agricultural Economics)*
- *Aquaculture Economics and Management*
- *Arthshastra: Indian Journal of Economics & Research*
- *Asian Journal of Agricultural Extension, Economics & Sociology*
- *Australian Journal of Agricultural and Resource Economics*
- *Canadian Journal of Agricultural Economics*
- *Ecological Economics*
- *Economic Affairs*
- *Economic Systems*
- *Economic and Political Weekly*
- *Economics-The Open Access Open-Assessment E-Journal*
- *Environment and Development Economics*
- *European Review of Agricultural Economics*
- *Forest Policy and Economics*
- *Indian Journal of Agricultural Economics*
- *Indian Journal of Agricultural Marketing*
- *Indian Journal of Economics and Development (Indian Journal of Industrial Economics and Development)*
- *International Journal of Economics, Commerce and Business Management*
- *International Journal of Economics, Commerce and Research*
- *International Research Journal of Agricultural Economics and Statistics*
- *Journal of Agricultural Economics*
- *Journal of Agricultural and Food Economics*
- *Journal of Economics*
- *Journal of Economics, Management and Trade (British Journal of Economics, Management and Trade)*
- *Journal of Fisheries Economics and Development*
- *Journal of Global Economics, Management and Business Research*
- *Maharashtra Journal of Agricultural Economics*
- *Shanlax International Journal of Economics*

List of suggested e-Resources

- Fisheries economics and policy related publication and tools including resilience-http://www.ifpri.org/publications?keyword=Fisheries+economics & ss_search_author=& sm_content_subtype_to_terms=All & sort_by=ds_year &f%5B0%5D=sm_research%3Anode%3A9838
- OECD Data for fisheries production statistics - https://data.oecd.org/fish/fish-landings.htm

- World bank: climate change, macroeconomics, competiveness, trade, poverty, gender, income inequality - https://www.worldbank.org/en/topic
- PROFISH- marine fisheries, aquaculture and climate changehttps://www.worldbank.org/en/topic/environment/brief/global-program-on-fisheries-profish
- Fisheries economics and policy; ecosystem valuation; cost benefit analysis; and conservation of ecosystem - https://www.youtube.com/channel/UCSUx8XzYbinaF0whJYXHU8Q
- Fisheries statistics details state wise - https://data.gov.in/sector/fishery
- Fisheries Economics related publications -http://www.seaaroundus.org/articles/
- National agricultural marketing related schemes - http://sfacindia.com/Nam.aspx
- National Marketing - https://enam.gov.in/web/
- Entrepreneurship, Gender and Climate change - https://www.worldfishcenter.org/publications-resources
- Policies, Institutions, and Markets - https://www.cgiar.org/research/program-platform/policies-institutions-and-markets/
- Climate Change, Agriculture and Food Security - https://www.cgiar.org/research/program-platform/climate-change-agriculture-and-food-security/
- Fisheries Economics related Indian Publications - http://eprints.cmfri.org.in/view/subjects/economics.html
- Fish Marketing - http://eprints.cmfri.org.in/view/subjects/Sub26.html
- Theses including fisheries economics - http://eprints.cmfri.org.in/view/subjects/theses.html
- FAOSTAT http://www.fao.org/faostat/en/#home
- Indiastathttps://www.indiastat.com/
- Marine Products Export Development Authority (MPEDA) https://mpeda.gov.in/MPEDA/#
- Ministry of Statistics and Programme Implementation http://mospi.nic.in/sustainable-development-goalssdgs
- Economic Survey 2018-19 https://www.indiabudget.gov.in/economicsurvey/
- ICAR-NCAP http://www.ncap.res.in/#

Suggested Broad Areas for Master's and Doctoral Research

- Profitability and comparative performance of different aquaculture systems
- Investment pattern and capital flow in fisheries sector over the years
- Price spread/consumer surplus, and marketing efficiency of different marketing channels in fisheries marketing
- Opportunities and challenges for organised fish retail markets
- Impact of mechanization/modernization in coastal fisheries on productivity, sustainability and livelihood
- Cost benefit analysis of different aquaculture production systems
- Cost benefit analysis of advanced aquaculture production systems like RAS
- Capital formation and fisheries development in different plans
- Social and ecological impact of coastal aquaculture
- Conservation economics
- Social and ecological benefit of waste water based aquaculture systems
- Preparation of model commercial project proposals
- Economic and financial analysis of fisheries project proposals
- Export performance and potential of fish and fish products
- WTO and its implications on the fisheries trade
- Forecasting of the structure and pattern of Indian seafood trade
- Export competitiveness of Indian fish and fish products
- Status and performance of fisheries co-operatives in marine and inland fisheries sector
- Financial appraisal of the different co-operatives
- Estimation of credit requirement of Indian fishing community
- Economic evaluation of the fisheries cooperatives -case studies
- Contribution of agriculture and fisheries to Indian economy over the years
- Capital formation In Indian Agriculture and allied sectors
- Demand and supply projections for fish and fish products

- Consumer preference and market segmentation in domestic and export markets for fish products
- Policy gaps and anomalies in Indian fisheries and aquaculture
- Science and politics of monsoon ban in coastal fisheries
- Production constraints in different aquaculture production systems
- Yield gap analysis of the different aquaculture production systems
- Impact of trade and environment with respect to high value export oriented fisheries
- Analysing the MSY, MEY and SOY of the different marine resources
- Comparative advantage and competitiveness of Indian fish products in relation to major exporting countries
- Impact of anti-dumping and subsidies on Indian fish exports
- Comparative study of land leasing policies for fish/shrimp farming in different States
- Financial advantage of formation of exclusive ministry/council for fisheries

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fisheries Extension

Preamble
(Fisheries Extension)

Fisheries Extension is the conscious provisions of information and communication support to fishermen and fish farmers who use marine, inland and backwaters. A great scope is seen in fisheries extension in various areas of fisheries sector like aquaculture, conservation, post-harvest technologies, fishery information and forecasting, community development, etc. Marine and Inland resources are yet to be exploited fully, which requires greater attention from the fisheries extension system. The Indian coastal zone is dynamic and diverse with a great potential for feeding the increasing human population. India has a coastal line of 8129 km with encouraging and massive infrastructure facilities such as 2.4 lakh fishing crafts operating along the coast, 7 major fishing harbours, 75 minor fishing harbours and 1,537 landing centres are functioning to cater to the needs of over 14.0 million fisherfolk. However, there are several problems facing the fishing industry today. The main consensus about the fishery industry is about the over exploitation of inshore fishery which is stagnating and heavy scope to exploit the offshore and deep sea fishery resources. Secondly, the socioeconomic status of fishermen, fish farmers is still substandard. About 25% of the population live in and around the coastal zone. Keeping all these in mind, the extension needs of the fishermen and fish farmers are the most serious concern in the fishing industry. The major task for extension, thus, becomes to collect the desired information, inform and convince the people about the value of new and better technology packages, make further refinement to suit them and motivate them to adopt it and draw benefit from it. The role of fisheries extension in the development of fisheries is, therefore, immense and considering this the Government of India has created a new Department of Fisheries under the Ministry of Fisheries, Animal Husbandry and Dairying.

Fisheries extension has to play a major role in exploiting offshore and deep-sea fishery opportunities with the help of government policies. Research in various thrust areas of fisheries extension, therefore, provides planners and policy makers with information for the growth of fisheries in India. Considering the vital part of the production of fisheries, the PG degree programme in the fisheries extension is important, and indeed unavoidable.

According to the National marine fisheries policy 2020, the Fisheries extension personnel with higher education on fisheries aspects focusing on fisheries extension only fulfil the mission and objectives of this policy.The unique human resources generated from the fisheries extension would also contribute to the creation of data-based fisheries management, market-led fisheries extension and fisheries advisory services that will be different from crops and livestock.

In view of the above, the present PG degree programme in Fisheries extension has been thoroughly updated and several new courses in M.F.Sc. and Ph.D. levels have been added. In the M.F.Sc. degree programme, courses such as Global Extension Landscape, Knowledge and Innovation Systems, Monitoring, Evaluation and Impact Assessment, Aquapreneurship Promotion and Value Chain Development, Risk Management and Climate Change Adaptation and Capacity Development have been introduced taking into account of the national and global scenario. Moreover, the existing courses are also updated to a great extent.

Courses such as Extension Service System Management, Technology Commercialization and Intellectual Property Management, Policy Engagement and Extension have been added as new courses in the Ph.D. degree programme. Considering the country's existing extension needs, the existing courses are also greatly modified.

Course Title with Credit Load
M.F.Sc. in Fisheries Extension

Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FEX 501	Global Extension Landscape	2+1
FEX 502	Communication and Journalism	2+1
FEX 503	Knowledge and Innovation Systems	2+1
FEX 504	Organizational Behaviour and Development	2+1
FEX 505	ICT for Development	2+1
FEX 506	Monitoring, Evaluation and Impact Assessment	2+1
FEX 507	Aquapreneurship Promotion and Value Chain Development	1+1
	Minor Courses (From the subjects closely related to a students major subject)	**8 Credits**
FEX 508	Sociology, Psychology and Community Organisation	2+1
FEX 509	Risk Management and Climate Change Adaptation	2+1
FEX 510	Capacity Development	1+1
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common Courses (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques 5. Agricultural Research, Research ethics and Rural Development Programmes	**5 Credits**
	Total Course Work Credits	**39 Credits**

Code	Course Title	Credit Hours
	Masters' Seminar	**1 Credit**
FEX 591	Master's seminar	0+1
	Masters' Research	**30 Credits**
FEX 599	Master's Research	0+15
FEX 599	Master's Research	0+15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fisheries Extension

I. Course Title : Global Extension Landscape

II. Course Code : FEX 501

III. Credit Hours : 2+1

IV. Aim of the course

To help the students to appreciate the process and the impact of extension reforms implemented in many countries, the new approaches that are evolving globally in different regions and the policy challenges in managing a pluralistic extension system.

V. Theory

Unit I

Basics of extension & advisory services: Genesis and Evolution of Extension; Understanding education, Extension education, Extension research and Extension service; Formal, Informal and Non-formal education; Principles and Philosophy of Extension Education; Meaning and Importance of Extension and Advisory services (EAS); Core competencies of an extension professional beyond ToT, Performing new functions to deal with new challenges.

Unit II

Extension systems and approaches: Public Extension Systems in India, Historical as well as current systems at state (DoF), national (NAREES) and international levels (WF, NACA, FAO, ICSF, WAS, AFS); Extension systems in different regions: South Asia (Bangladesh and Sri Lanka), South East Asia (Japan, China, Thailand, Indonesia and Vietnam), USA, and Europe, Extension approaches (General extension approach, commodity specialized approach, T & V approach, Participatory approach, Project approach, Farming systems approach Cost-sharing Approach, Educational institution approach); Paradigms of agricultural extension (Technology transfer, advisory work, Human resource development, Facilitation for empowerment); RRA and PRA, Participatory Learning and Action (PLA), Participatory technology development (PTD); Fisheries Co-management; ATMA; Marianad model, BENFISH, Matsyafed model.

Unit III

Extension delivery: Pluralism in Extension Delivery, Private sector (input firms, aqua-business companies, consultants); Non-Governmental Organisations (National/ international)/Civil Society Organisations (CSOs)/SHGs in providing extension; Farmer Producer Organisations - Scope, Strength and Weaknesses-experiences; Media and ICT based extension services; Managing pluralism in EAS - challenges and experiences.

Unit IV

Extension programs and institutions development: Meaning, Concept and

Major paradigms / models; Agriculture and rural Development programs; Important pre-independent extension programs; Extension/ToT programs: NES, ND, ORP, KVK, LLP, FSR & E, TAR-IVLP, NATP, NAIP, NMAET; Fisheries policies and programs: FFDA, BFDA, Blue revolution schemes; Institutions: NFDB, MPEDA-NETFISH, NaCSA, CAA, ICAR-FIs, NITIAayog, MANAGE, EEI.

Unit V

Challenges before extension and advisory services (EAS): New Challenges before farmers/fishers and extension professionals; Supporting fishers/farmers to manage the declining aquatic resources/CPRs; Gender Mainstreaming, How extension can enhance access to knowledge/resources among women & men fishers/farmers; Nutrition- Role of extension in promoting fish as healthy food; Linking fishers/farmers to markets; Adaptation to climate changes- How extension can contribute to up-scaling climate smart fisheries/aquaculture.

Unit VI

Supporting family farms: Doubling fishers/farmers income; In and out Migration in inland and marine fisheries; Attracting and Retaining Youth in Fisheries/Aquaculture; Fisher/Farmer distress; Facilitating access to credit, Inputs and services; Networking and partnership development including GFRAS (Global Forum for Rural Advisory Services) and its regional networks; Extension and Sustainable Development Goals (SDGs); Financing Extension; Mobilizing resources for extension; Strengthening extension policy interface, Generating evidence on impact of extension and policy relevant communication.

VI. Practical

Visits to formal, informal and non-formal educational organization and familiarizes their functional activities, Technology of transfer, advisory work, and Human resource development in fisheries programmes, ToT models of ATMA, Marianad, BENFISH, Matsyafed, etc., Public and private extension services of aqua-business companies, consultants, SHGs, KVK, NATP, NAIP, FFDA, BFDA, MPEDA-NETFISH, NaCSA, CAA, etc., Global and national ICT based fisheries extension services, Gender Mainstreaming in fisheries for poverty reduction, Climate resilient fisheries/aquaculture, Review of national, state and regional extension networks and policies.

VII. Suggested Reading

- Adhikarya R. 1994. *Strategic Extension Campaign – A Participatory-Oriented Method of Agricultural Extension.* Food and Agriculture Organization. Agricultural Education and Extension Service.
- Human Resources, Institutions and Agrarian Reform Division. Rome: FAO.
- Alex G *et al*. 2000. *Decentralizing Agricultural Extension: Lessons and Good Practices*. Washington, DC: The World Bank.
- Antholt C & Zijp W. 1994. *Participation in Agricultural Extension*. Washington, DC: The World Bank.
- Bathrick DD. 1997. *Fostering Global Well-Being: A New Paradigm to Revitalize Agricultural and Rural Development. Food, Agriculture, and the Environment discussion paper* 26. Washington, DC: IFPRI.
- Berdegué JA & Escobar G. 2001. *Agricultural Knowledge and Information Systems and Poverty Reduction*. AKIS Discussion Paper. Washington, DC: The World Bank.
- Birner R & Anderson JR. 2007. *How to Make Agricultural Extension Demand Driven–The Case of India's Agricultural Extension Policy*. IFPRI Discussion Paper. International Food Policy Research Institute. Washington, DC: IFPRI.

- Kaimowitz D. 1991. *The Evolution of Links Between Research and Extension in Developing Countries*. In WM Rivera & D.J. Gustafson, eds. Agricultural extension: institutional evolution and forces for change. Amsterdam: Elsevier.
- Rondinelli D. 1987. *Administrative Decentralization of Agricultural and Rural Development Programs in Asia*. In W.M. Rivera & S.G. Schram, eds. Agricultural extension worldwide: issue, practices and emerging priorities; New York.
- Rondot P & Collion MH. 2001. *Agricultural Producer Organizations: Their Contribution.*
- Schuh GE. 1987. The policy environment necessary to make extension effective. In W.M. Rivera & SG. Schram, eds. Agricultural Extension Worldwide: issues, practices and emerging priorities. London & NY: Croom Helm.
- Schware R & Shibata K. 2003. *Engendering ICT: Ensuring Gender Equality in ICT for Development*. PowerPoint presentation. Washington, DC: The World Bank.

I. Course Title : Communication and Journalism

II. Course Code : FEX 502

III. Credit Hours : 2+1

IV. Aim of the course

To orient the students towards the basics, approaches and applications of communication for facilitation and development.

V. Theory

Unit I

Communication: Meaning and importance, Perspectives, Characteristics, Elements, process, Types (Individual, group and mass communication), Directions(Upward, downward and horizontal) and Levels of communication; Verbal and non-verbal communication; Message - meaning and dimensions; Message distortion types; Barriers to Communication; Noise; Key Communicator, Homophily and Heterophily, Credibility, Fidelity, Empathy and feedback in communication; Communication skills & Competence, Communication effectiveness; Theories and Models of communication.

Unit II

Media and development communication: Audio Visual aids; Classification and selection; Traditional Media and Methods for communication and development programmes; Extension teaching methods; Extension & Development Communication- concept, importance and approaches; Organizational communication; Modularized communication, Business communication-concept, methods and processes; Use of social media in communication; Media mix.

Unit III

Understanding the structure and construction of news: Language and principles of writing; Basic differences between the print, electronic and online news, Organising a news story, 5W's and 1H, Inverted pyramid Criteria for news worthiness, Principles of news selection, Use of archives, Sources of news, Use of internet.

Unit IV

Journalism: Journalism – Meaning, scope and importance, principles, theories; Development journalism – meaning, scope and importance, principles, theories; Growth of and challenges for development/ farm journalism in India.

Unit V

Facets of Journalism: Basics of Writing – News stories, Feature articles, Magazine articles, Farm bulletins and folders; Art of clear writing: Readability and comprehension testing procedures; Script development and Story board preparation; Magazine journalism - profile and feature writing; Radio and television journalism - principles and practices of gathering, writing and producing news for radio and television; Photo journalism - visual language, skills and techniques; Photography; principles and use in extension; New media journalism – websites, blogs, social media; Responsible journalism - fairness and balance, libel, and the commercial nature of the media, Constructive criticism; Advertisements – principles and practice.

Unit VI

Media role: Role in democracy, Responsibility to society, Press and democracy, Contemporary debates and various issues relating to media, Ethics in journalism.

VI. Practicals

Communication skill development and public speaking; Developing extension materials: folders, leaflets, booklets, newsletters, popular and scientific articles, blogging, etc.; News writing and success stories writing; Digital photography and image editing; video production; Visit to news channels/ printing press/fishing villages; Organization of content - choice of media, categorization of photographs, queuing of audio and video clips, logical sequencing, text entry; Identification, articulation and analysis of major issues related to fisheries; Critical analysis of fisheries related news stories and feature articles from development magazines / newspapers; Designing, editing and publishing campus newsletters; Interface with editors of journals and magazines; Critical analysis of fisheries related radio news stories; Producing radio news items for broadcast; Digital photography and image editing; Study and practice of various kinds of video editing systems; Practice and use of digital photography.

VII. Suggested Reading

- Van Den Ban AW. *Communication for Rural Innovation: Rethinking Agricultural Extension*, Blackwell Pub.
- Harry A Carey *Food & Agriculture Org., Communication in Extension: A Teaching and Learning Guide 1999.*
- Francis Xavier Moakley. *Handbook of Audio-Visual Aids*, Publisher: Harcourt Brace Jovanovich. 1973.
- RK Samanta. 1990. *Development Communication for Agriculture*. D.K. publishers. New Delhi
- KB Mathur. 1994. *Communication for Development and Social Change*. Allied Publishers Limited, New Delhi
- Lesiskar RV and Pettit JD. *Business Communication*, Tata Mc Graw- Hill 7.
- Locker, K.O. & Kaczmark. *Business Communication-Building Critical Skills*, Tata McGraw Hill
- Bond FF – *An Introduction to Journalism*, Mac-million, Company, New York.
- Wainwright David – *Journalism Made Simple*. Rupa & Heinemani, London.
- Kamat MV – *Professional Journalism*, Vikas, New Delhi.
- Wolenloy Roland – *Journalism in Modern India*, Asia Publishing, House, London.
- Aggarwal VirBala, Gupta VS. – *Handbook of Journalism & Mass Communication*, Concept Publishing Company, New Delhi.
- Ray G L. 2005. *Journalism*, Kalyani Publishers.

I. Course Title : Knowledge and Innovation Systems

II. Course Code : FEX 503

III. Credit Hours : 2+1

IV. Aim of the course

To orient the students about the various knowledge and innovation systems in fisheries

V. Theory

Unit I

Knowledge systems: Knowledge- meaning, Epistemology, Sources and types; Origins of the innovation systems concept, Innovation vs Invention; Agricultural/ Fisheries Innovation System (AIS) and AKIS; Role of different actors in AIS; Importance of interaction and knowledge flows among different farming sectors.

Unit II

Innovation systems: Innovation – definition – innovation decision process, Role of Extension in AIS, Different views to analyse AIS, Structural view, Functional view, Process view and Capacity view.

Unit III

Diffusion and adoption process: Diffusion – meaning and elements; Diffusion research and its criticism; Generation of innovations in fisheries – Innovation development process; Concept and stages of Innovation-decision process; Diffusion process, Adoption process, Models of diffusion and adoption, Adopter categories and their characteristics; Factors influencing adoption and attributes of innovations.

Unit IV

Change agents in the adoption process: Change agent – meaning, roles, factors of success; Centralized and decentralized diffusion systems; Innovation in organizations; Consequences of innovations - model and classification; Opinion leader – Meaning, Characteristics, Types, Their measurement and Role Critical mass.

Unit V

Indigenous knowledge systems: Indigenous knowledge - meaning, scope and importance, Types and systems; Indigenous vis-a-vis Scientific knowledge; Indigenous-Information, Practices and technologies; Documentation, Validation, Conservation, and Dissemination of ITK and Grassroots level innovations in fisheries; Access and use of indigenous knowledge; Peoples' Biodiversity Register; Issues in protection of traditional knowledge / ITK - understanding Indian Biological Diversity Act and National Biodiversity Authority, Limits to benefit sharing – IPR, Prior Informed Consent, TRIPS vs. CBD; Integration of Indigenous knowledge and modern technologies.

Unit VI

Enabling and scaling up innovations: Role of enabling environment; Policies and institutions in enabling innovation; Methodologies for AIS Diagnosis; Typologies of existing methodologies, strengths and limitations; Scaling Up; Definitions, Changing views on scaling up, Approaches to Scaling Up: Push, Pull, Plant, Probe; Scaling up pathways; Drivers and spaces for scaling up; Framework and Tools for

Scaling up; Planning and implementing a scaling up pathways; Scalability assessment tools; Role of policies in scaling up: Influencing policies for scaling up; Innovation Management for scaling up knowledge and implications for Extension and Advisory Services.

VI. Practicals

Documentation of ITK in fisheries; Development of Case studies of ITK in fisheries; Institutions and NGOs involved in ITK collection and validation, testing appropriateness of ITKs; Concept mapping; describing fisheries technologies; explaining case study of the diffusion process of select fisheries innovations; Identify one fisheries activity and use AIS framework to diagnose actors and their roles, patterns of interaction, institutions determining interaction and the enabling policy environment and develop an AIS Diagnosis Report (Review and Key informant interviews); Undertake a case study on a successful case of scaling up knowledge and identify factors that contributed to its success; Identify one specific knowledge (a technology, an approach) that has been recently introduced and develop an Upscaling Strategy

VII. Suggested Reading

- Rogers Everett M. 2003. *Diffusion of Innovation*, Fifth Edition. New York, NY: Free Press. ISBN 0-7432-2209-1
- Davies Stephen. 1979. *The Diffusion of Process Innovations*. Cambridge University Press. Cambridge.
- Grenier Louise. 1998. '*Working with Indigenous Knowledge*', International Development Research Centre, Canada
- Warren Michael D and others. 1995. '*The Cultural Dimension of Development: Indigenous Knowledge Systems*', Intermediate Technology Publications, London.
- Warren Michael D, vonLiebenstein GW and Slikkerveer. 1993. Networking for indigenous knowledge. *In Indigenous Knowledge and Development Monitor*. Vol. 1 (1) pp 2-4.
- JulianInglis. 1993. *Traditional Ecological Knowledge: Concepts and Cases*, published by DRC, ISBN 0889366837.
- Berkes Fikret. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods*, IDRC, ISBN 0889369437
- Anon. 1998. *Aquatic Sciences and Fisheries Abstracts*, By United Nations Dept. of Economic and Social Affairs, Information Retrieval Limited, Cambridge Communications Corporation, v.28No.8001-10000 1998
- Robert S Pomeroy Rebecca Rivera-Guieb *Fishery Co-Management: A Practical Handbook*, published by IDRC, ISBN 1552501841

I. Course Title : Organisational Behaviour and Development

II. Course Code : FEX 504

III. Credit Hours : 2+1

IV. Aim of the course

To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations

V. Theory

Unit I

Basics of organizational behaviour: Introduction to organizations-Concept and Characteristics of organizations; Typology of organizations; Theories of organizations; Nature of organizational theory, Classical theories, Modern management theories,

System Theory, Criticisms and lessons learnt/analysis; Organization Behaviour-Concepts, Scope, Importance, Models of OB.

Unit II

Group behaviour in organization (organizational system): Foundations of group, Group behaviour and Group dynamics, Group Development and Cohesiveness, Group Performance and Decision Making, Intergroup Relations; Teams in Organisations-Team building experiential exercises, Interpersonal Communication and Group; Leadership, Meaning, types, Theories and Perspectives on Effective Leadership, Power and Influence, Leadership styles; Motivation-Concept & Theories, Managing motivation in organizations.

Unit III

Organizational conflict management: Conflict Management and Negotiation skills, Problem-solving techniques; Job analysis, Job performance and Job- stress management; Occupational stress – Meaning, sources, Effects, Coping mechanism, Effects and management; Occupational stress in farming, Farmer groups/ organizations, research and Extension organizations, Organizations Structure- Need and Types, Line & staff, functional, Committee, Project structure organizations, Centralization & decentralization; Organizational Culture vs Climate; Organizational Change; Organizational Learning and Transformation.

Unit IV

Organizational development and interventions: Organizational development-Concept and process; Meaning, Importance, Characteristics and types of Organization development, Interventions; OD consultant Types of OD consultants and their advantages, Qualifications, Comparison of traditional consultants vs. OD consultants.

Unit V

Management in organizations: Concept and principles of administration and management, Classical and modern theories, Schools of management thoughts, Functions of management – Planning, Organizing, Staffing, Directing and Leading, Controlling, Coordinating, Reporting and Budgeting; Managerial skills, Concept of HRM and methods, Job satisfaction and morale; Performance appraisal – Meaning, Concept and Methods. Authority and responsibility, Delegation and decentralization, line and staff relations; Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Coordination at different levels of extension management, Methods of coordination.

Unit VI

Management techniques: Management by Objectives (MBO) and Total Quality Management (TQM); Time management; Critical analysis of organizational set up of extension administration at various levels; Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organizations.

VI. Practicals

Simulated exercises on techniques of decision making / problem solving; Study the structure and function of fisheries enterprises, Designing organizational structure/ organograms; Group activity on leadership development skills, Field visit to extension organizations (MANAGE, ATARI, KVKs, ATMA, NGOs, etc.), FPOs, fisheries

cooperatives to understand the functions of management, Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns; Exercise on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization, Case studies/ success stories on performance of SHGs in fisheries, Case Analysis of organization in terms of process – attitudes and values, motivation, leadership, Study of individual and group behaviour at work in an organization; Conflicts and their management in an organization, Documenting occupational stress in farming, farmer groups/ organizations, Exercises on stress management and time management; Exercises on team building and negotiation skill development Understanding organizational change process tools and techniques, Case analysis on organizational change process; Stakeholder analysis mapping.

VII. Suggested Reading

- Ancona, Kochaw, Scully, Van Maanen, Westney. 1999. *Organizational Behaviour and Processes*. South Western College Publ., New York. Banerjee M. 1984. Organizational Behaviour. Allied Publ.
- Deka GC. 1999. *Organizational Behaviour - A Conceptual Application Approach*. Kanishka Publ.
- Dwivedi RS. 2006. *Human Relations and Organization Behaviour- A Global Perspective*. 5th Ed. Macmillan.
- Kumar A. 2000. *Organizational Behaviour Theory and Practice*. Anmol Publ.
- Luthans F. 1998. *Organizational Behaviour*. Tata McGraw Hill.
- Luthans F. 2001. *Organizational Behaviour*. McGraw Hill. NewstromJW & Davis K. 1997. Human Behaviour at Work. Tata McGraw Hill.
- Robbins SP. 2007. *Organizational Behaviour*. Prentice Hall.
- Shaun T and Jackson T. 2003. *The Essence of Organizational Behaviour*. Practice Hall of India.
- Stephen RR. 1999. *Organizational Behaviour*. 5th Ed. Practice Hall of India.

II. Course Title : ICT for Development

I. Course Code : FEX 505

III. Credit Hours : 2+1

IV. Aim of the course

To orient students on advances in ICT initiatives, knowledge management process smart/ disruptive technologies and data analytics.

V. Theory

Unit I

ICTs - concepts, roles and initiatives: ICTs- meaning, concepts, basics of ICTs, Global and National status, Types and functions of ICTs, Meaning of e-Governance, e-learning, m-Learning, Advantages and Limitations of ICTs.

Unit II

Knowledge management: Meaning, Approaches and Tools, Role of ICTs in Agricultural Knowledge Management, e-Extension, overview on Global and national e-Extension initiatives, Inventory of e-Extension initiatives in Agriculture and allied sectors from Central and State governments, ICAR, SAUs, private sector and NGOs in India.

Unit III

ICT applications: Knowledge centres (tele centres), CSC, Digital kiosks, Web portals, Community radio, Internet radio, Kisan call centres, Mobile based applications, INCOIS-PFZ advisories; Self-learning CDs on Package of practices, Augmented Learning, Virtual Learning, social media, Market Intelligence and Information Systems-e-NAM, Agmarknet, etc. Expert System/ Decision Support System/ Management Information Systems, Farm Health Management & Intelligence System for Plant /Animal/ Soil Health, Fishery, Water, Weather, etc., National e-Governance Plan in Agriculture (NeGP-A).

Unit IV

Networks and policies: Global and regional knowledge networks, international information management systems, e-Learning platforms (MOOCS, Coursera, EduEx, etc.); Digital networks among extension personnel, Farmer Producers Organisations (FPOs) / SHGs/ Farmers Groups, Video conference, Live streaming and Webinars, types and functions of social media applications, Guidelines for preparing social media content, Engaging audience, Data- analytics and Info graphics.

Unit V

Smart technologies for extension: Open technology computing facilities, System for data analytics/ mining/ modelling/ Development of Agricultural simulations; Remote Sensing, GIS, GPS, Information Utility (AIU).

Unit VI

Disruptive technologies for extension: Disruptive technologies Analysis; Internet of Things (IoTs), Drones, Artificial intelligence (AI), Block chain technology, Social media and Big Data analytics for extension.

VI. Practical

Content and client engagement analysis
Case studies and exercises on ICT based interventions in fisheries and agriculture
Designing extension content for ICTs; Creating and designing web portals, blogs, social media pages
Development and use of online and offline e-learning modules in fisheries
Live streaming extension programmes and organizing webinars
Visit to KCC; Exercises on developing mobile based applications;
Developing social media pages for disseminating fisheries related information;
Writing for digital media
Developing video content related to fisheries
Conducting exercise on remote sensing and GIS.

VII. Suggested Reading

- August E Grant and Jennifer H. Meadows (Ed.). 2012. *Communication Technology Update and Fundamentals*, Focal Press, USA.
- Batcheloret all. 2003. *ICT for Development: Contributing to the Millennium Development Goals: Lessons Learned from Seventeen ICT Development Projects*, World Bank.
- ICTs for Development (http://ict4dblog.wordpress.com/).
- Donner J and Parikh T. (eds). 2013. ICTD2013. *Proceedings of the Sixth International Conference on Information and Communication Technologies and Development* held in Cape Town, South Africa.
- Elder L, Emdon H, Fuchs R and Petrazzini B. (eds). 2013. *Connecting ICTs to Development*, Anthem Press, London.

- NISG 2004. *ICT for Development: Make ICT Work for People* – Compilation of ICT Cases in India, NISG, Hyderabad.
- The Internet and Poverty: Opening the Black Box, http://dirsi.net/web/files/files/Opening_the_Black_Box.pdf.

I. Course Title : Monitoring, Evaluation and Impact Assessment

II. Course Code : FEX 506

III. Credit Hours : 2+1

IV. Aim of the course

To make students' understand the concepts of participatory development planning, monitoring, evaluation and impact assessment.

V. Theory

Unit I

Introduction to monitoring: Monitoring- Definition, Objectives, Tools, Methods and Approaches; Major Components of project Monitoring; Special Diagnostic studies, Project Completion report, Project sustainability, Monitoring Standards; Past quality or performance, The quality of other systems, Desired quality, Professional standards, The quality required, Planning targets and Optimal quality.

Unit II

Concept of evaluation: Meaning and concept in different contexts; Why Evaluation is Done and When? Purpose of Evaluation; Principles of Evaluation; Types of Evaluation; Objective Oriented, Management Oriented; Context Evaluation, Input evaluation, Process Evaluation, Product Evaluation, Consumer oriented evaluation, Expertise Oriented Evaluation, Adversary Oriented Evaluation, Naturalistic and Principal oriented evaluation, Goal free evaluation and meta evaluation; Process of Evaluation, Evaluation at the beginning, Evaluation during the programme, Evaluation at the end; Use of evaluation findings; Statistical Tools for evaluation; Evaluation theories, Three broad categories of theories that evaluators use in their works, Programme theory, Social science theory, and Evaluation theory (other theories/ approaches - Utilization-Focused Evaluation & Utilization-Focused Evaluation (U-FE) Checklist, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation).

Unit III

Programme planning: Steps, Analyse programme effectiveness, AAccountability; Objectives, Types, Criteria and Approaches of programme evaluation; The context of program evaluation in agricultural extension; Competency and credibility of evaluator; Integration between theory and practice of evaluation; Evaluation forums, Workshops, Conferences and Apprenticeship / internship, Ten Steps in programme evaluation; SWOT Analysis; Bar Charts (Gantt Charts and Milestone Charts); Networks, Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM); Bennett's Hierarchy of Evaluation; LFA.

Unit IV

Impact assessment indicators and approaches: Meaning, Need, Features, Benefits, Concepts; Indicators for Impact Assessment, Direct indicators, Indirect or proxy indicators, Quantitative indicators, Qualitative indicators, Result chain/

hierarchy of indicators; Methods of Impact Evaluation, Learning retention of participants (KOSA), Impact on the job performance, Impact on organizational effectiveness, Impact on stakeholder's competency.

Unit V

Impact assessment framework: Meaning of inputs, Outputs, Outcomes, Impacts and their relation with monitoring, Evaluation and impact assessment; Indicators for impact assessment – meaning and concept; Selecting impact indicators; Types of impact indicators for technology and Extension advisory services, Social and behavioural indicators, Socio-cultural indicators, Technology level indicators, Environmental impact assessment indicators and Institutional impact assessment indicators; SDGs, Yield-related Public participation models; Crisis management, Conventional participation, Participation in project-cycle, Concurrent participation, dedicated participation framework; Social auditing: concept, elements, steps, potential problems, benefits.

Unit VI

Impact assessment approaches – Quantitative, Qualitative, Participatory and Mixed methods with their advantages and disadvantages; Quantitative Impact Assessment Types – Based on Time of Assessment (Ex-ante and ex-post), Based on Research Design (Experimental, quasi experimental, Non-experimental), Econometric Impact Assessment; (Partial Budgeting Technique, Net Present Value, Benefit Cost Ratio, Internal Rate of Return, Adoption Quotient etc.), Qualitative and Participatory Impact Assessment Methods, Quantitative and qualitative techniques for impact assessment, Social impact analysis; Economic impact analysis cost, Benefit analysis, Social-cost Benefit analysis, Partial budget analysis; Environmental impact analysis; Institutional impact analysis; Sustainability analysis, Human impact assessment methods.

VI. Practical

Search the literature using web / printed resources and identify evaluation indicators for the following: Utilization-Focused Evaluation, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation, Visit to Directorate of Extension in anuniversity and enquire about extension programmes being implemented / coordinated by Directorate, Developing an evaluation proposal of any one programme using 'Ten Steps in Programme Evaluation', Field studies for identification and ranking of criteria/indicators for impact assessment, Identifying a fisheries development programmes and their objectives being implemented in your state, Strengths, Weaknesses, Opportunities and Threats related to the identified programme objectives in the SWOT grid, Visit a nearby KVKs / ATIC. Select any agriculture technology with package of practices and extension advisory services promoted by KVK / ATIC, Identifying impact assessment indicators for social and behavioural indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators, Exercises on evaluation of fisheries development programmes using the techniques of evaluation; Exercises on CPM and PERT.

VII. Suggested Reading

- Capturing Experience: Evaluation, Evaluation and Impact Assessment Methods, http://web.mit.edu/urbanupgrading/upgrading/resources/bibliography/Evaluati on-Impact.html
- Equality Impact Assessment, http://www.scotland.gov.uk/Resource/

- *Evaluating Development Operations: Methods for Judging Outcomes and Impacts. Operations Evaluation Department*, The World Bank. Lessons & Practice Number 10, July 1997.
- John Pearch, Peter Raynard and Simon Zadek. *Social Auditing for Small Organizations: The Workbook. New Economics*: London. 1995.
- Louisa and Mike Edwards. *Toolkits: A Practical Guide to Assessment, Monitoring*. Review and Evaluation
- *Resources on Impact Assessment*. http://www.gdrc.org/ uem/eia/define.html

I. Course Title : Aquapreneurship Promotion and Value Chain Development

II. Course Code : FEX 507

III. Credit Hours : 1+1

IV. Aim of the course

To orient students on the importance of aquapreneurship, fish Markets, supply chains and value chain analysis

V. Theory

Unit I

Basics of aquapreneurship and Facilitation for entrepreneurship development: Entrepreneurship - Concept, Significance and Scope, Theories and models; Entrepreneurship Development Cycle and process; Aquapreneurship – Meaning, Drivers, Characteristics, Importance, Types of entrepreneurs; Startups, Small businesses, Startups group/ community-based entrepreneurship; Entrepreneur and Manager; Approaches for assessing characteristics of entrepreneurs, Enterprising tendency, Entrepreneurship intention, Entrepreneurship orientation; Critical competencies required for entrepreneur in managing the businesses, Technical, communication, Financial, Human; Entrepreneurial university approach. Approaches for developing agricultural enterprises through extension and advisory services, Individual, Group and Community based approaches; Specific roles of extension agents in creating agricultural entrepreneurships; Pluralistic extension and extension agents working with other agents; Free and fee for extension services for business upgrading for farmers/farmer groups; Competencies of extension professionals for creating entrepreneurships.

Unit II

Basics of business planning, entrepreneurial ecosystem and Infrastructure requirement: Feasibility report, Business plan, Bankable project and Detailed project report – Similarities and differences; Elements of business plan, The team and its competencies, Business idea, Gaps, Opportunities and risks, Key products and services, Target market and Consumer segments, Marketing plan, Financial plan, Intellectual property and others, Meaning, Elements; Government policy support and Schemes for development of agricultural and allied enterprises (Start-up India, Make in India, Digital India, Atal Innovation Mission and others; Entrepreneurship policy and schemes at different states of India); Sources of funding for agripreneurship/ aquapreneurship, Debt and equity capital, grants and subsidies, Angel investor, Venture capitalist, Bank lending, NABARD and others; Entrepreneurial culture, Mentoring and handholding incubators.

Unit III

Infrastructure for supporting agricultural entrepreneurship – Warehouse, Cold storage and Transportation and Other support systems, Technology development system, Education and training, Human capital and workforce, Systems for assessing capacity requirement and Capacity building, Local and global markets and Regulatory framework; Policy approaches for women entrepreneurship development, Organisations promoting entrepreneurship in India; Emerging perspectives, Focus on startups and support mechanisms, Climate-smart technology businesses; Block chains for value chain management.

Unit IV

Extension and value chain: Supply chains – Meaning, Structure, Value chains – Meaning, Importance, Types; Supply chains vs value chains; Value chain development and Value Chain extension; Steps in a value chain analysis; Three dimensions of the value chain process; Participatory tools used in a value chain analysis, Focus groups, Ranking and weighting, Historical calendars, Market mapping, Evaluation of Business development services, Market visits, Learning journeys, Semi-structured interview, Structured interviews, Direct observation; Extension toolkits and Approaches for value chain development; Value chain upgrading strategies on farmer and extension agent level.

VI. Practical

Field visit to any entrepreneurship promotion agency of Govt. of India (e.g. Small farmer agribusiness consortium, EDI etc.); Business plan preparation and presentation – covers all aspects of choosing the business idea, financial estimates, market planning and others and presentation; Assessing the entrepreneurship potential of a prospective entrepreneur – enterprising tendency, entrepreneurship intention and entrepreneurship orientation scales administration and explain the processes Field visit to market support system – warehouse, cold storage unit, regulatory market etc. Field visit to Banks and Venture capitalist/ angel investors or other private investing agencies; Value chain mapping using participatory approaches. Field visit to successful aquapreneurs –startup, Farmer Producer Organization, SHG business, large business to orient themselves with different types of aquapreneurship; Field visit to technology business incubator.

VII. Suggested Reading

- N. Mukherjee. 1997. *Participatory Rural Appraisal, Methodology and Applications*, Concept Publishing Company, New Delhi.
- R Chambers, P Arnold and Thrupp. 1989. *Farmers First: Farmer Innovation and Agricultural Research*. Intermediate Technology.
- Roger L Martin & Sally Osberg. 2007. *Social Entrepreneurship: The Case for Definition, Stanford Social Innovation Review*.
- http://www.ngobiz.org/picture/File/Social%20EnterpeuneurThe%20Case%20of%20Definition.pdf

II. Course Title : Sociology, Psychology and Community Organisation

I. Course Code : FEX 508

III. Credit Hours : 2+1

IV. Aim of the course

To orient the students towards basics in sociology, psychology and cognitive processes.

V. Theory

Unit I

Overview of sociology: Basic Concepts in Sociology, Society, Understanding of basic rural institutions, Social structure, Community, Social institution, Culture, Social change, Cultural change, Social system, Social process, Social conflict, Social values, Norms, Folkways, Mores, Customs; Cultural relativism, Cultural integration, Cultural lag, Acculturation; Family, Kin and Clan – its relationship with group behaviour and rural development; Social Stratification, Class and caste system, Their impact on rural development; Social Process and Social Interaction – Concepts, types; Competition, Conflict, Cooperation Accommodation and Assimilation, and change in social process due to developmental programmes, Community Organization (CO): Meaning and Models.

Unit II

Dynamics of change: Concept, Types and importance in rural community; Typology of change, Planned, Indoctrinational, Technocratic, Coercive, Emulative, etc. Theories of social change, Immanency, Functionalism, Economic, Technological, Historical, Ideological, Evolutionary and Field Theory; Factors affecting change under rural settings; Stimulants and Barriers to change, Social Capital, Collectivism, Interdependence in larger groups, Conformity and functional analysis of roles.

Unit III

Preamble to Psychology: Psychology as a science and its importance in extension education, Perception- Nature, Selectivity & Laws, Importance of perception in extension work, Sensation vs Perception; Attitudes - Meaning, Characteristics, Assumptions, Types, Theories and Models of attitude formation; Methods of changing attitudes, Stereotypes and Prejudices, Factors in attitude change, Liking / affect – meaning, Types and theories; Attraction – meaning, Types and theories; Persuasion – Meaning, theories and techniques; Social influence and groups – Conformity, Compliance and Obedience.

Unit IV

Information processing: Meaning, Principles; Basic assumption, Models of information processing, Waugh and Norman model of primary and secondary memory; Atkinson and Shiffrin's stage model of memory; Sensory memory- Working, Short and Long term memory, Other models including blooms taxonomy and Sternberg's Information Processing Approach, Computer- mind analogy, Teaching-Learning process.

Unit V

Attention and perception: Meaning, types, Theories and models; Consciousness; Motivation, Nature, Characteristics and types of motives, Techniques of motivating farm people, Measuring motivation, TAT, Sentence completion, etc., Emotion- its nature, Types of emotional response, Theories of emotion, Self-motivation; Harnessing emotions productively, Empathy and its theories, Reading emotions, Role of emotion in regulating human behaviour, Psychosocial distress and coping mechanisms in farming situations, Personality, Individual differences and theories of personality, Multiple Intelligences- IQ, Emotional intelligence, Social intelligence, Managing emotions; Relationship between IQ and EQ, Handling relationships; Social skills, Defence mechanisms- types and importance.

Unit VI

Cognitive processes and learning: Cognitive processes, Attention, Perception, Remembering and Forgetting, Knowledge and Expertise, Ffoundations and Theories; Principles and processes of perception; Consciousness, Meaning, Types, Sleep and Dreams; Learning and Memory, meaning, Learning, Foundations, Approaches, Styles and theories; Cognitive approaches of learning – Meaning, Principles theories and models; Memory, Foundations, types; Behavioural approaches of learning, Foundations and theories, Classical conditioning, Operant conditioning, Applied behaviour analysis; Social cognitive and constructivist approaches to learning, Foundations and theories, Social cognitive theory, Self-regulated learning; Learning styles, Meaning, Types and applications in learning.

VI. Practical

Learning - Classical conditioning and operant conditioning; Assessment of emotional intelligence; Exercises in problem solving; Exercises in visual perception; Measuring self-concept using psychometric tools; Experiment on factors influencing information processing; Assessment of attitudes; Visit to a village to study rural institutions; Focus group discussions to identify stimulants and barriers to changes existing in rural community; Understanding perception - Attentional Blink and Repetition Blindness exercise; Understanding attention -Testing selective attention capacity and skills and processing speed ability through Stroop test; Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking; Assessing learning styles through Barsch and Kolb inventories; Practical experience in building self-esteem; Hands on experience in methods of persuasion; Field experience in assessing social judgement; Simulation exercise to understand decision-making under different situations; Exercise in rational decision-making.

VII. Suggested Reading

- Coon D and Mitterer J. 2007. *Introduction to Psychology: Gateways to Mind and Behaviour* (11th Edition). Belmont, California: Thomson Wadsworth.
- Dodgen L and Rapp A. 2000. *Sociology: Looking Through the Window of the World* (3rd edition). Iowa: Kendall Hunt. (Includes basic terms in sociology.)
- Germov, John and Poole, Marilyn eds. 2010. *Public Sociology: An Introduction to Australian Society* (2nd Edition). Crows Nest, NSW: Allen & Unwin. (Please note this is a Level 3 Sociology textbook.)
- Holmes D, Hughes K and Julian R. 2012. *Australian Sociology: A Changing Society*. Pearson Australia.
- Mulcahy, Cutinelli, Warne and Woodruff. 2009. *Psyched: Psychology* for Year Ten. Sydney: Cambridge University Press.

II. Course Title : Risk Management and Climate Change Adaptation

I. Course Code : FEX 509

III. Credit Hours : 2+1

IV. Aim of the course

To equip students to identify, evaluate and evolve ways to address (mitigate and manage) risks and climate change.

V. Theory

Unit I

Understanding risk and distress: Introduction to risk, Risk management,

Uncertainty, Sensitivity and Distress, General risk theory, Risk analysis methods, Risk perception and decision making, Indicators of risk and distress in agriculture, Identification, Selection and Assessment, Understanding the agrarian distress in Indian agriculture, Sources of distress in Indian farming, Changing farm size, Land use, Cropping patterns, Pricing policy, Markets and terms of trade, Typology of crisis in agriculture; Droughts, Floods and Indian agriculture, Distress and farmer suicides, Causes and socio-economic consequences

Unit II

Managing risk and distress: Ways to reducing/managing risk and distress in Indian agriculture/fisheries; Crop and life insurance; Developing support systems; Planning, Implementation and evaluation of risk/distress management programs; Institutional frameworks for risk and disaster management – NDMA & SDMAs; Developing District Agriculture Contingency Plans; Risk management by diversification; Good practices and lessons from other countries; Responses of government, Non-government and extension system to agrarian crisis; National Farmers Policy.

Unit III

Extension professionals and risk management: Understanding social-Psychological and behavioural dimensions of farmers under risk/distress; Risk perception and communication; Helping farmers manage farm level risks, Mobilising resources, Linking with markets, Strengthening capacities; Working with village level risk management committees; Operational skills for preparing contingency and disaster management plans; Institutional and extension innovations in managing risk and distress; Policy and technological preferences for dealing with drought and flood.

Unit IV

Introduction to climate change science: Basic concepts of and terms in climate change science; Impacts of climate change; Anthropogenic drivers of climate change, Climate change and Indian agriculture; Climate adaptation vs. Disaster risk reduction; Anticipated costs of adaptation; Climate change and poor; Overview of UNFCCC framework and institutions, Kyoto Protocol and beyond; India's National Action Plan on Climate Change and National Mission on Strategic Knowledge on Climate Change; National Coastal Mission, Institutional arrangements for managing climate change agenda.

Unit V

Introduction to climate change adaptation and mitigation: Introduction to Climate Change Adaptation, Conducting a vulnerability assessment (CVI and SEVI frameworks), Identifying and selecting adaptation options; Global, national and state level initiatives and plans to support climate change adaptation, Private sector and civil society initiatives and activities; Mainstreaming climate change adaptation into development planning, Financing climate adaptation and budgetary allocations for programmes, Gender and climate change adaptation, Agricultural development programmes and strategies towards climate change adaptation and mitigation, Community based and Ecosystem based adaptation strategies, Preparing evidence based intervention plans for vulnerability reduction at micro and macro-levels.

Unit VI

Climate Smart Agriculture (CSA) and extension & advisory services: Climate smart agriculture; Developing climate smart and climate resilient villages; Stakeholders and determinants involved in climate smart agriculture; Climate smart agriculture and EAS; Innovative extension approaches used in CSA; Climate information services, Farmers perceptions about climate change; Farm and household level manifestations and adaptation strategies; Barriers and limits to adaptation; Farmers feedback on performance of extension methods; Skills, competencies and tools required for extension professionals at different levels and development departments in up scaling CSA.

VI. Practical

Hands-on practice in using risk assessment/analysis tools; Case studies on risk / distress assessment in agriculture -Indian and global lessons / Experiences from NICRA Project in agriculture and allied sectors; Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience; Hands on practice on use of vulnerability and risk assessment tools and techniques; Case studies on success stories of climate change adaptation and community based initiatives; Developing district and village level intervention plans for climate change adaptation; Field Visits to State Disaster Management Authority; Case studies on climate smart agriculture / villages from India and world; Case studies on impact assessment of crop insurance programs, disaster management programs; Capstone project on documenting ITKs and local practices related to reducing risk / climate resilience agriculture

VII. Suggested Reading

- Bruce James P, Egener ID and Black RA. 2011. *Adapting to Climate Change: A Guide for Ontario Municipalities* (in press).
- Bruce James P, Egener ID. Mark and Noble David. 2006. *Adapting to Climate Change: A Risk-based Guide for Ontario Municipalities*. Accessed from: http://www.nrcan.gc.ca/ earthsciences/projdb/pdf/176a_e.pdf
- Health Canada. 2011. *Communicating the Health Risks of Extreme Heat Events*. Accessed from: http://www.hc-sc.gc. ca/ewh-semt/climat/index-eng.php
- ICLEI. *Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation*. Accessed from: http://www.iclei.org/index.php?id=8708
- Insurance Bureau of Canada. Municipal Risk Assessment Tool. Accessed from: http:// www.ibc.ca/en/Natural_Disasters/Mu nicipal_Risk_Assessment_Tool.asp
- Insurance Bureau of Canada. 2011. Insurance in Ontario: What you need to know. Accessed from: http://www.ibc.ca/en/ Need_More_Info/documents/ Industry_Updates/ Industry_Up date_ON.pdf
- Insurance Bureau of Canada. 2011. *Municipal Storm and Sanitary Infrastructure Risk Assessment Tool Project*. Accessed from: http://www.ibc.ca/en/Natural_Disasters/do cuments/ MRAT%20Leavebehind_EN_Jun3-11.pdf
- Mabey N, Gulledge J, Finel B and Silverthorne K. 2011. *Degrees of Risk: Defining a Risk Management Framework for Climate Security*. Accessed from: http://www.e3g.org
- Ontario Ministry of the Environment. 2011. *Climate Ready: Ontario's Adaptation Strategy and Action Plan*. Accessed from: http://www.ene.gov.on.ca/stdprodconsume/groups/lr/ @ene/ @resources/documents/resource/stdprod_085423.pdf
- Ontario Ministry of the Environment. 2012. *Climate Ready: Ontario's Adaptation Strategy and Action Plan* (2011-2014). Presentation at Adaptation Planning in Eastern Ontario

I. Course Title : Capacity Development

II. Course Code : FEX 510

III. Credit Hours : 1+1

IV. Aim of the course

To make students' understand the concepts of training, capacity building, capacity development and human resource development in the context of roles and responsibilities of extension professionals

V. Theory

Unit I

Capacity development- an overview: Training, Capacity building, Capacity development and HRD, Meaning and differences; Training principles and Phases of training; Need and principles of Capacity development; Types and levels of capacities, Institutional capacities (include the rules, regulations and practices that set the overarching contextual environment), Organizational capacities (how various actors come together to perform given tasks), Individual capacities (technical, functional and leadership skills)

Unit II

Capacity building: Types of capacity building, Based on structure (structured, semi-structured & unstructured), Based on context (orientation, induction and refresher), and other categories (online, Webinar, distance etc.); Components of capacity development; Capacity development cycle; Approaches in Capacity Development, Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach Steps in Designing and Planning of Capacity Development- Step 1. Select the participants, Step 2. Determine the participants' needs, Step 3. Formulate goal and objectives, Step 4. Outline the content, Step 5. Develop instructional activities, Step 6. Prepare the design, Step 7. Prepare evaluation form, Step 8. Determine follow-up activities; Evaluation of training: types and techniques of training evaluation

Unit III

Capacity assessment and development methods: Concept of Need Assessment; Approaches in Need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey; Data Collection Methods in Identifying Needs, Rational Methods (Observation, Informal talks, Complaints, Comparison, Analysis of report, Opinion poll, Buzz session, Analysis of the new programme), Empirical Methods (Job analysis, Performance evaluation, Checklist or Questionnaire Method, Tests, Critical Incident Technique, Card Sort Method, Focus Group Discussion, Interview, SWOT Analysis); Information and Skills required in Need Analysis; Identification of Needs through Task Analysis, Task identification, Task Analysis, Gap Analysis.

Unit IV

Capacity development methods: Lecture, Discussion, Syndicate, Seminars, Conference, Symposium, Role Play, Case study, Programmed Instruction, T - group/ Laboratory methods, Brain storming; Delphi technique, Johari window; Factors Determining Selection of Methods, Capacity development objectives, Subject matter, Categories of participants, and the available resources like time, Location, Budget; Capacity Development Aids; Capacity Developer (Trainer), Meaning and concept;

Types of Capacity Developers (regular, *ad-hoc*, part time, guest and consultants); Roles of Capacity Developer (explainer, clarifier, supporter, confronter, role model, linker, motivator, translator/interpreter, change agent); Good Capacity Developer, Qualities, Skills and Roles. Human resource development; Meaning, Importance and Benefits; Types of HRD Systems & Sub-systems, Career system; Components of HRD System, Performance Appraisal, Potential Appraisal, Task System, Development System, Socialisation System, Governance; Functions of HRD-Organisational Development, Career Development, Capacity Development.

VI. Practical

Capacity development needs assessment exercise; Planning organizing and conducting an extension capacity development programme; Designing a programme; Writing learning objectives; Developing objectives into curriculum; Training plan; Organizing capacity development workshop; Evaluation with pre & post training tests; Exercise on business games, simulation exercises, in-basket exercise; Activities on programmed instruction, experiential learning techniques; Exercises on Transactional analysis and Fish bowl Technique; Preparing questionnaires using Delphi technique; Conducting brain storming and buzz sessions on topics related to fisheries; Organizing FGDs in fishing villages/institutions; Conducting SWOT analysis of any institutions or any fisheries technologies; Preparation of checklist/ questionnaires on capacity development related to fisheries department officers / fish farmers; Role plays on fisheries related problems; Conducting exercises on need assessment; Practicing facilitation techniques; Self-discovery exercises

VII. Suggested Reading

- Agochiya D. 2002. *Every Trainer's Handbook*. Sage Publ. David Gross. 1997. Human Resource Management - The Basics. TR Publ.
- Davis Keth & Newston W John 1989. *Human Behaviour at Work*. 8th Ed. McGraw-Hill.
- Hersey Paul & Balanchard H Kenneth. 1992. *Management of Organizational Behaviour Utilizing Human Resource*. 5th Ed. Prentice-Hall of Post Graduate Syllabus, Department of Agril. Extension, UBKV [10] India.
- Kalyani Publ. Rao TV. 2003. *Readings in Human Resource Development*. Oxford Publ. Co.
- Knoontz Harold & Weihhrich Heinz 1990. *Essentials of Management*. 5th Ed. McGraw-Hill.
- Lynton RP & Pareek U. 1993. *Training for Development. DB*. Taraporewale Sons & Co.
- Punna Rao P & Sudarshan Reddy M. 2001. *Human Resource Development Mechanisms for Extension Organization*.
- Silberman Mel. 1995. Active Training. Press Johnston Publ. Co., New Delhi. Singh RP. 2000. *Management of Training Programmes*. Anmol Publ.
- Subba Rao P. 2005. *Management & Organizational Behaviour*. Himalaya Publ. House.
- Sundaram RM, Gupta V, George SS. 2006. *Case Studies in Human Resource Management*. ICFAI, Hyderabad.
- Tripati & Reddy. 2004. *Principles of Management*. Tata McGraw-Hill.
- Wayne MR & Robert MN. 2005. *Human Resource Management*. International Ed. Pearson Prentice Hall.

Course Title with Credit Load
Ph.D. in Fisheries Extension

Course Code	Course Title	Credit Hours
	Major Courses	**12 Credits**
FEX 601	Methodologies in Extension Research	2+1
FEX 602	Educational Technology and Instructional Design	2+1
FEX 603	Gender Mainstreaming and Livelihood Development	2+1
FEX 604	Extension Service System Management	2+1
	Minor Courses	**6 Credits**
	(From the subjects closely related to a students major subject)	
FEX 605	Technology Commercialisation and Intellectual Property Management	2+1
FEX 606	Policy Engagement and Extension	2+1
FEX 607	Participatory Approaches in Fisheries Extension	1+1
	Supporting Courses	**5 Credits**
	(The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence).	
	Total Course Work Credits	**23 Credits**
	Doctorial Seminar	**2 Credits**
FEX 691	Doctoral Seminar-I	0+1
FEX 692	Doctoral Seminar-II	0+1
	Doctoral Research	**75 Credits**
FEX 699	Doctoral Research (Semester II)	0+15
FEX 699	Doctoral Research (Semester III)	0+15
FEX 699	Doctoral Research (Semester IV)	0+15
FEX 699	Doctoral Research (Semester V)	0+15
FEX 699	Doctoral Research (Semester VI)	0+15
	Total Ph.D. Program Credit Hours	**100 Credits**

Course Contents
Ph.D. in Fisheries Extension

I Course Title : Methodologies in Extension Research
II. Course Code : FEX 601
III. Credit Hours : 2+1

IV. Aim of the course

To cater the need of equipping the scholars with essential skills in conducting high quality research which helps them to design working strategies, processes and models for professional development.

V. Theory

Unit I

Measurement properties of research instruments: Measurement properties: Dimensionality, Reliability and Validity; Dimensionality – Unidimensionality and multidimensionality, Methods of assessing dimensionality, Formative and reflective constructs; Validity, Importance, Internal validity - face validity; Content validity, Substantive Validity, Structural Validity; External validity, Convergent and Discriminant Validity, Known-group validity, Criterion-Related Validity, Consequential Validity, Nomological validity; Methods of assessing various forms of validities, Judges rating, Lawshe's Content Validity Ratio, Item-objective congruence index; Latent variable method; Reliability - Internal consistency reliability – Split-Half, Cronbach alpha; Temporal Stability reliability - test-retest method; Interrater Consistency and Consensus - interrater reliability and interrater agreement; Alternative Forms or parallel forms reliability – Reliability of difference - Factors Affecting the Validity and Reliability of Test Scores; Generalizability Theory.

Unit II

Errors in management: Errors – Meaning and sources; Types - Sampling error, Non-sampling or measurement error and Processing error – Meaning, causes; Effects of errors and biases on data quality; Bias in behavioural research – Meaning, causes, Types – Respondent and researcher biases; Methods of reducing errors and biases in surveys, Questionnaires, Personal interviews, Focus groups and Online methods.

Unit III

Scales, indices and tests: Approaches to measurement and scale development - Classical test theory, Formative or index models, The C–OAR–SE approach and Item Response Theory; Item analysis in Classical test theory, Item difficulty and item discrimination; Scoring performance in scales and tests, Meaning, types and methods; Scale development strategies, Deductive and empirical; Stimulus-centred scales, Method of equally appearing intervals, Paired comparison, Person scaling – Q methodology; Subject-centre scales, The Likert scale and Semantic Differential; Steps in constructing a multi-dimensional scale using confirmatory factor analysis,

Response scales, Guttman'sscalogram analysis and The Rasch method.

Unit IV

Indices and tests: Indexes –Meaning, types, Importance; Similarities and differences with scales, Methods of constructing indexes; Common indexes used in extension, Measurement invariance, Meaning, types, Methods of assessing measurement invariance, Tests – meaning, types, importance; Steps in conducting various tests, knowledge test.

Unit V

Qualitative research methods and emerging approaches: Qualitative methods – Meaning; Types – Ethnography, Grounded theory, Phenomenology, Ecological psychology, Discourse Analysis; Observational research; Case study research – Sampling and sample size; Data collection methods, In-depth interviews, Focus groups, Direct observation, Record review; Content analysis; Unobtrusive Measures; Projective and semi-projective techniques; Selecting right qualitative method – Strengths and limitations of qualitative research; Analysis and interpretation of qualitative research data; Research synthesis – meaning, importance, methods; Systematic reviews and meta-analysis – meaning, steps, and applications; Policy research. Mixed methods research – meaning, purpose, types and applications; Participatory research – Meaning, importance, types, methods and tools and applications; Action research – Meaning, importance, Principles, Types, Steps in conducting action research, application in behavioural sciences. Social Network Analysis – Meaning, importance, types, steps in social network analysis, applications; Advanced methods of measuring perception and beliefs. Multi criteria decision making, analytical hierarchy approach.

Unit VI

Ethics in extension research: Research reports – Meaning, types, contents; Presentations – Meaning, types, principles of good presentation - Tell 'Em" and KISS 'Em" principles; Research publications – meaning, importance, types; Guidelines for preparing research papers - Peer review process, citation styles; Open access publishing; Publishing in social media, Software's in academic writing, Ethics in conducting behavioural research; Human subject research – Meaning, history, and ethical guidelines; Ethical aspects of collecting and using Indigenous knowledge and farmers technologies; Ethical practices in publishing; Plagiarism – meaning, sources, Identifying and correcting plagiarism in a research paper using anti-plagiarism software.

VI. Practical

Practice in developing research instruments; Methods of assessing measurement properties of research instruments - dimensionality, reliability and validity; Hands-on experience in constructing tests, scale and indexes; Practice in summated scale development using confirmatory factor analysis; Hands on experience in assessing measurement invariance; Practicing and collecting data using participatory tools and techniques, analysing and interpreting qualitative data; Hands-on experience in writing systematic review using meta-analysis; Field practice in conducting action research; Practical experience in writing research paper; Hands on exercises using software for qualitative data analysis; Practice in detecting and correcting plagiarism using software.

VII. Suggested Reading

- Burns RB. 2000. *Introduction to Research Methods*. Sage Publ. Chandrakandan K & Karthikeyan C. 2004. *Behavioural Research Methodology*. Classical Publ.
- Daivadeenam P. 2002. *Research Methodology in Extension Education*. Agro-Tech Publ. Academy.
- Kerlinger N Fred. 2002. *Foundations of Behavioural Research*. Surjeet Publ.
- Kothari CR. 2000. *Research Methodology Methods & Techniques*. 2nd Ed. Wishwa Prakasham.
- Ray GL and Mondal S. 1999. *Research Methods in Social Science and Extension Education*. Naya Prokash.
- Roger L and Domino WSK. 1980. *Research Methods*. Prentice Hall.
- Sadhu AM and Singh A. 2003 *Research Methodology in Social Science*. Himalaya Publ. House. Sarantakos S. 1998. Social Research. 2nd Ed. Macmillan.
- Sinha SC and Dhiman AK. 2002. *Research Methodology*. ESS Publ.
- Verma RK and Verma G. 2002. *Research Methodology*. Commonwealth Publ.

I. Course Title : Educational Technology and Instructional Design

II. Course Code : FEX 602

III. Credit Hours : 2+1

IV. Aim of the course

To develop knowledgeable, responsive and effective teachers committed to educating diverse group of learners in a dynamic extension landscape.

V. Theory

Unit I

The landscape of educational technology and instructional design: Understanding various terms, Educational technology, Instructional design, Instructional systems design, Curriculum design, Pedagogy, Andragogy; Brief overview of the origin and evolution of ET and ID as theory and practice; what is the relevance of ET and ID relevant in extension and rural advisory services? Extensional professionals as instructional designers and architects of the learning experience; Types of learning or learning domains, Bloom's taxonomy of the cognitive domain, Krathwohl and Bloom's affective domain and Simpson's psychomotor domain

Unit II

Technology enabled learning: What is the role of technology in education? Digital media, new tools and technology; Open and distance Learning (ODL); Online Education - Synchronous and Asynchronous learning models; eLearning, Massive Open Online Courses - SWAYAM, Open Education Resources (OERs), Course CERA, EduEx, CoL, RLOs; Digital education and its applications in higher agricultural education; Smart classrooms and Campuses, Web-based remote laboratory (WBRL); Integrating media and digital tools into ID; Types and implications of disruptive technologies for higher education and extension; Augmented learning; Adaptive learning; meaning, features and good practices in using open source Learning Management Systems (Moodle); Quality assurance and certification in e-learning.

Unit III

Theories and models of instruction: Howard Gardner's Theory of Multiple Intelligences, David Kolb's Experiential Learning Cycle, Albert Bandura's Social Learning Theory, Rand Spiro's Cognitive Flexibility Theory and its Application in

eLearning, Wlodkowski's Motivational Framework for Culturally Responsive Adult Learning; ADDIE Model, Dick and Carey Model, SAM Model, Bloom's Taxonomy; Integrating the theories of instruction into the practice of ID in extension and RAS ecosystem.

Unit IV

Creating instruction and instructional strategies: Overview of planning, Designing and implementing the curricula and learning experiences; Needs Analysis - meaning, approaches and steps; Task and content analysis - meaning, approaches, steps and techniques (topic analysis, procedural analysis, and the critical incident method); Learner analysis – meaning, importance and approaches, Relevance of Maslow's Hierarchy of Needs and learning styles, Captive Audience vs. Willing Volunteers, Universal vs. user-centered design, Learner Analysis Procedures; Writing learning objectives: Meaning of Learning Goal and Learning Objectives; ABCDs of well-stated objectives; Setting goals, translating goals into objectives; Contextualising ADDIE process within the Extension learning environment; Organizing content and learning activities, scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, Programmed instruction, Synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies.

Unit V

Organizing content and learning activities: Scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, programmed instruction, synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies.

Unit VI

Trends in instructional design and evaluating instruction: Alternatives to ADDIE (Analysis, Design, Development, Implementation and Evaluation) model - Rapid prototyping and constructivist ID, Reflections on instructional design as science and as an art; Relating ID models and process in extension learning environment; Research in education and instructional design, Meaning of Assessment, Measurement and Evaluation; Developing learner evaluations and their reliability & validity; Assessment techniques for measuring change in knowledge, Skill and attitude of learners, Objective Test Items, Constructed-Response Tests, Direct Testing, Performance Ratings, Observations and Anecdotal Records, Rubrics, Portfolios, Surveys and Questionnaires, Self-Reporting Inventories, Interviews; Conducting learner evaluation pre, during and post-instruction; Formative and Summative Evaluation- meaning, approaches and steps; Evaluating Learner Achievement and the Instructional Design Process; Evaluating the success of instruction; Performance appraisal of teachers.

VI. Practical

Preparation of the analysis report that includes the task/content analysis and learner analysis and the design plan includes learning objectives and corresponding

instructional strategies and assessment items; Prepare course outline and lesson plan with an appreciation for diverse learning styles based on temperament, gender, and cultural/ethnic differences and deliver a lecture for UG/PG students; Assessing learning styles through Barsch and Kolb inventories; Development and testing of survey instruments for evaluating learning outcomes/ competencies of students; Development and testing of survey instruments for performance appraisal / competency assessment of teachers; Design an online e-learning module on a topic of interest as a capstone project, Integrate and apply the knowledge and skills gained from the course for creating an effective learning experience for a target audience; Designing and developing a theme based knowledge portals; Exercises on designing an online course using open source LMS like Moodle or EdX; Select and evaluate or design for social al media; Prepare a short research paper on recent theories and models of instructional design; Interview an instructional designer of your choice and prepare a synthesis report about what job roles he/she perform, What ID processes does he or she use, Challenges faced; Develop a prototype for one of the lessons in your design plan using PowerPoint or a website builder such as Weebly to create the screens integrating multimedia content and various functionalities; Field visit to a virtual learning/augmented learning lab, e-learning labs, distance learning centres, etc; Hands-on practice with video-editing software, web conferencing and video conferencing solutions.

VII. Suggested Reading

- Agarwal JC. 2007. *Essentials of Educational Technology Innovations in Teaching – Learning*. 2nd Ed. Vikas Publ. House.
- Agarwal R. 2000. *Educational Technology and Conceptual Understanding*. Anmol Publ.
- Dayal BK. 2005. *Educational Planning and Development*. Dominant Publ.
- Grover I, Kaushik S, Yadav L and Varma SK. 2002. *Communication and Instructional Technology*. Agro Tech Publ. Academy.
- Jacobsen D, Eggen P and Kauchak D. 1985. *Methods for Teaching - A Skills Approach*. 2nd Ed. Charles E. Merrill Publ.
- Joyee B and Well M. 1980. *Models of Teaching*. 2nd Ed. Prentice Hall.
- Khan PM. 2002. *Text Book of Extension Education*. Himanshu Publ.
- Rush N. 1987. *Technology Based Learning - Selected Readings*. London Publ. Co., New York.
- Tara Chand. 1999. *Educational Technology*. Anmol Publ.

I. Course Title : Gender Mainstreaming and Livelihood Development

II. Course Code : FEX 603

III. Credit Hours : 2+1

IV. Aim of the course

To orient students on the importance of "Gender mainstreaming" as well as the other concepts related to gender. The students will be able to understand the gender roles and responsibilities and how in the present times, the roles may be shifting

V. Theory

Unit I

Gender related concepts and divides: Historical perspective of gender; Feminism and emergence of gender as a concept, Scope of gender studies in agriculture and rural development; Agrarian Importance of Gender; Understanding the importance

of gender in national and global agriculture, Key gender issues and challenges in agriculture/fisheries, Gender and value chain, Global actions to address gender, Needs and strategies to address gender and women empowerment, Gender related concepts and divides; Understanding of the concepts of gender, Gender equality and equity, Gender balance, Gender blind, Gender relations, Gender neutrality, Gender bias and Discrimination, Gender rights, Gender roles and responsibilities, Gender budgeting, Gender divides and their implications such as gender digital divide, gender access to resources and inputs divide, gender mobility divide, gender wage divide, Gender needs; Practical and Strategic.

Unit II

Gender analysis: Gender analysis, Importance, usage, prerequisites, Tools for gender analysis, Gender sensitive indicators: HDI, GDI, GEM; Gender and technology, How gender and technology impact each other, Gender neutral technology, Gender sensitive technology, Gender supportive assistance in technology adoption-Gender in fisheries research and extension.

Unit III

Gender mainstreaming, women empowerment and policies for women: Gender mainstreaming: Importance of gender mainstreaming in agriculture, Extension strategies to address gender issues such as gender and health, Nutrition, Gender in agricultural / fisheries value chains, Gender and climate change adaptation, Gender and globalization & liberalization for mainstreaming gender concerns into the national programmes and policies, Women Empowerment; Importance of women empowerment, Current national women empowerment and gender indices, Women empowerment approaches (technological, organizational, political, financial, social, legal and psychological), Global Best Practices, Policies and Frameworks, Global best practices, Women empowerment and Gender mainstreaming models and Frameworks for addressing gender concerns in agriculture/fisheries, approaches of various organizations; Gender mainstreaming and special women focused programmes in agriculture and rural development.

Unit IV

Livelihoods and its challenges: Basic concepts of livelihood and development, Types of development-Immanent/inherent and interventionist/ intentional; Why promote livelihood; Livelihood intervention: Definition, types, Spatial, segmental, sector, sub-sector; Systemic view of Livelihoods, Understanding Rural Livelihoods, Farm, Non-Farm, and off farm; Linkages with Farm and Off-farm Livelihoods; Economic Models; Livelihood Challenge, Political economy of Livelihoods, Issues of access to farm and non-farm livelihoods; Livelihoods from a Gender Perspective, Feminization of agriculture/ poverty, Women in the unorganized sector, The issue of unpaid and informal work; Livelihood Coping Mechanism, Climate Change and Livelihoods; Livelihoods and Disasters.

Unit V

Livelihood frameworks, intervention and promotion approaches: Sustainable Livelihoods Approaches (SLAs)-Definition and origins of SLA; Assets or capitals and capabilities in SLA and its linkage to the other capitals; Vulnerability Assessment- Shocks, trends, seasonality; Policies, institutional context and processes; Conceptual Frameworks-DFID, CARE, UNDP, OXFAM, BASIX livelihood triad,

Nine square Mandala or Rural Livelihood System's Framework, etc; Past, Present and Possibilities for the future of the SLA, critiques of the approach.

Unit VI

Livelihood promotion approaches: Approaches and programs in India; Livelihood and a Rights Based Approach-MGNREGA and its critique; Livelihood and a Social Capital based approach: NRLM; Livelihood Augmentation (LA)- Basic concepts; Pathways: a) Entrepreneurial strategies for LA; b) NRM based intervention; c) Market based interventions including Value-chain analysis; d) ICT based interventions; e) Livelihood and allied agriculture based livelihood; f) Forest based Livelihoods vis a vis Livelihood Protection and Promotion: Contribution of NTFP in supporting rural livelihoods.

VI. Practical

Visit to a village for understanding gender roles and for capturing shifts in gender roles in fisheries; Conducting gender analysis in a village using gender analysis tool; Exercise for identification and prioritization of issues affecting/needs for men and women in fisheries; Village visit to understand the livelihood pattern of villagers and how the other socio-economic factors affect the livelihood of people; Application of participatory rural appraisal skills for understanding village context; Engagement of working with rural communities and their grass-root institutions, understanding dynamics of working in a group; Visit to different agri-business models as mentioned in the Block 'C'. Group assignments may be given to document the field experience in the form of case study of an enterprise/ entrepreneur/ members and other related stakeholders; Visit to agencies supporting women empowerment followed by report presentation. Each student to visit a different organization such as State Rural Livelihood Mission, Women Development Corporation, Department of Agriculture, Important NGOs working for women empowerment; Interaction with a successful women entrepreneur/ SHG; Case studies based on livelihood promotion and rural development. Case studies on Livelihood augmentation and gender related issues in fisheries sector.

VII. Suggested Reading

- Agarwal B. 1986. *Women, Poverty and Agricultural Growth in India*, JPS, New Delhi.
- Agarwal Bina. 1994. *A Field of One's Own: Gender and Land Rights in South Asia*, Cambridge: Cambridge University Press.
- Bhasin K. *Understanding Gender*, New Delhi, Kali for Women, 2000
- Menon Nivedita. 1999. *Gender and Politics in India*, New Delhi: Oxford.
- Patricia Uberoi. 2009. *Freedom and Destiny: Gender, Family, and Popular Culture in India*, Oxford University Press, New Delhi
- *Report on Conditions of Work And Promotion of Livelihoods In The Unorganized Sector* by National Commission For Enterprises In The Unorganized Sector, GoI, Academic Foundation, Delhi, 2008.

I. Course Title : Extension Service System Management

II. Course Code : FEX 604

III. Credit Hours : 2+1

IV. Aim of the course

To make students' understand extension administration and management, and the functions associated with management.

V. Theory

Unit I

Extension service system: Meaning and scope of extension service system and its management; Public administration and bureaucracy - concepts, origin and development; Marxian, Weberian and Gandhian thoughts on bureaucracy; bureaucratic vs. developmental organisation.

Unit II

Processes of management: POSDCORB; Structure, Organisation, Function, Working and management of public extension service agencies like DoFs, FFDA, BFDA, MPEDA, NFDB, NABARD, Fisheries Development Corporations, State Fish Seed Development Corporations, KVKs, SAUs, Fisheries Co-operatives, international agencies, corporate sector, private organizations and MNCs.

Unit III

Organisational conflicts: Delegation of power, Autonomy and Organisational communication and Conflicts in governmental, UN agencies, Non-governmental and Private extension service organisations; Conflicting roles and responsibilities of extension agents.

Unit IV

Organisational communication: Meaning, methods, types and techniques; Functions and importance in motivation and control; Formal and informal communication networks in GOs, NGOs and POs; Behaviour of individuals in organisations; Organisational change and communication; Patterns of communication of organisational communication; Managing organizational communication in fisheries sector.

Unit V

Research, extension and client systems linkages: Linkages and coordination between Dept. of Fisheries and other line Depts. like Irrigation / Water Resources, Environment, Forestry, Agriculture at grassroots, District, State and Central levels; HRD policy in governmental, Non-governmental and Private extension service organizations, Strengthening governance - Transparency, Accountability and People's participation.

Unit VI

Strengthening extension service system: Strengthening the Human Resources of Extension System, Strengthening the Information and Communications Technology (ICT) Capacity, Decentralize the existing extension system, Developing Participatory Public Extension System: PRA, RRA, etc., Investments needed to strengthen extension systems, Civil Works, Equipment, Vehicles, Technical Assistance and Operational Expenses, Supervising, Monitoring, and Evaluating extension projects.

VI. Practical

Case study and analysis of State Departments of Fisheries in selected States; Case studies in structure organization, staffing, career advancement, quality of service delivery at grassroots level in governmental, nongovernmental and private extension service organisations like DoFs, FFDA, NABARD, State Fish Seed Development Corporations, KVKs, Fisheries Co-operatives, NGOs, and private sector

organisations; Study of patterns of communication and effectiveness of Fisheries Development Organisation; Study visit to DoF, NGOs, NABARD, private sector agencies involved in fisheries extension.

VII. Suggested Reading

- Dillinger B. 1995. *Decentralization, Politics and Public Services*. In A. Estache, ed. *Decentralizing Infrastructure: Advantages and Limitations*. Discussion Paper. Washington, DC: The World Bank.
- Garfield E, Guadagni M & Moreau D. 1997. Colombia: *Decentralisation of Agricultural Extension Services*, World Bank Extension. Washington, DC: The World Bank.
- KaleelFMH & Krisnamurthy J. 2007. *Market Led Extension Dimensions and Tools*. Agro Tech Publ. Academy.
- Parker AN. 1995. *Decentralization: the Way Forward for Rural Development? Agriculture and Natural Resources Department*. Washington, DC: The World Bank.
- Rajmanohar TP & Kumaravel KS. 2006. *Contract Farming in India*. ICFAI Univ. Press, Hyderabad.
- Rivera WM. 1996. *Agricultural Extension in Transition Worldwide: Structural, Financial and Managerial Strategies*. Public Admin. Develop. (UK), 16: 151–161.
- Smith LD. 1997. *Decentralization and Rural Development: The Role of the Public and Private Sector in the Provision of Agricultural Services*. Technical Consultation on Decentralization. Food and Agriculture Organization. Rome: FAO.
- Subbalakshmi V. 2005. *Globalization - Indian Experience*. ICFAI Univ. Press, Hyderabad.
- Suresh K. 2005. *Rural Markets - Emerging Opportunities*. ICFAI Univ. Press.

I. Course Title : Technology Commercialisation and Intellectual Property Management

II. Course Code : FEX 605

III. Credit Hours : 2+1

IV. Aim of the course

To develop a critical understanding among extension students about how the technology commercialization process is linked to IPR management and entrepreneurship development.

V. Theory

Unit I

Overview of intellectual property rights: Introduction to IPR; Overview & Importance; Genesis; IPR in India and IPR abroad; Patents, Copyrights, Trademarks & Trade secrets, Geographical indication, Industrial design; Emergence of IPR Regimes and Governance Frameworks, Trade-Related Aspects of Intellectual Property Rights (TRIPS), Convention on Biological Diversity (CBD), Cartagena Protocol, International Union for Protection of New Plant Varieties (UPOV), and BIMSTEC.

Unit II

IPR protection laws and systems: National IPR Policy; and IPR laws; Procedures for filing IP protection; Systems of IP protection and management in agricultural universities and research institutions and also by stakeholders; Mechanisms of IPR Management, Institutional arrangement, IP Management processes – invention disclosure; IP portfolio management; Infringement management; National Biodiversity Act (2002); Protection of Plant Varieties and Farmers Rights Act

(2001); Guidelines for registration and transfer of biological resources; Farmers rights; Mechanisms of documenting/ collecting, protecting and commercialising farmers varieties and other biological resources; National Biodiversity Authority, PPVFRA and other agencies involved in management of biological resources in India, Access to Genetic Resources and Sharing of Benefits.

Unit III

Traditional and indigenous knowledge: Grassroots and Farmers Innovations – Meaning, forms and importance; Systems of documentation, Registration, Protection and Commercialisation, Documentation of traditional indigenous knowledge - Traditional Knowledge Digital Library (TKDL), Community Biodiversity Registers (CBRs), People's Biodiversity Registers (PBRs), Plant Biodiversity Register, and Honeybee Network.; The Global Concerns on Use of Genetically Modified Organisms in Food and Agriculture; The Cartagena Protocol on Biosafety; Regulation of GMO in India.

Unit IV

Technology commercialisation and IP valuation: Technology - Definition, functions, Process of technological advancement – Invention, Discovery, Innovation and Technology; Types of innovation, Basic research, Breakthrough innovation, Disruptive Innovation and Sustaining Innovation; Technology transfer and commercialisation, Technology transfer vs Commercialisation; Technology commercialisation process, Elements, Models, Systems and processes; Technology commercialisation strategies, Meaning, approaches for technology commercialisation, technology scaling up, technology licensing, Handholding, Agripreneur development.

Unit V

Technology assessment and refinement: Meaning; Importance; Approaches and methods of assessment and refinement of various technologies, Stakeholder oriented approaches including participatory technology assessment and refinement; Returns to investment; IP Valuation-Oxford context, IP Valuation methods, Cost approach; Income approach, Discounted Cash Flow, Risk-Adjusted Net Present Value, Net Present Value with Monte Carlo Simulation and Real Options Theory; Market approach, Industry Standards Method, Rating/Ranking Method, Rules of Thumb Approach and Auction Method; Hybrid approaches; Royalty rate method.

Unit VI

Technology incubation and promotion: Technology business incubation - Meaning, functions and types; Stakeholder-oriented incubation process, Livelihood incubation, village incubators, System of technology incubation, Incubation process; its effectiveness; Managing profit oriented and non-profit incubators; Schemes for promoting incubators in India; Technology Scouting and Innovations in technology incubation, Technology promotion: Meaning, Types, Business meetings, Scientist-industry/ Entrepreneur meets, Technology conclave, Business plan competition, Farmers fairs, Technology shows; Business Etiquette; Business networking.

VI. Practical

Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University; Understanding the IPR protection practices – Visit to Patent Attorney office; Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark; Documenting Traditional

and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge; Hands on experience in technology licensing process including drafting agreements; Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator; Hands on experience in planning and organising technology promotion events; Hands on experience in various techniques in business communication and Business etiquette; Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering Geographical indications; Technology assessment/ validation of traditional and indigenous knowledge – QuIK and other methods; Hands on experience in technology valuation.

VII. Suggested Reading

- CMA / IIMA, *Implications of WTO Agreements for Indian Agriculture*, Oxford & IBH
- Fundamentals of patent law: interpretation and scope of protection. By Matthew Fisher. Hart, 2007. (KD1369. F57x 2007, Library 4 West)
- Ganguli P. *Gearing Up for Patents: The Indian Scenario*, Orient Longman
- *Guide for the Preparation of Patent Drawings*. USPTO, 2002. (C21.14/2: D79/2, Library 3 East)
- *Guide to the International Registration of Marks Under the Madrid Agreement and the Madrid Protocol*. WIPO, 2004. (K1557. G85x 2004, Reference, Library 2 East)
- *Intellectual Property: Patents, Trademarks, Copyrights, Trade Secrets*. By Catherine J. Holland. Entrepreneur Press, 2007. (KF2980. I539 2007, Library 4 West)
- *Patent, Copyright & Trademark: A Desk Reference to Intellectual Property Law*. By Stephen Elias. Nolo Press, 1996. (KF2980. E44 1996, *Microform, Library use only*, Library 2 East)
- *Patent, Trademark, and Copyright Searching on the Internet*. By Charles C. Sharpe. McFarland, 2000. (T210. S53 2000, Reference, Library 2 East)
- Sikder S. *Contemporary Issues in Globalisation- an Introduction to Theory and Policy in India*, OUP
- *Trademark: Legal Care for Your Business & Product Name*. byStepen Elias. Nolo, 2007. (KF3180.Z9E43 2007, Ready Reference, Library 1 West)

I. Course Title : Policy Engagement And Extension

II. Course Code : FEX 606

III. Credit Hours : 2+1

IV. Objective

To develop the capacities of students to successfully engage with policy actors and bringing about desirable policy changes to strengthen extension.

V. Theory

Unit I

Understanding policy, policy advocacy and tools: Why policies are important for extension? Role in providing structure, Ensure funding and Framework for providing functions-examples; Policy: definitions and types; Is policy a product or a process or both? Policies and institutions, How these influences defining organizational roles and performance in extension organizations, Role of policies in upscaling knowledge.

Unit II

Role of extension in influencing policies to enable innovation; Definition of advocacy, Approaches to policy advocacy-Advising, Media campaigning, Lobbying, Activism, Information education communication (IEC) and Behaviour change communication

(BCC); Advocacy for RAS; Policy advocacy strategy.

Unit III

Policy analysis and development process: Explain the meaning and use of policy analysis in decision making; Describe different types of policy analysis, Empirical, Evaluative or normative policy analysis, Retrospective/ prospective policy analysis, Predictive/prescriptive/descriptive policy analysis; How to do policy analysis?, Understand the process of policy analysis, Highlight the different methods and techniques used in policy analysis, Doing ethical policy analysis; Tools for policy impact- research tools, Context assessment tools, Communication tools, Policy influence tools, Who drives policy change?, National Governments, Donors, Civil Society-varied experiences.

Unit IV

Understanding the environment and key actors in policy space: Problem identification, Policy adoption, Implementation and evaluation; Stakeholder mapping, Identifying opportunities and Barriers, Mobilising financial resources; Dealing with policy incoherence: Identifying contradictions and challenges in policy implementation, Generating evidence.

Unit V

Role of policy research: Analysing the usefulness and appropriateness of the evidence; Using evidence in policy advocacy; Good practices in influencing policies Organising policy dialogues; Policy engagement strategy, Engaging with policy makers; GO and NGO experiences; Policy working groups; advisory panels; use of committees.

Unit VI

Policies in fisheries sector: Policy and regulatory environment in Marine Fisheries Sector, Inland Fisheries Sector, Brackish water Aquaculture Sector, Freshwater Aquaculture Sector, International policy and regulatory scenario in fisheries sector; FAO's CCCRF; UN's Law of the Sea and other conventions; EU's Common Fisheries Policy; Fisheries policy and regulation of select countries in Asian and American region; WTO and Fisheries; Subsidies and taxation in fisheries sector, NIFAP, Marine Policy.

VI. Practical

Analysis of country/state level fisheries/ extension policy to understand the policy intentions from strengthening EAS, Analysis of fisheries policies of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation, Interaction with key policy actors in EAS arena at the state/ national level (e.g.: Secretary of fisheries, Director of fisheries, etc) to explore policy level challenges in EAS, Identifying what evidence policy makers look for from extension research (Is the evidence available? If so what form? (Reports, Briefs etc), If not, develop a plan; Explore how different stakeholders influence policies (e.g.: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use, Identifying policy level bottlenecks that constrain effective EAS delivery at the district level- E.g.: Issues around linkages between KVK and ATMA; inter-departmental collaboration; public private partnerships; joint action etc., Case studies on sub-sectoral review of fisheries policy and legislative framework in select Indian States; Case studies on shrimp culture policy and

development in Thailand and East Coast of India; Case studies on leasing policy in Bihar, Rajasthan, Tamil Nadu, Orissa, Karnataka, Maharashtra and Himachal Pradesh; Case studies on implications of WTO agreements for Indian and world fisheries.

VII. Suggested Reading

- Ananthan PS, B Nightingale Devi and Nisha Elizebeth Joshua (Compilation). 2010. *Policy and Regulatory Environment for Fisheries and Aquaculture in India: A Compendium* Vol I: Policies and Case Studies, Vol.II: Legislation, and Vol. III: Legislation-State MFRAs; CIFE, Mumbai.
- Ananthan PS, Dilip Kumar and RS Biradar. 2010. *Policy Guidelines and Framework for Fisheries and Aquaculture Development in India*-Second Draft for Discussion, CIFE.
- Dilip Kumar, Ananthan PS. *et al*. 2008. *Proceedings of Five Zonal Workshops on Fisheries Policy in North Eastern States, East Coast States, West Coast States, Central Zone States and Northern states* organised during 2006-2008 by CIFE.
- Michael L Weber, 2001. From Abundance to Scarcity: *A History of U.S. Marine Fisheries Policy*, Island Press, New York.
- Salagrama, Venkatesh, *Fish Out of Water: Story of Globalisation, Modernisation and Artisanal Fisheries of India.*

I. Course Title : Participatory Approaches in Fisheries Extension

II. Course Code : FEX 607

III. Credit Hours : 1+1

IV. Aim of the course

To make students' gain knowledge on participatory approaches in fisheries extension programmes.

V. Theory

Unit I

Participatory approaches for aquatic resources management and development: Need, Importance and guiding principles; Community mobilization methods, Farmer-First Approach; Trickle Down System, Concept, Method and processes; Knowledge Driven Extension System, Concept and method.

Unit II

Community based fisheries management and Fisheries co-management: Concept, Origin, Importance, Types, Method, Processes, Stakeholder rights, Responsibilities and participation, Institutional mechanisms, Implementation constraints, Experiences from other countries; Conflict resolution and management; Public-Private-Community Partnership.

Unit III

Participatory Learning Approach (PLA): Role-plays, Case studies, Brainstorming, and ranking of priority issues, Discovery-based experiential learning, Participatory education methods like FGD.

Unit IV

Participatory appraisal techniques: Census mapping, Resource mapping, Social mapping; Selection of participatory methods and their uses; Farmer Field Schools for Aquaculture, Strength and weakness, Constraints in PRA methods.

VI. Practical

Conducting Participatory Rural Appraisal in select villages and developing action plans; Conducting focused group discussion and developing action plan; Facilitating group formation based on the felt needs and to implement the action plans / plan of work; Reviewing national and international case studies on participatory approach to aquaculture research and development; Case studies and simulation exercises on fisheries co-management /community based fisheries management.

VII. Suggested Reading

- Adhikary. 2006. *Participatory Planning and Project Management in Extension Science*. Agrotech Publ. Academy.
- BK. 2008. *PRA/PLA and Participatory Training*. Adhyayan Publ. & Distr.
- Brown D, Derek S & Simon FS. 2005. *Mainstreaming Fisheries Co-Management in the Asia-Pacific*. Asia-Pacific Fishery Comm. Rep. Publ. 2005/24, FAO, United Nations Regional Office for Asia and the Pacific, Bangkok.
- Chambers R, Arnold P & Thrupp LA. 1989. *Farmers First: Farmer Innovation and Agricultural Research*. Intermediate Technology Publ.
- Chambers R. 1983. *Rural Development Putting the Last First*. Longman.
- Edwards P, Little DC & Demaine H. 2002. *Rural Aquaculture*. CABI.
- Kumar D. 1999. *Trickle Down System (TDS) of Aquaculture Extension for Rural Development*. RAP Publ.
- Mukharjee N. 2002. *Participatory Learning and Action*. Concept Publ. Co. Singh.
- Robert SP. 2005. *Fisheries Co-Management*: A Practical Hand Book. CABI.
- Somesh Kumar. 2002. *Methods for Community Participation*. Vistaar Publ.

List of Suggested Journals

- *Advance Research Journal of Social Science, ISSN 0976-5611*
- *Advances in Management, ISSN 0974-2611*
- *Aquaculture Economics and Management, ISSN 1365-7305*
- *Asian Journal of Agricultural Extension, Economics & Sociology, ISSN 2320-7027,*
- *Asian Journal of Extension Education (Maharashtra Journal of Extension Education), ISSN 0971-3115*
- *British Journal of Environment and Climate Change, ISSN 2231-4784*
- *Climate Change and Environmental Sustainability, ISSN 2320-6411*
- *Contemporary Social Sciences, ISSN 0302-9298*
- *Fisheries Management and Ecology, ISSN 0969-997X*
- *Gujarat Journal of Extension Education, ISSN 2322-0678*
- *Human and Ecological Risk Assessment, ISSN 1080-7039*
- *IIMS Journal of Management Science, ISSN 0976-030X*
- *Indian Journal of Agricultural Marketing, ISSN 0971-8664*
- *Indian Journal of Extension Education and Rural Development (Rajasthan Journal of Extension Education), ISSN, 0973-1113*
- *Indian Journal of Extension Education, ISSN 0537-1996*
- *Indian Journal of Marketing, ISSN 0973-8703*
- *Indian Journal of Positive Psychology, ISSN 2229-4937*
- *Indian Journal of Social Research, ISSN 0019-5626*
- *Indian Research Journal of Extension Education, ISSN 0972-2181*
- *International Journal of Applied Social Science, ISSN 2394-1405*
- *International Journal of Climate Change Strategies and Management, ISSN 1756-8692*
- *International Journal of Education and Management Studies, ISSN 2231-5632*
- *International Journal of Extension Education, ISSN 2319-7188*
- *International Journal of Home Science Extension and Communication Management, ISSN 2348-1099*
- *International Journal of Human Resource Management and Research, ISSN 2249-6874*

- *International Journal of Human Resource Management, ISSN 2319-4936*
- *International Journal of Humanities and Social Sciences, ISSN 2319-393X*
- *International Journal of Information Systems Management Research and Development, ISSN 2250-236X*
- *International Journal of Research in Applied, Natural and Social Sciences, ISSN 2347-4580*
- *International Journal of Sales & Marketing Management Research & Development, ISSN 2249-6939*
- *International Journal of Sales & Marketing Management, ISSN 2319-4898*
- *International Journal of Social Science, ISSN 2249-6637*
- *International Journal of Social Sciences Review, ISSN 2347-3797*
- *Jharkhand Journal of Development and Management Studies, ISSN 0973-8444*
- *Journal of Agricultural Extension Management, ISSN 0976-3120*
- *Journal of Community Mobilization and Sustainable Development, ISSN 2230-9047*
- *Journal of Economics, Management and Trade (British Journal of Economics, Management and Trade), ISSN 2456-9216*
- *Journal of Education, Society and Behavioural Science (British Journal of Education, Society and Behavioural Science), ISSN 2456-981X*
- *Journal of Extension Education, Bhubaneswar, ISSN 0976-8246*
- *Journal of Extension Education, Coimbatore, ISSN 0971-3123*
- *Journal of Extension Systems, ISSN 0970-2989*
- *Journal of Global Economics, Management and Business Research, ISSN 2454-2504*
- *Journal of Knowledge and Communication Management, ISSN 2277-7938*
- *Journal of Psychology, ISSN 0976-4224*
- *Journal of Social Sciences, ISSN 0971-8923*
- *Journal of Sociology and Social Anthropology, ISSN 0976-6634*
- *North American Journal of Fisheries Management, ISSN 0275-5947*
- *Prabandhan: Indian Journal of Management, ISSN 0975-2854*
- *Selp Journal of Social Science, ISSN 0975-9999*
- *SMART Journal of Business Management Studies, ISSN 0973-1598*
- *Studies on Home and Community Scienc*e, ISSN 0973-7189
- The Anthropologist, ISSN 0972-0073

List of Suggested E-resources

- Diffusion of innovations http://www.youtube.com/watch?v=B5Kx0hV6jhY
- Resources on Impact Assessment, http://www.gdrc.org/uem/eia/define.html
- Capturing Experience: Evaluation, Evaluation and Impact Assessment Methods, http://web.mit.edu/urbanupgrading/upgrading/resources/bibliography/Evaluati on-Impact.html
- Equality Impact Assessment, https://www.webarchive.org.uk/wayback/archive/20180518072937/ http://www.gov.scot/Publications/2005/02/20687/52421
- The Internet and Poverty: Opening the Black Box, http://dirsi.net/web/files/files/Opening_the_Black_Box.pdf
- ICTs for Development (http://ict4dblog.wordpress.com/)
- Bruce, James P., Egener, I.D. Mark, and Noble, David. 2006. Adapting to Climate Change: A Risk-based Guide for Ontario Municipalities. http://ww.coastalchange.ca/download_files/external_reports/Bruce_(2006)_Adaptingto Climate Change_ARisk-basedGuideforONMunicipalities.pdf
- Ontario Ministry of the Environment. (2011). Climate Ready: Ontario's Adaptation Strategy and Action Plan. https://www.ontario.ca/document/climate-ready-adaptation-strategy-and-action-plan-2011-2014-0
- Air Quality Benefit Assessment tools. http://science.gc.ca/eic/site/063.nsf/eng/h_97170.html
- Mabey, N., Gulledge, J., Finel, B., and Silverthorne, K. 2011. Degrees of Risk: Defining a Risk Management Framework for Climate Security. http://www.e3g.org
- ICLEI. Changing Climate, Changing Communities: Guide and Workbook for Municipal

Climate Adaptation. Accessed from: http://www.iclei.org/index.php?id=8708
- Insurance Bureau of Canada. Municipal Risk Assessment Tool. Accessed from: http://www.ibc.ca/en/Natural_Disasters/Mu nicipal_Risk_Assessment_Tool.asp
- International Panel of Climate Change. https://www.ipcc.ch/links/
- National Institute of Agricultural Extension Management (MANAGE) https://www.manage.gov.in/publications
- Directorate of Knowledge Management in Agriculture (https://icar.org.in/content/directorate-knowledge-management-agriculture)
- NAARMhttps://naarm.org.in/publications/

Suggested broad areas for Master's and Doctoral research

- Comparative study on performance of public, private and market led extension systems
- Performance and impact of ATMA model of service delivery/knowledge dissemination
- Communication effectiveness of different media
- Impact of social media in technology transfer
- Impact of community radio and ICT led extension systems
- Case studies on co-management and community based fisheries management experiences in India
- Training need assessment of State Department of Fisheries
- Impact of B.Voc Programmes in addressing need of skilled human resource in fisheries and aquaculture sector
- Aquapreneurship and youth
- Recruitment policy and career advancement in State Department of Fisheries (or) State Fisheries Universities
- Role and importance of PRIs and NGOs in implementing fisheries development programmes
- Critical factors in successful development of community based organisations
- Reach and impact of fisheries innovations
- Stakeholder analysis of fisheries innovations
- Developing effective interactive e-learning and multimedia products
- Reach and impact of fisheries innovations
- Socio-economic impact assessment of development programmes
- HRM practices of Various State Fisheries Departments, NGOs and private consultancies
- Division of labour and gender equity among fishing communities
- Content analysis of development oriented articles / features in print /electronic media for their reach, readability, and persuasion and conviction
- Political economy of mass media and development journalism
- Case studies on documentation and validation of ITK practices in fisheries sector Impact of Tsunami 2005 on fishers' livelihoods and fisheries
- Pattern of rehabilitation work and its impact
- Returns to investment in fisheries and aquaculture extension
- Evolving participatory result oriented monitoring and evaluation system for fisheries development programmes in developing countries. Developing appropriate scaling technique for measuring the attitude of fishers towards conservation technologies
- Professionalism in Service Delivery System Performance of public and NGO led extension systems
- Developing and field testing of effective training tools for trainers
- Conflict between small scale fishers and large scale fishers and inadequacy of the present resolution mechanism.
- Social change, mobility and integration in fishing communities
- Case studies on success stories in use of ICT for fisheries development Limiting factors in effective use of ICT for Development
- Comparative study of effectiveness performance of extension systems in India and other developing South-East Asian Countries (Indonesia / Thailand) or developing agrarian economy based countries
- Levels of workload among Fishers and their impact on health
- Administrative advantage of formation of exclusive ministry/council for fisheries

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 5

Fisheries Science
– Fish Physiology and Biochemistry

Preamble
(Fish Physiology and Biochemistry)

Fish physiology and Biochemistry is a basic discipline in the field of fisheries science. Physiology is the scientific study of the normal function in living systems in their living environment. One of the major objectives is to know the basic function of organs and their interaction at a macro-level while biochemistry provides more basic understanding in a micro-level about the existence of life in the organism. Physiology is closely related to anatomy which is the study of form and structure. Fish physiology seeks to understand the mechanisms that work to keep the fish body alive and functioning, through scientific enquiry into the nature of mechanical, physical, and biochemical functions of fishes, their organs, and the cells of which they are composed. Biochemistry will broaden our understanding on the physiology and helps to understand the chemical aspects of biological processes. The principal level of focus of physiology is at the level of organs and systems within the body. The endocrine and nervous systems play major roles in the reception and transmission of signals that integrate function in animals. Homeostasis is a major aspect with regard to such interactions within the organisms. The biological basis of the study of physiology, integration refers to the overlap of many functions of the systems of the body, as well as its accompanied form. It is achieved through communication that occurs in a variety of ways, both electrical and chemical. Few of the most extensively researched and applied areas in fish physiology and biochemistry is the physiology of reproduction as well as the nutritional physiology. With the help of this course, students learn to find scientific answers to the problems related with the various modes of aquaculture production before attempting to solve them. This course takes a systematic approach with emphasis on the reproductive, circulatory, endocrine, muscular, nervous, metabolic, and respiratory systems. The knowledge will certainly enable students to amicably address the failure in captive reproduction, larval growth and survival issues of new aquaculture candidates, adaptation to altered habitats, growth and immunity under various salinities, mitigation strategies for alleviating stresses and identifying welfare indicator of fishes in different aquaculture systems. In addition to the basic body systems, the course also covers the deviations from normal physiology such as stress and adaptive physiology and interactions of physiology with environment in context of foreseeable climate change scenario.

The major emphases of the discipline are as follows:

How the physiological processes happen and their biochemical basis
How they might change with environment and their biochemical basis
How one process inûuences the other
How this relates to real scenario of finfish and shellfish aquaculture.

Overall, Purpose of the 'Fish Physiology and biochemistry" course, is to provide a foundation on many basic processes that keep a fish alive and how understanding biochemical and physiological processes have practical applications. Further, the understanding of physiology will help to find reasons to recurrent practical problems such as fish mortalities, low production or breeding failure and ways to help the situation. In academics the understanding of physiology and biochemistry is invaluable for interpreting data from many

fields such as nutrition, immunity, and genetics. Understanding why something happen leads to new questions and therefore new research directions can be created. The course focuses on physiological processes in fish including reproduction, nutrition, respiration, circulation, acid-base balance, smotification, osmo-ionic regulation, swimming and buoyancy, sensory physiology, egg and larval physiology, digestion, energetic and growth, immunity and adaptations to adverse climate and environments.

With the background of immense importance of the 'Fish Physiology and Biochemistry", members of the BSMA committee and the invited experts from pioneer institution like IITs and industry reviewed the existing PG and Ph.D. course syllabus critically several times, incorporated the recent content learning both in theory and practical to bring it in this elevated format to groom the fish physiology and biochemistry specialists and professionals to the industry, R&D and academics. The syllabus has been made following the same pattern maintained in preparing other disciplines. Under M.F.Sc. program minor change in title of 1 course has been made with several minor changes in the contents of different courses to keep the syllabus more relevant to the needs of the day. In Ph.D. program, only course was subjected to major changes and a new course "Diagnostic Biochemistry and Physiology" has been introduced to understand and to develop new methods of identifying disturbances in fish welfare well before of sickness and outbreak of diseases. In M.F.Sc one course "Aquatic radioecology" has been excluded from the syllabus due to lack of facilities needed to run such course.

Justification for Fish Physiology and Biochemistry Disciplines in Fisheries Science

Earlier committee reports such as, Fifth Deans' Committee Report (2013) and Report of PG and Ph.D restructuring done under the Chairman ship of Dr. Keshavanath (2009) have recommended offering "Fish Physiology and Biochemistry" for the PG/Ph.D. in Fisheries Science. The new Education Policy 2020 envisages making the education system more flexible for the Higher education students. At the PG and Ph.D. level naturally, it is essential to branch out into more specialisations and there is a need to offer many courses for students to choose from. Thus, students will be offered with a wider choice of courses and they need not be restricted to a limited no. of courses. Moreover, withdrawing the already introduced Courses on "Fish Physiology and Biochemistry" after few years would certainly affect the career of those students earned degree. It would be detrimental to the settlement of those students who pursued the courses.

Course Title with Credit Load
M.F.Sc. in Fish Physiology and Biochemistry

Course Code	Course Title	Credit Hours
	Major Courses	**20 Credits**
FPB 501	Fish Physiology	2+1
FPB 502	Reproductive Physiology and Endocrinology	2+1
FPB 503	Fish Biochemistry	2+1
FPB 504	Metabolism of Biomolecules	2+1
FPB 505	Cellular and Molecular Physiology	2+1
FPB 506	Crustacean Physiology	1+1
FPB 507	Diagnostic Biochemistry	2+1
	Minor Courses (From the subjects closely related to a student's major subject)	**8 Credits**
FPB 508	Tools and Techniques in Biochemistry	1+2
FPB 509	Principles in Fish Nutrition	2+1
FPB 510	Nutraceuticals as Functional Foods	1+1
FPB 511	Fish Pathology and Immunobiology	1+1
FPB 512	Sensory Physiology	1+1
FPB 513	Physiology of Fish Behaviour	1+1
FPB 514	Pharmaco-biology of Aquaculture Drugs	1+1
FPB 515	Eco-physiology of Fishes	1+1
FPB 516	Enzymology	2+1
FPB 517	Fish Nutrigenomics	2+1
FPB 518	Feeds and Feed Technology	2+1
FPB 519	Nutritional Requirement and Feeding Management	2+1
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**6 Credits**
	Common Courses (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills	**5 Credits**

Course Code	Course Title	Credit Hours
	3. Intellectual Property and its management in Agriculture	
	4. Basic concepts in Laboratory Techniques	
	5. Agricultural Research, Research ethics and Rural Development Programmes	
	Total Course Work Credits	**39 Credits**
	Masters' Seminar	**1 Credit**
FPB 591	Master's seminar I	0 + 1
	Masters' Thesis Research	**30 Credits**
FPB 599	Master's Research (Semester III)	0 + 15
FPB 599	Master's Research (Semester IV)	0 + 15
	Total M.F.Sc. Program Credit Hours	**70 Credits**

Course Contents
M.F.Sc. in Fish Physiology and Biochemistry

I. Course Title : Fish Physiology
II. Course Code : FPB 501
III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic physiology of fish

V. Theory

Unit I

Cell Physiology: Structures, Membranes, Organelles and Functions; Cell cycle; Signaling and cell death; Cellular functions in aquatic environment; Extracellular matrix biology; Bioluminescence and physiology of electric organs in fishes.

Unit II

Physiology of GIT: Anatomy; Digestion, Absorption and assimilation of food salt and water; Digestive enzymes, Neural and hormonal regulation; Impact of nutrition.

Unit III

Physiology of respiration: Morphology of gills, Respiratory pigments and their functions; Mechanism of gaseous exchange, Gill ventilation countercurrent principle, CO_2 transport,; Fluid dynamics on gill functions and respiratory mechanisms.

Unit IV

Circulatory system: Structure and functions of heart, Blood circulation, Blood pressure, Composition of blood, Heart and cardiac output, Structure of blood/ haemolymph pigments; Water salinity and blood composition.

Unit V

Physiology of Osmoregulation and Respiration: Excretory and osmoregulatory organs in fish and shellfish and their functions; Mechanism of osmotic and ionic regulation; Acid base regulation, Mechanism of excretion of nitrogenous waste; mechanisms of osmoregulation against aquatic pollutants.

Unit VI

Physiology of Reproduction: Structure and functions of gonads, Gametogenesis; Vitellogenesis; Gonadal steriodogenesis; Seasonality of reproduction, and endocrine control of reproduction; Circadian rthyme in fish physiology; Aquatic pollutants and reproduction.

VI. Practical

Cell proliferation assay: Estimation of haemoglobin /haemocyanin and blood CBC; Estimation of ion transporter activity; Measuring osmolality of blood/ haemolymph; dissection and display of reproductive system, Estimation of hormones.

VII. Suggested Reading

- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: from Basic Studies to Biotechnological Applications*. Springer Publ.
- Evans DH and Claiborne JB. 2009. *Physiology of fishes*, Fourth edition, CRC press.
- Farrell AP. 2011. *Encyclopedia of fish physiology: from genome to environment*. Volume 1-3, Academic Press.
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 2 *The Endocrine System*. Academic Press.
- Hoar WS, Randall DJ and Donaldson EM. 2014. Fish Physiology Vol. 9A, *Reproduction: Endocrine Tissues and Hormones*. Academic Press.
- Hoar WS. 2014. *Fish Physiology* Vol. 9B. Academic Press
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 4 *The Nervous System, Circulation and Respiration*. Academic Press
- Johnston 2014. Fish physiology (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014: "v, 318p" ISBN: 978-93-5107-130-3 .
- Samantaray K. 2015. *Physiology of Finfish and Shellfish*. New India Publ. Agency.
- Smith Lynwood S. 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Nielsen 1983. *Animal Physiology: Adaption and Environment* New York Cambridge University Press Edition: 3rd: "xii, 619p"
- Val. 2006. *Physiology of Tropical Fishes. California* Elsevier Academic Press: "xiv, 634p"; 23cm ISBN: 0-12-350445-7.
- William O Reece and Eric W Rowe. 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7, Wiley-Blackwell p. 576.

I. Course Title : Reproductive Physiology And Endocrinology

II. Course Code : FPB 502

III. Credit Hours : 2+1

IV. Aim of the course

Basic concepts of reproductive physiology and endocrinology.

V. Theory

Unit I

Modes of reproduction: Sex determination and differentiation; Sexual dimorphism; Primary and secondary sex characters; Bisexual reproduction; Hermaphroditism, Sex reversal; Parental care reproductive behavior and adaptations.

Unit II

Neuroendocrine regulation: Pituitary gland and hypophthalamus; Structure and functions of GnRH other neuropeptides, Gonadotropins; Gonadotropin receptors structure, Function and regulation of their secretion.

Unit III

Gonad development and maturation: Oocyte and spermatocyte growth, Vitellogenesis; Nutrient transport and incorporation into oocytes; Oocyte maturation and ovulation; Spermiation; Metabolic changes during gametogenesis; Nutrient regulation of gonad development and endocrine function; Seminal vesicle and function.

Unit IV

Reproductive Rhythm: Daily and seasonal rhythms; Environmental cues, Photo-transduction, Role of melatonin and neuropeptides, Lunar clock, Biological Clock,

Time of day, reproduction; Pheromones; Migration in fish.

Unit V

Reproductive technology: Hormonal manipulation of reproduction; Cryopreservation of gametes/ germ cells; Artificial insemination, Synthetic hormones and analogues for induced spawning; Stripping and fertilization.

Unit VI

Peripheral endocrine glands and hormones: Structure and functions; Thyroid, ultimobranchial body, Corpuscles of Stannius, Adrenal homologues, and Urophysis, PTH-related peptides, Calcitriol, Pancreatic hormones; Gut hormones; Neuroendocrine hormones.

VI. Practical

Dissection and display of reproductive and endocrine organs. Assay of hormones-testosterone, estradiol, cortisol, thyroxine; histological examination of gonad, maturity; Short term preservation of milt; Cellular morphology of pituitary gland.

VII. Suggested Reading

- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea*. Biology Reviews.
- Agarwal NK. 2008. *Fish Reproduction*. APH Publ.
- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: from Basic Studies to Biotechnological Applications*. Springer Publ.
- Croom HME. 2003. *Fish Endocrinology*.
- Diwan AD, Joseph S and Ayyappan S. 2008. *Physiology of Reproduction*, Breeding and Culture of Tiger Shrimp. Narendra Publ. House.
- Hoar WS and Randall DJ. 1969. *The Endocrine System* Volume 2. Academic Press.
- Maria RJ, Augustine A and Kapoor BG. 2008. *Fish Reproduction*. Science Publ. Matty AJ. 1985.
- Norris DO and Lopez KH. 2011. *Hormones and Reproduction of Vertebrates*. Vol. I Fishes. Academic Press.
- Reinecke. 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc.: "xx, 441-871pp" ISBN: 978-1-57808-415-9.
- Sherwood NM and Hew CL. 2014. *Fish Physiology* Vol. 13. *Molecular Endocrinology of Fish*. Academic Press.

I. Course Title : Metabolism of Biomolecules

II. Course Code : FPB 504

III. Credit Hours : 2+1

IV. Aim of the course

Metabolism of different biomolecules.

V. Theory

Unit I

Carbohydrate metabolism: Glycolysis, TCA cycle; Feeder pathways of carbohydrate metabolism: Pentose phosphate pathway and gluconeogenesis; Glycogen metabolism, Regulation of blood glucose level.

Unit II

Lipid metabolism: Biosynthesis of fatty acids; Oxidation of fatty acids; Ketone bodies; desaturation and Elongation mechanisms; Control of fatty acid metabolism.

Unit III

Oxidative phosphorylation: Substrate level phosphorylation; Electron Transport Chain; NADH, NADPH, and $FADH_2$. Fo-F1 ATP synthesis.

Unit IV

Protein and amino acid metabolism: Biosynthesis of protein; Degradation of amino acids; Transamination and deamination, ammonia carrier and excretion; Biosynthesis of non-essential amino acids.

Unit V

Nucleic acids metabolism: Purine and pyrimidine metabolism, Biosynthesis of deoxyribonucleotides and ribonucleotides.

Unit VI

Vitamins and mineral metabolism: Metabolomics; Basic concepts and applications, Xenobiotic metabolism.

VI. Practical

End product estimation of aerobic and anaerobic carbohydrate metabolism (pyruvate and lactate) Estimation of lipoprotein lipase, acetyl choline esterase LDH, MDH, AST, ALT, NADH, NADPH, RNAses and DNAses.

VII. Suggested Reading

- *Bios Instant Notes Molecular Biology*. 4th Edition, 2016 by Mclennan.
- David L. Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- Gupta SN. 2019. *Biochemistry of Metabolic Processes*.
- John W Pelley. 2010. *Rapid biochemistry*. Elsevier.
- Pandya A. 2015. *Biomolecules and Biochemical Metabolism of Fuels: Carbohydrate, Protein, Lipid Metabolism*.
- Sharma MK. 2013. *Biomolecules and Metabolic Activities*.

I. Course Title : Cellular and Molecular Physiology

II. Course Code : FPB 505

III. Credit Hours : 2+1

IV. Aim of the course

To understand the cellular signaling cascades and related molecular physiology.

V. Theory

Unit I

Cell structure: General organization of euaryotic and prokaryotic cell; Structure and function of cell organelles, Cell membrane, Compartments, Electrolytes and Extracellular matrix, Membrane fluidity.

Unit II

Cell cycle and division: Meiosis and Mitosis regulation of cell cycle factors affecting cell cycle; Apoptotic and necrotic pathways.

Unit III

Cell signaling: General principles; Second messenger system; Concept of ligand; Ligand and receptor interactions Mechanism of cell signaling, Intracellular and extracellular receptors (Ion channel linked, G-Protein linked and enzyme linked) mediated signaling pathways; GPCR structures and functions; Concepts of

membrane bound receptors and cytoplasmic/ nuclear receptor; second messenger system; Steroid hormone actions.

Unit IV

Cellular trafficking: Endocytic and Exocytic pathways membrane transport protein sorting vesicular transport.

Unit V

Gene expression: DNA replication, transcription translation and regulation of gene expression.

Unit VI

Translation and epigenesist: Pre and Post transcriptional and post translational modifications; Gene splicing, duplication and mutation, DNA damage and repair, Pathways; Epigenetic regulations.

VI. Practical

RNA isolation and cDNA synthesis, PCR, Genomic DNA isolation, PAGE and SDS-PAGE, DNA barcoding.

VII. Suggested Reading

- Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K and Walter P. 2015. *Molecular Biology of the Cell* (6th edition), New York: Garland Science. 1464 pp.
- CIFE. 1998. *Genetics and Biotechnological Tools in Aquaculture and Fisheries*. Mumbai CIFE.
- Cooper GM and Robert EH. *The Cell: A Molecular Approach* (6th edition) Hausman RE. 2013. Sunderland, Massachusetts: Sinauer Associates. 832 pp.
- Davbre PD. 1998. *Basic Molecular Biology: Essential Technique*. John Wiley and Sons, New York. p.208
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- Henry T Yost. 1972. *Cellular Physiology*.
- Krebs JE, Goldstein ES and Kilpatrick ST. 2017. Lewin's Genes XII. Jones & Bartlet Publishers, MA, USA 829 pp.
- Lakra WS. 2004. *Fisheries Biotechnology*. Narendra Publishing House, Delhi.
- Mordecai P, Blaustein MD, Joseph PY, Kao. 2004. *Cellular Physiology: Mosby's Physiology* Monograph Series, ie.
- Sambrook J and Russel D. 2001. Molecular Cloning. 3rd Ed. Cold Spring Harbour Laboratory
- Verma PS. 2004. *Cell Biology, Genetics, Molecular Biology: Evolution and Ecology*. 350 pp. ISBN-13: 978-8121924429 *Instant Notes in Molecular Biology*, 2000 by Turner (Author), MCLENNAN (Author), Bates (Author), WHI (Author).

I. Course Title : Crustacean Physiology

II. Course Code : FPB 506

III. Credit Hours : 1+1

IV. Aim of the course

To understand basic physiology of crustacean.

V. Theory

Unit I

Reproduction: Reproductive physiology of crustaceans, Neuroendocrine glands and their functions.

Unit II

Molting and growth: Physiology of Molting, molting cycle, Growth.

Unit III

Ion and metabolites homeostasis: Osmoregulatory and Excretory physiology of crusataceans.

Unit IV

Digestive physiology: Function and structure of different components of digestive system, Feeding and sensory appendages, Hepatopancreas, Chemoreception.

VI. Practical

Identification of different organs, morphology of gonads; Molting cycle in relation to environment; osmolality and ionic estimation of haemolymph, anatomy of digestive tract.

VII. Suggested Reading

- Mente E. 2003. *Nutrition, Physiology and Metabolism in Crustaceans*.
- Ernest S, Chang and Martin Thiel. 2015. *Physiology: Volume IV (The Natural History of the Crustacea* Book 4.
- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea. Biology Reviews*.
- Diwan AD, Joseph S and Ayyappan S. 2008. *Physiology of Reproduction, Breeding and Culture of Tiger Shrimp*. Narendra Publ. House.
- Diwan 2007. *Physiology of Marine White Shrimp: Fenneropenaeusindicus*. Delhi Narendra Publishing House: "x, 245p." ISBN: 81-85-375-93-3
- Wilder MN. 2019. *Advances in the Science of Crustacean Reproductive Physiology and Potential Applications to New Seed Production Technology*. *In:* Jithendran, K.P.; Saraswathy, R.; Balasubramanian CP, Kumaraguru Vasagam KP, Jayasankar V, Raghavan R, Alavandi SV, and Vijayan KK. (eds.)*, BRAQCON 2019: World Brackishwater Aquaculture Conference. Journal of Coastal Research,* Special Issue No. 86, pp. 6–10. Coconut Creek (Florida), ISSN 0749-0208.
- Subramoniam T. 2016. *Sexual Biology and Reproduction in Crustaceans*. Academic Press. 1st Edition.

I. Course Title : Tools and Techniques in Biochemistry

II. Course Code : FPB 508

III. Credit Hours : 1+2

IV. Aim of the course

Different experimental techniques in the fish Biochemistry.

V. Theory

Unit I

Theory and application of spectrophotometry: Beer-Lambert's law; Calibration plot; UV-visual, fluorescent, IR, CD spectroscopy, Atomic mass spectroscopy, RT-PCR and NMR, X-ray crystallography.

Unit II

Basic principles of chromatography: Theory and applications of paper, Affinity, Column, Thin layer, Ion-exchange, Size exclusion and gas chromatography, HPLC; HP-TLC; LC-MS; Factors affecting chromatographic resolutions, Resolving power and retention time.

Unit III

Radioimmunoassay (RIA) and Enzyme-linked immunosorbent assay (ELISA): Basic principle and application in quantitative estimation of biological analytes; Development of assays.

Unit IV

Electrophoresis: Theory and applications of electrophoresis; Gel electrophoresis of proteins and nucleic acids, Determination of molecular weight of proteins and nucleic acids; Electrophoretic Mobility Shift Assay (EMSA).

VI. Practical

Spectrophotometric estimation of biomolecules: Spectrum analysis, Validation of Beer-Lamberts law IR spectroscopy FTIR, NMR Isolation and purification of protein; protein isolates and concentrate preparation, chromatographic purification of proteins, Separation of amino acids by paper chromatography; TLC separation; HPLC analysis GC-MS analysis; Qualitative and quantitative estimation of fatty acids by gas chromatography; Isolation of plasmid and genomic DNA, Total RNA, PCR, RT-PCR and qPCR, Separation of proteins and nucleic acids by gel electrophoresis: Vertical and horizontal electrophoresis. RIA and ELISA.

VII. Suggested Reading

- *Encyclopaedia of Tools and Techniques in Biochemistry and Molecular Biology*, 3 Vol Set, 2015 by Darrel Crasta.
- Katoch, R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*.
- Sharma, R.K. and. Sangha, S.P.S. 2020. *Basic Techniques in Biochemistry and Molecular Biology*.
- Wilson and Walker, 2010. *Principles and Techniques of Biochemistry and Molecular Biology*.
- *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology* 8th edition, 2018 by Andreas Hofmann (Editor), Samuel Clokie (Editor).

I. Course Title : Diagonistic Biochemistry

II. Course Code : FPB 507

III. Credit Hours : 2+1

IV. Aim of the course

To understand the different aspects of biochemical diagnostic Techniques.

V. Theory

Unit I

Blood analysis: Analytes in blood, Tissues, Invasive and non-invasive techniques of blood drawing in fish, Their limitations and interpretation, Hemoglobin, Hematocrit, Plasma proteins, Glucose tolerance test.

Unit II

Enzymes and metabolic disorders: Subcellular distribution of enzymes, Isolation and purification of enzymes, General properties, Enzyme activity, Marker enzymes, Metabolic disorders related to carbohydrate, Lipid, Protein and nucleic acid metabolism in fishes.

Unit III

Enzyme markers: Enzymes and iso-enzymes of clinical significance; Acid phosphatase, Alkaline phosphatase, Amylase, angiotensin converting enzyme,

Cholinesterase, Creatine phosphokinase, Gammaglutamyl transferase, Lactate dehydrogenase.

Unit IV

Vitamins and minerals: Vitamins and Minerals sub-clinical and clinical deficiencies, Electrolytes and acid-base balance**,** Regulation of electrolyte content of body fluids, Biochemical indicators for vitamin and mineral stress.

Unit V

Lipids carriers and disorders: Chylomicrons, VLDL and IDL, HDL, LDL - Implications in disease, Fatty liver, liver, kidney and bone disorders, Liver function tests, Detoxification mechanisms of gill, liver and kidney, Pesticide poisoning.

Unit VI

Immunoglobulins: Structure, Classes, Properties and functional significance of Immunoglobulins, Monoclonal antibodies.

VI. Practical

Estimation of blood glucose, albumin and globulin, gel electrophoresis of serum proteins, quantification of serum proteins, determination of A/G ratio in serum, Analysis of stress proteins; Liver and plasma enzyme assay (GOT, GPT, ALP, AchE, CPK, LDH, Urease); Blood hemoglobin, serum bilirubin, Blood calcium. Histology of vital organs. Estimation of vitamin A and D. Tests for immunoglobulins.

VII. Suggested Reading

- *Clinical Biochemistry*, Michael Murphy, Elsevier, 2018.
- *Clinical Biochemistry*, 2016 by Maheshwai Nanda
- *Manipal Manual Of Clinical Biochemistry*, 2013 by Nayak Shivananda.
- *Practical Clinical Biochemistry Methods And Interpretations*, 2020 by Ranjna Chawla

I. Course Title : Principles of Fish Nutrition

II. Course Code : FPB 509

III. Credit Hours : 2+1

IV. Aim of the course

To understand the basic principles of fish nutrition and the role of different nutrients.

V. Theory

Unit I

Protein nutrition: Protein and amino acids, Their specific functions, Classification and evaluation criteria of dietary protein (nutrient gain, nutrient efficiency, TGC, PER, NPU, BV, EAAI, chemical score), Protein deficiency symptoms.

Unit II

Lipid nutrition: Lipids and fatty acids, Their specific functions, Classification and evaluation of lipid quality, Lipid deficiency symptoms.

Unit III

Carbohydrate nutrition: Carbohydrates, Functions, Classification and Utilization of carbohydrate in fish diets.

Unit IV

Vitamin and mineral nutrition: Specific functions, Classification, Sources of vitamins and minerals and their deficiency symptoms.

Unit V

Nutritional energetics: Definition, Different forms of energy and energy value of feed (gross energy, digestible energy, metabolizable energy, net energy), Importance of protein-energy ratio in fish diets.

Unit VI

Larval and Brood stock nutrition: Larval gut morphology, Importance of live feed and formulated feeds in larval nutrition, Nutrients required for egg and sperm quality and reproductive efficiency.

VI. Practical

Proximate analysis; moisture, crude protein, crude lipid, gross energy, ash, acid insoluble ash, crude fibre, nitrogen free extract of feed and fish tissue, analysis of fatty acids and amino acids, calcium, phosphorus, vitamin C content of feed.

VII. Suggested Reading

- *ADCP (Aquaculture Development and Co-ordination Programme)*. 1980. Fish Feed Technology, ADCP/REP/80/11.FAO, Rome.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*, Chapman and Hall Aquaculture Series, London.
- *FAO Training Manual Related to Feed Analysis*.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*, Springer Praxis Publishing, Chichester, U.K.
- Halver JE. 1989. *Fish Nutrition, Academic Press*, San Diego, Califonia.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.
- Paulraj R. 1993. *Aquaculture Feed*. CMFRI publication, 84 pp.

I. Course Title : Nutraceuticals as Functional Foods

II. Course Code : FPB 510

III. Credit Hours : 1+1

IV. Aim of the course

To understand the role of nutraceuticals in the physiological wellbeing of fish and shellfish.

V. Theory

Unit I

Functional foods v/s Nutraceuticals: Definitions, Concepts and Beneficial roles, Application of functional foods in immune modulation and disease prevention.

Unit II

Characteristics of nutraceuticals and delivery systems: Nanotechnology of drug delivery system such as biocompatible polymers, Stimuli responsive polymers.

Unit III

Modes of action and benefits: Probiotics, Prebiotics, Stanols and sterols, Their immunomodulatory effects.

Unit IV

Stress mitigation and growth enhancement: Interrelationships of stress and growth in fish, Functional feed additives and role of functional foods in stress mitigation and growth enhancement.

VI. Practical

Estimation of immunomodulatory parameters (lysozyme, NBT, MPO, antibody titre), estimation of antioxidant enzymes (SOD, catalase, GPx), extraction of bioactive compounds, in vitro antioxidant assay, Pro PO.

VII. Suggested Reading

- DeFelice SL. 1995. *The Nutraceutical Revolution: Its Impact on Food Industry R & D. Trends in Food Science and Technology*, 6(2), pp.59-61.
- Luckstadt C. 2008. *Utilization of Acidifiers in Nutrition and Feeding of Tropical Fish–A Mini-Review*. Bulletin of Fish Biology Volume, 10(1/2), pp.105-109.
- Kalra EK. 2003. *Nutraceutical-Definition and Introduction*. AapsPharmsci, 5(3), pp.27-28.

I. Course Title : Fish Pathology and Immunobiology

II. Course Code : FPB 511

III. Credit Hours : 1+1

IV. Aim of the course

Different aspects of immunostimulants and their effect on fish immunity, stress and disease resistance.

V. Theory

Unit I

Basic principles of immune system: Immune system in fishes, Cell and organ involved in immunity.

Unit II

Mechanism of immunity: Different mechanisms, Humoral and cell mediated immunity, Cytokines, Interferon, Lymphokine, Chemokines, Their role in immune response.

Unit III

Immunoprophylaxis: Immunoprophylaxis in fish, Toxin, Toxoid and Vaccines, Immuno-stimulant and immunomodulation.

Unit IV

Antibodies and their function: Biosynthesis of antibody, Function of different antibodies; Interaction of Endocrine with immune system; antibody classes and genes involved.

VI. Practical

Challenge study, Lysozyme activity, Estimation of NBT and MPO Estimation of CBC. Estimation of prophenol oxidase, Estimation of superoxide dismutase, Estimation of IgM.

VII. Suggested Reading

- Anderson DP. 2003. *Textbook of Fish Immunology*. Narendra Publishing House, Delhi.
- *BIOS Instant Notes in Immunology*, 2011 by Peter Lydyard, Alex Whelan, et al.
- Delves PJ. 2017. *Roitts Essential-Immunology*. Wiley Blackwell, UK.
- Ellis AE. 1985. *Fish and Shellfish Pathology*. Academic Press, London.
- *Fish Diseases and Disorders*. CABI, Wallingford, UK 2010
- Folds JD. 1999. *Clinical Immunology*. ASM Press, U.S.A
- Leatherland JF. 1998. *Fish Diseases and Disorders*. Vol 2. CABI Publishing, Oxon.
- Richard C. 2015. *Immunology A Short Course*. Wiley Blackwell, UK.
- Roberts RJ. 2012. *Fish Pathology*. 4th Ed. W.B. Saunders.
- Sharma DK. 2015. *Immunology*. New India Publishing Agency, New Delhi.
- Sparks A. 1972. *Invertebrate Pathology: Non-ommunicable Diseases*. Academic Press, New York
- Swain P and Sahoo PK. 2006. *Fish and Shellfish Immunology* NPH, Delhi.
- Stolen JS. 1986. *Fish Immunology*. Elsevier, Amsterdam.

I. Course Title : Sensory Physiology

II. Course Code : FPB 512

III. Credit Hours : 1+1

IV. Aim of the course

To understand different sensory organs and their functional mechanism in fish.

V. Theory

Unit I

Sense organs and their functions: Electroreceptors, Chemoreceptors, Baroreceptors, Propioreceptors, Hydroreceptors and Photoreceptors.

Unit II

Olfactory and auditory organs: Physiological mechanisms; Fisheries acoustics.

Unit III

Sensory neurons: Action potential, Synapse, Neurotransmitters, Impulse transmission, Excitation-contraction coupling.

Unit IV

Luminescence: Chemoluminescence and bioluminescence; Chromatophores; electrophysiology.

VI. Practical

Practical on chemoreception using different feeding attractants. Study of chemosensor cell function in response to salinity, dissolved oxygen levels and pH changes Chromatophores function in relation to background colour light, temperature, etc.

VII. Suggested Reading

- Toshiaki Hara and Barbara Zielinski. 2006. *Fish Physiology: Sensory Systems Neuroscience*. Volume 25.
- TH Bullock, A Fessard *et al*. *Electroreceptors and Other Specialized Receptors in Lower Vertrebrates*: 3 / 3 (Handbook of Sensory Physiology).
- Joseph A Sisneros. 2011. *Fish Hearing and Bioacoustics*: An Anthology in Honor of Arthur N. Popper and Richard R. Fay: 877 (*Advances in Experimental Medicine and Biology*).
- Shaun P Collin, N Justin Marshall *et al*. 2003. *Sensory Processing in Aquatic Environments*.

I. Course Title : Physiology of Fish Behaviour

II. Course Code : FPB 513

III. Credit Hours : 1+1

IV. Aim of the course

To understand the behavioural physiology of fish.

V. Theory

Unit I

Fish behavior: Concept, types, and regulatory mechanism.

Unit II

Feeding and predation: Predatory avoidance; Feeding behavior

Unit III

Social and reproductive behavior: Sexual and aggressive behavior; Parental behavior; Endocrine control of behaviours.

Unit IV

Adaptation mechanism in altered environment: Migration, Schooling, Shoaling, bottom dwelling.

VI. Practical

Tagging studies, Audio visual recording of behavior in simulated experiment.

VII. Suggested Reading

- Katherine Sloman Sigal Balshine Rod Wilson Volume 24. *Fish Physiology: Behaviour and Physiology of Fish*.
- Margaret E. Brown. 2013. *The Physiology of Fishes: Behavior*.
- Tony J. Pitcher, 2012. *The Behaviour of Teleost Fishes*.

I. Course Title : Pharmaco-biology of Aquaculture Drugs

II. Course Code : FPB 514

III. Credit Hours : 1+1

IV. Aim of the course

To understand aquaculture drugs and their delivery mechanism.

V. Theory

Unit I

Drugs in aquaculture and fish health management: E.O., FDA and ISO standards of levels of drugs.

Unit II

Pharmacological studies: Kinetics and dynamics; Detoxification; Drug metabolic profile; Liver function tests.

Unit III

Chemotherapeutic agents: Antiprotozoal agents, Ectoparasiticide, Antihelmenthic, Anaesthetics; Dosage determination/ optimization.

Unit IV

Antimicrobial drugs: Antibacterial, Antifungal, Antiviral drugs and their delivery system.

VI. Practical

Estimation of residual level of different drugs; Minimum Inhibitory Concentration of drugs test, Pharamaco-kinetics of aquaculture drugs

VII. Suggested Reading

- Bryan LE. 1989. *Handbook of Experimental Pharmacology*. Vol 91. Springer-Verlag, Berlin.
- Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Press, London.
- Herwig N. 1979. *Handbook of Drugs and Chemicals used in the Treatment of Fish Diseases*. Charles C Thomas, Springfield
- Khory RN. 1999. *Material Medica of India and their Therapeutics*. Komal Prakashan, Delhi
- Lancaster R. 1980. *Pharmacology in Clinical Practice*. William Helnemann Medical Books Ltd., London
- Pandey G. 2017. *Fish Pharmacology and Toxicology*. DPH, New Delhi.
- Riviere JE. *Veterinary Pharmacology and Therapeutics*. John Wiley and Sons, U.S.A
- Radostits M. 2000. *Veterinary Medicine*. Bookpower Publisher, China
- Singh ISB. 2003. *Aquaculture Medicine* Cochin University 2003. 336p
- Stockopf MK. 1993. *Fish Medicine*. W.B. Saunders Company, London

I. Course Title : Ecophysiology of Fishes

II. Course Code : FPB 515

III. Credit Hours : 1+1

IV. Aim of the course

To understand the physiology of fish in changing ambient environment.

V. Theory

Unit I

Fish habitats: Disruption of habitats; Pollutants, Toxicants and Radionuclides emittants.

Unit II

Climate change effectors: Impacts on ecology, Growth and reproduction; Mitigation mechanisms; Migration patterns.

Unit III

Thermal and hypoxic stress: Physiological and metabolic responses; Heat shock protein (HSP); Hypoxia Inducing Factor (HIF); cardiovascular and gill ventillatory systems.

Unit IV

Radioecology: Occurrence of radioactive substances in water and threat on food chain, Use of radioisotopes in tracer techniques for metabolic studies, International radiological limits for the export and import of aquatic products; Radioactive substances and fish physiology.

VI. Practical

Estimate threshold of thermal and hypoxia tolerance, Estimation of LC_{50} of pollutants, Estimation of stress enzymes, isozymes, Estimation of cortisol. Use of isotopes in tracer techniques for metabolic studies, Quantification of Tritium and other radioisotope levels in fish tissues.

VII. Suggested Reading

- JC Rankin, Frank B Jensen. 2020. *Fish Ecophysiology* (Fish and Fisheries Series, Volume 9) Special Indian Edition.
- T Braunbeck, W Hanke *et al*. 1991. *Fish: Ecotoxicology and Ecophysiology: Proceedings of an International Symposium*, Heidelberg, September, 1991.
- Jeffrey Richards, Anthony Farrell, Colin Brauner. 2009. *Fish Physiology: Hypoxia*. Volume 27.
- Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
- Eddy B and Handy RD. 2014. *Ecological and Environmental Physiology of Fishes*: 04 (Ecological and Environmental Physiology Series), Oxford University Press.
- Pankhurst NW, Herbert NA. 2013. *Fish Physiology and Ecology: The Contribution of the Leigh Laboratory to the collision of paradigms*. New Zealand Journal of Marine and Freshwater Research. DOI https://doi.org/10.1080/00288330.2013.80823.

I. Course Title : Enzymology

II. Course Code : FPB 516

III. Credit Hours : 2+1

IV. Aim of the course

To understand enzyme kinetics and regulation.

V. Theory

Unit I

Enzymes: Introduction; enzyme specificity; Mode of action; Nomenclature, Classification and EC numbering; Structure of enzymes, active site.

Unit II

Enzyme kinetics and equilibrium: Kinetics; Enzyme equilibrium; Single substrate enzyme kinetics and factors affecting the rates of enzyme catalyzed reactions; Michaelis- Menten equation; K_m and V_{max} values; Enzyme efficiency; Line weaver and Burke Plots; Multi-substrate enzyme kinetics.

Unit III

Enzyme inhibition: Reversible and non-reversible, Competitive, Uncompetitive and Non-competitive inhibition; Enzyme poisoning.

Unit IV

Enzyme regulation: Allosteric enzymes; Factors affecting enzyme activity, Holoenzyme and coenzyme, Zymogens, Isoenzymes, Ribozymes; Immobilized and restriction enzymes.

Unit V

Role of vitamins in enzyme reactions: Structure and biological function of coenzyme A, Thiamine pyrophosphate, Pyridoxal phosphate, NAD+, NADP+, FMN, FAD, Lipoic acid and vitamin B12; Mechanisms of reactions catalyzed by above cofenzymes.

Unit VI

Role of elements in enzyme reactions: Copper enzymes, Superoxide dismutase, Cytochrome oxidase Coenzymes; Molybdenum enzymes: Xanthine oxidase; Zinc enzymes: Carbonic anhydrase, Carboxy peptidase and Interchangeability of zinc and Cobalt in enzymes; Vitamin B12 and B12 coenzymes.

VI. Practical

Enzyme extraction and purification, specific activity, enzyme substrate reactions, mode of enzyme kinetics, assay of enzyme activity (alkaline phosphatase, transaminases, amylase, LDH, MDH, G6PD).

VII. Suggested Reading

- David L. Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- *ENZYMES: Biochemistry, Biotechnology*, Clinical Chemistry, 2/E, 2008 by Trevor Palmer and Philip Bonner.
- *Fundamentals of Enzymology: Cell and Molecular Biology of Catalytic Proteins*, 1999 by Price Nicholas C. and Lewis Stevens.

I. Course Title : Fish Nutrigenomics

II. Course Code : FPB 517

III. Credit Hours : 2+1

IV. Aim of the course

To understand the nutrient-gene interactions in fish

V. Theory

Unit I

Functional Genomics: Comparative nutrigenomics to understand the metabolic diversity; Nutritional biochemistry and Climate change.

Unit II

Nutritionally important genes: Genes regulation by protein lipid, Carbohydrates, Genes in fatty acid synthesis, Desaturases, Elongases, Genetic control of metabolic pathways.

Unit III

Omic Studies: Transcriptomics, Proteomics and Metabolomics.

Unit IV

Epigenesis: Methylation, Acetylation and Farnesylation, Nutrigenetics, Histone modifications.

Unit V

Techniques used in omic studies: RT PCR, cDNA synthesis, Realtime PCR, Gene cloning and Restriction digestion.

Unit VI

Basic bioinformatics tools: Primer designing, Softwares, Data mining and NGS data analysis. Full genome sequencing of fishes

VI. Practical

Short term nutrigenomics experiment for gene expression study; glycolytic enzymes expressions in fish liver; studies on fatty acid synthesis; Desaturases and elongases expressions.

VII. Suggested Reading

- Fingerman M, Nagabhushanam R and Thompson MF. 1997. *Recent Advances in Marine Biotechnology* (vol1-3). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Glick BR and Pasternak JJ. 1999. *Molecular Biotechnology: Principles and Applications of*

Recombinant DNA Technology, ASM Press, Washington, D.C.
- Lehninger AL. 1984. *Principles of Biochemistry*. CBS Publishing, New Delhi.
- Primrose SB. 1989. *Modern Biotechnology*. Blackwell Scientific, Oxford.
- Rodney B. 1998. *Concepts in Biochemistry*. Cole Publishing Company London.
- Kaput J, Rodriguez RL. 2006: *Nutraceutical Genomics*. Wiley Interscience Hoboken, New Jersey.
- Martin SAM, Król E. *Nutrigenomics and Immune function in Fish: New Insights from Omics Technologies*. Dev Comp Immunol. 2017; 75(Suppl C): 86–98.
- Afman L, Müller M. 2006. *Nutrigenomics: from Molecular Nutrition to Prevention of Disease*. J Am Diet Assoc 106: 569-576.
- Fenech M, El-Sohemy A, Cahill L, Ferguson LR, French TA *et al*. 2011. *Nutrigenetics and Nutrigenomics: Viewpoints on the Current Status and Applications in Nutrition Research and Practice*. J NutrigenetNutrigenomics 4: 69-89.
- Pedro M.Rodrigues, Tomé S.Silva, Jorge Dias and Flemming Jessen. 2012. *Proteomics in aquaculture: Applications and trends. Journal of Proteomics*. 75: 4325-4345
- Panserat S, Kaushik S. 2010. *Regulation of Gene Expression by Nutritional Factors in Fish*. Aquacult Res 41: 751–762.
- Panserat S, Kirchner S, Kaushik S. 2007. *Nutrigenomics*. In: Nakagawa H, Sato M, Gatlin D III (eds) *Dietary Supplements for the Health and Quality of Cultured Fish*. CAB International North America, USA, pp 210–229.

I. Course Title : Feeds and Feed Technology

II. Course Code : FPB 518

III. Credit Hours : 2+1

IV. Aim of the course

To learn basic concept of feed formulation and different feed processing techniques

V. Theory

Unit I

Feed formulation: General principles and criterions, Different methods of feed formulation; Pearson's square method and least cost formulation (quadratic equation, solver function, graphic solution, Linear programming and software assisted formulations), Limitations of formulation methods.

Unit II

Types of feed: Wet, Moist and Dry (pellets – steam compressed, extruded and crumbled, flakes, powdered/ mash, micro-encapsulated, micro-bound and micro-coated diets), Farm made feeds, experimental diets; Reference diet, purified and semi-purified diet, Compact pellet, Floating and slow sinking pellet feeds; Starter, grower, Finisher and Broodstock feeds, High energy eco-friendly and medicated feed.

Unit III

Feed processing technology: Receiving of raw materials, Equipments used in feed manufacture and processing; Grinder/pulverizer, mixer, Pelletizer/extruder, Crumbler, drier, Vacuum coater/ fat sprayer, Automatic bagging and sealing, Role of pre-conditioning in feed preparation, Effects of processing on the nutritional value and availability of nutrients.

Unit IV

Feed storage: Hydro-stability of feed and their storage; Prevention of spoilage

from rancidity, Fungus and associated toxins; Vectors of fish disease in feed and quality control; Nutritional value in relation to feed storage.

Unit V

Feed additives and supplements: Binders, carotenoids, Attractants, Antioxidants, probiotics, Prebiotics, Synbiotics, Immunostimulants, Nutraceuticals, Acidifiers and preservatives, Bile acids, Herbal additives and Vitamins, minerals, Limiting amino acids, Essential fatty acids, Phospholipids, and cholesterol.

Unit VI

Quality control in fish feed manufacturing: Quality control procedures, Raw materials, Finished products; Safety of farm fish products, Harmful residues (pesticides, antibiotics, and pollutants), Geometrical, and physical feature; Mechanical characteristics in air, Behavioural characteristics in water, Feed economics and evaluation.

VI. Practical

Feed formulation: Preparation of mineral and vitamin premix. Feed additives, binders, water stability test, and available lysine. Determination of feed particle size. Development of feed dispensers both for laboratory and pond feeding as part of project assignment. Visit to feed processing industries.

VII. Suggested Reading

- *ADCP (Aquaculture Development and Co-ordination Programme)*. 1980. Fish Feed Technology, ADCP/REP/80/11.F.A.O., Rome.
- D' Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture Chapman and Hall Aquaculture Series*, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II Heenemann, Berlin.
- Halver JE. 2002. *Fish Nutrition*. Academic Press, San Deigo, C.A.
- ICAR-IRRI Outreach programme
- Muir JF and Robert D. (Eds.). 1998. *Recent Advances in Aquaculture* Vol.II., Blackwell Science
- New MB. 1987. Feed and Feeding of Fish and Shrimp. *A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture*. ADCP/REP/87/26 F.A.O., Rome.

I. Course Title : Nutritional Requirement and Feeding Management

II. Course Code : FPB 519

III. Credit Hours : 2+1

IV. Aim of the course

To learn nutritional requirements, feeding methods and feed management of commercially important fish and shellfish

V. Theory

Unit I

Nutritional requirements of finfish and shell fish: Nutritional requirements of larvae, Growout and Broodstock of commercially important finfish and shellfish,

–Methods of studying nutritional requirements; Qualitative and quantitative methods; Nutrients deficiency symptoms.

Unit II

Nutritive value of live food: Algae, Artemia, Cladocerans, Ostracods, Rotifers and Copepods, Bio enrichment of artemia and zooplankton, Experimental diets; Reference diet, Purified and semi-purified diet.

Unit III

Response indices for nutrient requirement studies: Weight gain, Specific growth rate (SGR)/ Daily growth coefficient (DGC), Thermal growth coefficient (TGC) and, Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER), Net Protein Utilization (NPU), Physiometabolic parameters, Dose response curves, Gonadosomatic Index (GSI).

Unit IV

Body composition of fish and shellfish: Influence of nutrients on body composition and flesh quality; Effect of rations on fecundity and egg quality.

Unit V

Feeding methods and devices: Broadcasting, bag feeding, tray feeding, Raft feeding, Demand feeder, Mechanical automatic feeder, Blower feeder, Check tray feed monitoring, Ration size/ feeding rate and feeding frequency, Restricted feeding and mixed feeding.

Unit VI

Feeding management: Application of research findings to farming situations, Record keeping, growth prediction and feeding management.

VI. Practical

Determination of feed intake in fry and fingerlings; Determination of nutrient requirements of fish/prawn using purified diet; Analysis of experimental data from growth study; Measures of protein quality (PER, NPU, BV); Exercise on feeding.

VII. Suggested Reading

- D' Abramo LR, Conklin DE and Akiama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, Los Angeles.
- De Silva, SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver, J. E, andTiews, K. T. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II, Heenemann, Berlin.
- Halver, J. E. 1989. *Fish Nutrition*. Academic Press, San Diego, CA.
- Halver, J. E. and Hardy, R. W. 2002. *Fish Nutrition*. Academic Press, London.
- Cho, C.H. and Kaushik, S.J.1990. *Nutritional Energetics in Fish: Energy and Protein Utilization in Rainbow Trout*. World Review on Nutrition and Dietetics.61: 132-172.
- Houlihan, D., Boujard, T. and Jobling, M. 2001. *Food Intake in Fish*. Blackwell Science Ltd., London.
- Kaushik, S.J. 1998. *Nutritional Bioenergetics and Estimation of Waste Production in Non-Salmonids*. Aquat living resour 11(4): 211-217
- New, M. B. 1987. Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.
- NRC.2011. *Nutrient Requirements of Fish*.

Course Title with Credit Load
Ph.D in Fish Physiology and Biochemistry

Course Code	Course Title	Credit Hours
	Major Course	**12 Credits**
FPB 601*	Advances in Fish Physiology	2+1
FPB 602*	Advances in Fish Biochemistry	2+1
FPB 603*	Climate change and adaptive physiology	2+1
FPB 604*	Analytical Biochemistry and Instrumentation	1+2
	Minor Courses (From the subjects closely related to a student's major subject)	**6 Credits**
FPB 605	Endocrinology	2+1
FPB 606	Intermediary Metabolism	2+1
FPB 607	Proteomics and metabolomics	1+1
FPB 608	Diagnostic biochemistry and physiology	1+2
FPB 609	Macro and Micronutrient Nutrition	2+1
FPB 610	Feed Technology and Feed Mill Management	2+1
FPB 611	Larval and Brood stock Nutrition	1+2
	Supporting Courses (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	**5 Credits**
	Total Course Work Credits	**23 credits**
	Doctoral Seminar	2 Credits
FPB 691	Doctoral Seminar-I	0+1
FPB 692	Doctoral Seminar - I	0+1
	Doctoral Research	**75 Credits**
FPB 699	Doctoral Research (Semester II)	0 + 15
FPB 699	Doctoral Research (Semester III)	0 + 15
FPB 699	Doctoral Research (Semester IV)	0 + 15
FPB 699	Doctoral Research (Semester V)	0 + 15
FPB 699	Doctoral Research (Semester VI)	0 + 15
	Total Ph.D. Program Credit Hours	**100 Credits**

*Major compulsory subjects

Course Contents
Ph.D in Fish Physiology and Biochemistry

I. Course Title : Advances in Fish Physiology
II. Course Code : FPB 601
III. Credit Hours : 2+1

IV. Aim of the course

To understand the advances in fish Physiology

V. Theory

Unit I

Cardio-vascular Physiology: Laws of Thermodynamics; Raoult's law; Partial pressure of oxygen and carbon dioxide in gas and blood; Blood pressure; Cardiac morphology and output; ECG; Environmental influences of fish Cardiovascular physiology; Cardiac plasticity in fish.

Unit II

Physiology of bimodal gas exchanges: Haemoglobin; structure and functions; Carbonic anhydrase and respiration; Oxygen sensing; Respiratory control, Concept of fluid dynamics across respiratory structures; Mechanism of gaseous exchange.

Unit III

Physiology of ion transport and excretion: Functional morphology of branchial ionocytes; Mechanism of ion transport and water balance, Osmo-sensing, Role of gut and Kidney in osmoregulation, Nitrogen excretion.

Unit IV

Understanding growth in fish: Myogenic cells and growth; Muscle satellite cells; muscle fibre dynamics, Genetic and environmental factors regulating muscle growth; Diversity and plasticity in muscle fiber.

Unit V

Reproduction and Fertility: Formation of eggs and spermatozoa; Vitellogenin: structure, Synthesis and transportation to oocytes; Egg envelop proteins; Gonadal steriodogenesis; Physiology of Fertilization; Mechanism of egg activation and endocrine disruption.

Unit VI

Reproductive biotechnology: Cryopreservation of milts/germ cells, Process of sex reversal; Development of surrogate brooders, Growth hormone, transgenesis in fish.

VI. Practical

Measurement of heart rate, ECG; Measurement of Osmolality of plasma and muscle, Techniques for examining of channel proteins under environmental conditions,

Assay of reproductive steroids; Examination of progress of gonad maturity in fish; DNA/RNA ratio measurement as an indicator of growth parameter.

VII. Suggested Reading

- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: from Basic Studies to Biotechnological Applications*. Springer Publ.
- Dietmar Kültz. 2012. *The Combinatorial Nature of Osmosensing in Fishes*. Physiology (Bethesda), 27(4): 259-75. doi: 10.1152/physiol.00014.2012. PH
- Evans DH and Claiborne JB. 2009. *Physiology of Fishes*, Fourth edition, CRC press.
- Farrell AP. 2011. *Encyclopedia of fish physiology: from genome to environment*. Volume 1-3, Academic Press.
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 2 The Endocrine System. Academic Press
- Hoar WS, Randall DJ and Donaldson EM. 2014. Fish Physiology Vol. 9A, *Reproduction: Endocrine Tissues and Hormones*. Academic Press.
- Hoar WS. 2014. Fish Physiology Vol. 9B. Academic Press
- Hoar WS and Randall DJ. 2014. Fish Physiology Vol. 4 The Nervous System, Circulation and Respiration. Academic Press
- Johnston 2014. Fish physiology (Series 1-35 volumes) New Delhi Reed Elsevier India Private Limited 2014: "v, 318p" ISBN: 978-93-5107-130-3
- Lee CS and Donaldson EM. eds. 2012. *Reproductive Biotechnology in Finfish Aquaculture*. Elsevier.
- Nielsen 1983. Animal Physiology: adaption and environment New York Cambridge University Press Edition: 3rd: "xii, 619p"
- Samantaray K. 2015. *Physiology of Finfish and Shellfish*. New India Publ. Agency.
- Smith Lynwood S. 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Smith Lynwood S. 1999. *Introduction to Fish Physiology*. Narendra Publishing House
- Val. 2006. Physiology of tropical fishes. California Elsevier Academic Press: "xiv, 634p"; 23cm ISBN: 0-12-350445-7.
- William O. Reece, Eric W. Rowe. 2017. *Functional Anatomy and Physiology of Domestic Animals*, 5th Edition. ISBN: 978-1-119-27086-7, Wiley-Blackwell p. 576.
- Yoshida, Manabu, Asturiano, Juan F. (Eds.) 2020. *Reproduction in Aquatic Animals: From Basic Biology to Aquaculture Technology*. SPRINGER.

I. Course Title : Advances in Fish Biochemistry

II. Course Code : FPB 602

III. Credit Hours : 2+1

IV. Aim of the course

To understand advances in fish biochemistry.

V. Theory

Unit I

Saccharide chemistry: Significance of monosaccharides; Amino sugars, Acidic sugars, Glycosides, Sulfonated sugars; Oligosaccharides; Mannan oligosaccharide, Fructose oligosaccharide, Galactose oligosaccharide, Polysaccharides; Glycans, Glycogen, Mannan, Levan, Alginates, Chitin, Heparin, Keratin sulphate, Chitosan and hyaluronic acid, Carbohydrates of immunological importance.

Unit II

Lipid chemistry: Simple and complex lipids; Classification; Significance of fatty acid derivatives, Prostaglandins, Thromboxanes, Leukotrienes; Plasmalogens, Gangliosides, Sphingomyelin, Cerebrosides, Liposomes, Glycero-phospholipid

metabolism, Lipids of clinical significance; Distribution patterns of lipids.

Unit III

Protein chemistry: Classification; Significance of glycoproteins, Lipoproteins, Protein folding, Trafficking and protein sequencing, Bioactive peptides; Chaperones, Heat shock proteins; Antifreeze proteins, Cytochrome P450, Metallothionenes, Immunoglobulins, Clinical proteomics, Proteins of clinical significance.

Unit IV

Nucleic acid chemistry: Classification; Types of DNA and RNA, Metabolic functions of nucleotides, Sense and antisense RNA, RNA interference; Cistron, Operon and transposon; RNA splicing, miRNA and lnRNA.

Unit V

Enzyme chemistry: Classification, Types of enzymes, Mechanisms of enzyme action, Enzyme kinetics, units of enzyme activity, Coenzymes, Co-factors and prosthetic groups, Enzymes of clinical significance.

Unit VI

Vitamin and mineral chemistry: Classification, Active forms of vitamins, Types of vitamins and essential minerals; Deficiency syndromes of vitamins and minerals; Clinical significance of vitamins and essential minerals.

VI. Practical

Extraction, purification and quantification of specific proteins by SDS-PAGE; Estimation of phytic acid, Estimation of fatty acids by GC-MS; Assay of metabolic enzymes. DNA and RNA isolation, Restriction digestion, amplification of DNA by PCR, analysis of amino acids and steroids. Assays of vitamins A and C.

VII. Suggested Reading

- David L Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- David Hames and Nigel Hooper. 2011. *BIOS Instant Notes in Biochemistry*.
- David Bender and Kathleen Botham (Eds.) 2018. *Harper's Illustrated Biochemistry* 31st Edition, Victor Rodwell.
- Gupta SN. 2019. *Biochemistry of Metabolic Processes*.
- John W Pelley. 2010. *Rapid Biochemistry*. Elsevier.
- Kasturi Samantaray. 2012. *Principles of Biochemistry with Special Reference to Fishes*.

I. Course Title : Climate Change and Physiology of Adaptation

II. Course Code : FPB 603

III. Credit Hours : 2+1

IV. Aim of the course

To understand environmental factors affecting fish physiology leading to adaptation.

V. Theory

Unit I

Basic concepts of global warming and climate change; concept of carbon credit

Unit II

Interaction of climate change with multiple stressors (Pesticides, salinity, starvation, hypoxia, disease, pH, water hardness, turbidity; microbial load) and its impacts on fish.

Unit III

Stress responses: Primary, Secondary and tertiary stress responses; General Adaptive Syndrome, Genetically based adaptation, Modulation of intermediary metabolic pathways.

Unit IV

Thermal adaptation mechanisms: Types of heat shock proteins, Anti-freeze proteins and their roles, Enzyme variants (Isozymes), Thermal limits; Thermal optima; Mechanism of thermal adaptations, Oxygen and capacity limited thermal tolerance; Adaptive changes in proteins.

Unit V

Global warming impacts: Habitat, reproductive performance; Embryonic and larval development; Growth; Osmoregulation; Cardiovascular functions, Thermal death, DNA decay.

Unit VI

Mitigation strategies: Cross protection through behavioural, Adaptational, Nutritional and Genetic intervention.

VI. Practical

Evaluation of stress markers; plasma cortisol level, glucose, HSP expression, HIF expression; Determination of oxygen consumption rates; Determination of temperature, salinity and hypoxia tolerance in fish.

VII. Suggested Reading

- Eddy B and Handy RD. 2014. *Ecological and Environmental Physiology of Fishes*: 04 (Ecological and Environmental Physiology Series), Oxford University Press.
- JC Rankin, Frank B, Jensen. 2020. *Fish Ecophysiology* (Fish and Fisheries Series, Volume 9) [Special Indian Edition.
- Jeffrey Richards, Anthony Farrell, Colin Brauner. 2009 Fish Physiology: Hypoxia. Volume 27.
- Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
- Pankhurst NW, Herbert NA. 2013. *Fish Physiology and Ecology*: *The Contribution of the Leigh Laboratory to the Collision of Paradigms*. New Zealand Journal of Marine and Freshwater Research. DOI https://doi.org/10.1080/00288330.2013.80823.
- Pecl GT, Araújo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, Clark TD, Colwell RK, Danielsen F, Evengård B and Falconi L. 2017. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, 355(6332), p.eaai9214.
- Schmutter K, Nash M and Dovey L. 2017. Ocean acidification: assessing the vulnerability of socioeconomic systems in Small Island Developing States. Regional Environmental Change, 17(4), pp.973-987.
- T Braunbeck, W Hanke *et al*. 1991. *Fish: Ecotoxicology and Ecophysiology: Proceedings of an International Symposium*, Heidelberg, September, 1991.

I. Course Title : Analytical Biochemistry and Instrumentation

II. Course Code : FPB 604

III. Credit Hours : 1+2

IV. Aim of the course

To understand the principles and application of analytical instruments.

V. Theory

Unit I

Spectrophotometry: UV-visual, Fluorescent spectrophotometer, Infra-red, mass spectroscopy MALDI-TOF, ESI_TOF CD spectroscopy, NMR spectroscopy, X-ray crystallography, Atomic absorption spectroscopy, ICP-MS.

Unit II

Electrophoresis: Capillary, Vertical slab and horizontal electrophoresis, Immuno-electrophoresis, 2-D electrophoresis, Imaging: SEM, TEM.

Unit III

Chromatography: Paper, TLC; HP-TLC; LC-MS ion exchange, Molecular sieving, Affinity, FPLC, HPLC and Gas Chromatography, Sonication, Centrifugation techniques, ultracentrifugation.

Unit IV

Molecular techniques: Blotting (Southern, Northern, Western) techniques; Plasmid isolation and cloning; qRT-PCR.

VI. Practical

Quantitative estimation of metabolites and enzymes, purification of proteins from tissue samples, chromatographic separation and fractionation of proteins, characterization of proteins by Native PAGE, SDS- PAGE and 2D electrophoresis, Spectrophotometric estimation of fish protein, nucleic acids and glycogen; Enzyme assay from fish tissues; Molecular weight determination of fish protein by PAGE; Isolation of plasmid and genomic DNA, and amplification by PCR, cloning of gene in vectors, selection of recombinant and non –recombinant clones, Agarose gel electrophoresis; Southern and dot blotting; Fatty acid analysis by GCMS.

VII. Suggested Reading

- Darrel Crasta. 2015. *Encyclopaedia of Tools and Techniques in Biochemistry and Molecular Biology*, 3 vol set.
- Katoch. R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*.
- Sharma RK and Sangha SPS. 2020. *Basic Techniques in Biochemistry and Molecular Biology*.
- Wilson and Walker. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*.

I. Course Title : Endocrinology

II. Course Code : FPB 605

III. Credit Hours : 2+1

IV. Aim of the course

To understand the endocrine functions in fish.

V. Theory

Unit I

Endocrine glands: Structure and functions of pituitary, Pineal, Thyroid, Ultimobranchial body, Corpuscles of Stannius, Gonads, Kidney, Adrenals, Urophysis.

Unit II

Mechanism of hormone action: Hormone receptors and signaling pathways.

Unit III

Hormones in calcium and Phosphorus homeostasis: Calcitonin, Stanniocalcin, Calcitriol, PTH- related peptide, Mechanism and interaction of PTH, Calcitonin and vitamin-D on Ca^{++} metabolism.

Unit IV

Hormones in growth, Digestion and colour change.

Unit V

Role of hormones in osmotic, Ionic regulation and adaptation, The Renin; angitensin system.

Unit VI

Reproductive hormones: Neuropeptides and hormones in regulating gonadotropins; Gonadal steroids and peptides, Prostaglandins, Adrenal steroids; Steroidogenesis

VI. Practical

Histological study of endocrine glands; *in vivo* demonstration of endocrine glands; estimation of vitamin D3; assay of steroid hormones; quantification of vitellogenin by ELISA. Analysis of expression of insulin growth factor-1 and IGFBP.

VII. Suggested Reading

- Adiyodi KG and Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea.* Biology Reviews.
- Greenwood MP, Flik G and Balment RJ. 2009. The Corpuscles of Stannius, Calcium-Sensing Receptor, and Stanniocalcin: *Responses to Calcimimetics and Physiological Challenges. Endocrinology*, 150(7): 3002–3010.
- Agarwal NK. 2008. *Fish Reproduction*. APH Publ.
- Babin PJ, Lubzens E. 2007. *The Fish Oocyte: From Basic Studies to Biotechnological Applications*. Springer Publ.
- Croom HME. 2003. *Fish Endocrinology*.
- Diwan AD, Joseph S and Ayyappan S. 2008. *Physiology of Reproduction, Breeding and Culture of Tiger Shrimp*. Narendra Publ. House.
- Hoar WS and Randall DJ. 1969. The Endocrine System Volume 2. Academic Press.
- Maria RJ, Augustine A and Kapoor BG. 2008. *Fish Reproduction*.
- Norris DO and Lopez KH. 2011. *Hormones and Reproduction of Vertebrates*. Vol. I Fishes. Academic Press.
- Reinecke. 2006. *Fish Endocrinology*, Vol. 2": Enfield "Science Publishers, Inc.: "xx, 441-871pp" ISBN: 978-1-57808-415-9
- Sherwood NM and Hew CL. 2014. Fish Physiology Vol. 13. *Molecular Endocrinology of Fish*. Academic Press.
- Yonathan Zohar, José Antonio Muñoz-Cueto, Abigail Elizur, Olivier Kah 2010. *Neuroendocrinology of Reproduction in Teleost Fish*. General and Comparative Endocrinology 165 (2010) 438–455.

I. Course Title : Intermediary Metabolism

II. Course Code : FPB 606

III. Credit Hours : 2+1

IV. Aim of the course

To understand the intermediary metabolism of biomolecules.

V. Theory

Unit I

Scope and significance: Integration and regulation of lipid, Carbohydrate and protein metabolism in fishes.

Unit II

Lipid metabolism: Oxidation of fatty acids (SFA, MUFA, PUFA, HUFA); Biosynthesis of n-3 and n-6 fatty acids; Desaturases and elongases in freshwater fish; Biosynthesis of triglycerides, Phospholipids, Sphingolipids and cholesterol.

Unit III

Carbohydrate metabolism: Coordinated regulation of glycogen synthesis and breakdown; Enzymatic control of glycolysis; Feeder pathways for glycolysis; TCA cycle; Gluconeogenesis; pentose phosphate pathway; Electron transport chain.

Unit IV

Protein metabolism: Oxidative degradation of amino acids; Transamination and deamination; Biosynthesis of amino acids.

Unit V

Nucleic acid metabolism: Synthesis of deoxy and ribonucleotides; Uric acid production; Derivation of nucleotide groups of CoA, NAD, FAD from ATP.

Unit VI

Metabolomics, Proteomics, Transcriptomics; Nutrigenomics; Environmental metabolomics.

VI. Practical

Assay of mitochondrial and cytoplasmic enzymes, quantification of genes of metabolic pathways.

VII. Suggested Reading

- *Bios Instant Notes Molecular Biology*. 4th Edition, 2016 by Mclennan.
- David L Nelson. *Lehninger Principles of Biochemistry*, 6th edition.
- John W Pelley. 2010. *Rapid Biochemistry*. Elsevier
- Pandya A. *Biomolecules and Biochemical Metabolism of Fuels: Carbohydrate, Protein, Lipid Metablism* by Gupta SN 2019. Biochemistry of Metabolic Processes.
- Sharma MK. 2013. *Biomolecules and Metabolic Activities*.

I. Course Title : Proteomics and Metabolomics

II. Course Code : FPB 607

III. Credit Hours : 1+1

IV. Aim of the course

To understand the emerging field of metabolomics.

V. Theory

Unit I

Introduction to Metabolomics and Proteomics: Functional and Structural Proteomics.

Unit II

Analytical methods: Separation and detection methods of proteins and metabolites; 2D-electrophoresis, mass spectrometry, Protein arrays HPLC, GC-MS.

Unit III

Experimental and computational methods: Databases, Genevestigator and OncoMine – browsing microarray-derived gene expression profiles.

Unit IV

Environmental Metabolomics: Nutrigenomics and metabolic health; Future challenges.

VI. Practical

Gene expression study of metabolic pathways, Cross feeding mechanism, 2D-electrophoresis, mass spectrometry, bio-informatics tools.

VII. Suggested Reading

- Afman L, Müller M. 2006. Nutrigenomics: from molecular nutrition to prevention of disease. *J Am Diet Assoc* 106: 569-576.
- Attwood TK and Smith DJP. 1999. *Introduction to Bioinformatics*. Addison Wesley Longman.
- Brown SM. 2000. *Bioinformatics: A Biologist's Guide to Biocomputing and the Internet*. Eaton Publ.
- Fenech M, El-Sohemy A, Cahill L, Ferguson LR, French TA *et al*. 2011. *Nutrigenetics and Nutrigenomics: Viewpoints on the Current Status and Applications in Nutrition Research and Practice*. *J NutrigenetNutrigenomics* 4: 69-89.
- Kaput J, Rodriguez RL. 2006. *Nutraceutical Genomics*. Wiley Interscience Hoboken, New Jersey.
- Lesk AM. 2008**.** *Introduction to Bioinformatics*. Oxford University Press.
- Martin SAM, Król E. *Nutrigenomics and Immune Function in Fish: New Insights From Omics Technologies. Dev Comp Immunol*. 2017; 75(Suppl C): 86–98.
- Mount DW. 2001. *Bioinformatics: Sequence and Genome Analysis*. ColdSpring Harbor Press.
- Overturf K. 2009. *Molecular Research in Aquaculture*. Blackwell Publishing, 395 pp.
- Panserat S, Kaushik S. 2010. *Regulation of Gene Expression by Nutritional Factors in Fish*. *Aquacult Res* 41: 751–762
- Panserat S, Kirchner S, Kaushik S. 2007. *Nutrigenomics*. In: Nakagawa H, Sato M, Gatlin D III (eds) Dietary supplements for the health and quality of cultured fish. CAB International North America, USA, pp 210–229
- Pedro M Rodrigues, Tomé S Silva, Jorge Dias and Flemming Jessen. 2012. *Proteomics in Aquaculture: Applications and Trends. Journal of Proteomics*. 75: 4325-4345
- Schlena M. 1999. *DNA Microarrays: A Practical Approach*, Oxford University Press, London, UK, 232 pp.

I. Course Title : Diagnostic Biochemistry and Physiology

II. Course Code : FPB 608

III. Credit Hours : 1+2

IV. Aim of the course

To monitor the systems that keep body functioning.

V. Theory

Unit I

Clinical Signs and sample collection: History, Clinical signs, Environmental conditions, Site history, Handling of animals, Sample collection, Methods of

processing and preservation of samples; Fish Welfare Management; Fish welfare and emotions- functional aspects; Behavioural responsiveness; Fear; pain; Appetite, Satiety, Exercise, Metabolic shifts; Diet-gene interaction for fish welfare.

Unit II

Evaluation of cardiovascular and respiratory disorders: Partial pressures in gill and blood; Hb estimation, Blood CBC, RBC morphology, pH, Carbonic anhydrase, Blood gases: O_2, CO_2, HCO_3, H+; ECG; Doppler test; C-reactive protein; Gill morphology/pathology; oxygen exercise; Cardiovascular monitoring.

Unit III

Evaluation of homeostasis and Acid-base: Respiratory and metabolic acids, Their elimination; Blood osmolality, Chloride, Carbonic anhydrase, pH, Lactate, Ammonia; Kidney morphology.

Unit IV

Growth, reproductive and immunity disorders: Tissue DNA/RNA ratio; Metabolic enzyme profiles; Liver function tests; Appetite estimation; Hormone assay: Gonadotropins, Sex-steroids, cortisol, Blood enzymes: GOP, GPT, ALP, Glucose, CPK, LDH, Lactate, Albumin, Immunoglobin, AChE, Blood ammonia, Urea and creatinine; NH_4, NBT, Ovarian/liver biopsy, Blood CBC; Ultrasonography.

VI. Practical

Handling an sample collection; Tissue DNA/RNA; Hb estimation, RBC morphology, Blood pH and Carbonic anhydrase; Blodd gas analysis: O2, CO2, HCO3, H+; ECG; Ultra-sound, Blood osmolality, Chloride, lactate, ammonia, urea; Glycolytic enzymes; Liver function test, Blood enzymes: GOT, GPT, ALP, CPK, LDH, AChE, NBT, Immunoglobin, blood CBC, liver/ovary biopsy; ultrasonography.

VII. Suggested Reading

- *Clinical Biochemistry*, Michael Murphy, Elsevier 2018.
- *Clinical Biochemistry*. 2016 by Maheshwai Nanda
- *Manipal Manual Of Clinical Biochemistry*. 2013 by Nayak Shivananda.
- *Practical Clinical Biochemistry Methods and Interpretations*. 2020 by Ranjna Chawla
- Walker P 2005. *DNA-based Molecular Diagnostic Techniques*. Daya, Delhi 2005.

I. Course Title : Macro and Micronutrient Nutrition

II. Course Code : FPB 609

III. Credit Hours : 2+1

IV. Aim of the course

To understand recent developments in macro and micro nutrient nutrition for fish and shellfish.

V. Theory

Unit I

Protein and aminoacids: Requirements, functional roles of aminoacids, Ideal protein concept, Nitrogen excretion, Aminoacidantagonism, Improving nitrogen retention, Dietary supply of synthetic aminoacids in different forms.

Unit II

Lipid and essential fatty acids: Functions and deficiencies, Fatty acid oxidation,

Antioxidants, Role of phospholipids and steroids.

Unit III

Optimization of carbohydrates in diets: Strategies for improving carbohydrate utilization; Potential of exogenous enzymes, Solid state fermentation (SSF).

Unit IV

Micronutrients: Physiological roles and functions of vitamins and minerals; Forms of supply of minerals and vitamins, Deficiency symptoms.

Unit V

Recent developments in energy nutrition and feed additives: Recent advances in nutritional energetics and feed additives, Medicated feeds (farm-made and commercial), Regulations and certification of feed additives.

Unit VI

Designer fish production: Tailoring flesh quality, Food safety, Roles of nutrients and additives (fatty acids, antioxidants, drugs etc.), Flesh quality evaluation (colour, texture and sensory), Estimation of fatty acids, Aminoacids and minerals in ingredients, feeds and Flesh of fish and shrimp; Dietary effects on nitrogen excretion.

VI. Practical

Protein quality estimation (PER, NPU), Digestibility studies. Estimation of fatty acids and amino acids.

VI. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*. ADCP/REP/80/11.F.A.O., Rome.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish*.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Hepher B. 1988. *Nutrition of Pond Fishes*. Cambridge University Press, Cambridge.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

I. Course Title : Feed Technology and Feed Mill Mangement

II. Course Code : FPB 610

III. Credit Hours : 2+1

IV. Aim of the course

To study the feed formulation techniques; design of feed mill and feed manufacturing; feed quality assurance and regulations.

V. Theory

Unit I

National and global scenario of feed ingredients and feed industry: Availability demand and supply; types of feeds, BIS and international standards for fish feed, overview of feed mill business.

Unit II

Feed formulation: Different methods of feed formulation, Use of feed formulation softwares; Nutritional and physical quality of feed ingredients; Importance of additives formulation of nutritionally balanced diet (amino acid, micronutrients).

Unit IV

Feed manufacturing process and control: Receiving of raw material, Grinding, Mixing, Conditioning, Pelleting /extrusion, Drying and cooling. coating/top dressing, Packaging and labelling, Factors affecting feed manufacture and stability of nutrients, Effects of processing on the nutritional value of feeds, Processing methods for non-compacting feed; Economics of feed manufacturing.

Unit III

Emerging new feed ingredients: Scope and exploration of new feed ingredients, Anti-nutritional factors and methods of detoxification (e-beam irradiation, solvent extractions, SSF, Protein concentrates/isolates, genetic improvement of plants etc.).

Unit V

Storage and quality control: Ingredient quality assurance, Feed processing quality assurance and processed feed quality assurance, Miscellaneous adventitious toxins and effect on feed safety; Storage of feed and quality deterioration, CGMPs and HACCP feed regulation, Feed transmitted bioterrorism and its implications.

Unit VI

Design of a feed mill unit: Layout, Feed mill design and safety of operation, Maintenance and record keeping.

VI. Practical

Analysis of anti-nutritional and toxic substances in feed ingredients and feed; Formulation of diets using software. Preparation of different types of feed and their quality evaluation; Effect of feed storage on nutritional value of feed, preparation of farm made feeds.

VII. Suggested Reading

- ADCP (Aquaculture Development and Co-ordination Programme). 1980. *Fish Feed Technology*, ADCP/REP/80/11.F.A.O., Rome.
- D'Abramo LR, Conklin DE and Akiyama DM. 1977. *Crustacean Nutrition: Advances in Aquaculture* Vol. 6. World Aquaculture Society, Baton Roughe, L. A.
- De Silva SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture* Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and Crustaceans*. Springer Praxis Publishing, Chichester, U. K.
- Halver JE and Tiews KT. 1979. *Finfish Nutrition and Fishfeed Technology* Vol. I and II. Heenemann, Berlin.
- Halver JE and Hardy RW. 2002. *Fish Nutrition*. Academic Press, London.
- Halver JE. 1989. *Fish Nutrition,* Academic Press, San Diego, California.
- Heijden PGM van der. 2016. *The aquaculture sector of Zambezi Valley, Mozambique: Description of the current situation and emerging opportunities*.Centre for advance Innovation. Wageningenuniversity.
- ICAR-IRRI Outreach programme reports
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*, Kluwer Academic Publishers.
- Muir JF and Robert D. (Eds.). 1968. *Recent Advances in Aquaculture* Vol.II. Blackwell Science.

- New MB. 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome.

I. Course Title : Larval and Broodstock Nutrition

II. Course Code : FPB 611

III. Credit Hours : 2+1

IV. Aim of the course

To understand the role of nutrition in reproductive performance and larval development of fish and shellfish

V. Theory

Unit I

Embryonic and larval development: Nutritional profile of egg yolk and mechanism of egg yolk utilization, Degradation of egg yolk platelets and granules, Utilization of egg protein, Amino acid and lipid, Influence of abiotic factors on yolk absorption; Criteria for evaluation of early larval development.

Unit II

Larval digestive system: Ontogenesis of digestive systems, Digestion and absorption of protein and lipid, Mechanism of transition from endogenous to exogenous nutrition.

Unit III

Larval nutrition: Importance of live foods, Weaning diets and their importance in larval nutrition; Nutritional requirements and deficiency symptom, Nutritional status of larvae

Unit IV

Broodstock nutrition: Effect of nutrition on fecundity, Fertilization, Embryonic development and larval quality.

Unit V

Improving brood-stock performance: Special ingredients and specific nutrients for improving gonadal development and reproductive performance; Effective feeding periods for optimum brood-stock performance.

Unit VI

Feeding strategies: Manual, mechanical and automatic Feeding; feeding devices and strategies, Larval feeding behaviour and feed management.

VI. Practical

Preparation of larval feed, Nutritional profiling of egg yolk and larvae. Nutritional analysis of live food organisms, Estimation of proteases in larvae, Estimation of gonado-somatic index and fecundity.

VII. Suggested Reading

- CIFE. 1993. *Training Manual on Culture of Live Food Organisms for Aqua Hatcheries*. Central Institute of Fisheries Education, Versova, Mumbai.
- De Silva, SS and Anderson TA. 1995. *Fish Nutrition in Aquaculture*. Chapman and Hall Aquaculture Series, London.
- Guillame J, Kaushik S, Berqot P and Metallier R. 2001. *Nutrition and Feeding of Fish and*

Crustaceans. Springer Praxis Publishing, Chichester, U. K.
- Hagiwara A, Snell TW, Lubzens E and Tamaru CS. 1997. *Live Food in Aquaculture*. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer Academic Publishers, London.
- Holt JG. 2011. *Larval Nutrition*. John Wiley & Sons, Inc.
- Lovell RT. 1998. *Nutrition and Feeding of Fishes*. Kluwer Academic Publishers.

List of suggested Journals

- *Advances in Marine Biology*
- *Fish Physiology and Biochemistry*
- *General and Comparative Endocrinology*
- *Frontiers in Aquatic Physiology*
- *Frontiers of Physiology*
- *American Journal of Physiology*
- *Scientific Reports*
- *Plos One*
- *Journal of Experimental Biology*
- *Journal of Comparative Physiology*
- *Comparative Biochemistry and Physiology*
- *Endocrinology*
- *Journal of Endocrinology*
- *Reproduction*
- *Biology of Reproduction*
- *Reproductive Sciences*
- *Journal of Endocrinology*
- *Animal Reproduction Science*
- *Molecular Reproduction and Development*
- *Reproduction Fertility and Development*
- *Journal of Fish Biology*
- *Canadian Journal of Aquatic Science*
- *Journal of Physiology and Biochemistry*
- *Current Research in Physiology*
- *Journal of Physiology and Pathophysiology*
- *Indian Journal of Physiology and Pathophysiology*
- *Journal of Cellular Physiology*
- *Cellular Physiology and Biochemistry*
- *Histology and Histopathology*
- *American Journal of Physiology - Endocrinology and Metabolism*
- *Annual Review of Cell and Developmental Biology*
- *Aquaculture*
- *Climate Change*
- *Climate Change and Environmental Sustainability*
- *Developmental Biology*
- *International Journal for Vitamin and Nutrition Research*
- *International Journal of Food Sciences and Nutrition*
- *Journal of Animal Physiology and Animal Nutrition*
- *Journal of Nutritional Biochemistry (Nutrition Reports International)*
- *Journal of Nutritional Science and Vitaminology*
- *Aquaculture Nutrition*
- *Aquaculture Research*
- *Fish and Fisheries*
- *Fish and Shellfish Immunology*
- *Fisheries and Fisheries*
- *Fisheries management and ecology*
- *Fisheries Research*

- *Indian Journal of Fisheries*
- *Journal of Biology*
- *Journal of Comparative Neurology*
- *Journal of Environment and Bio-sciences*
- *Journal of Environmental Biology*
- *Journal of Fish Behaviour*
- *Molecular Marine Biology and Biotechnology*

List of suggested e-resources

- https://oregonstate.edu/
- https://www.dtu.dk/english
- https://www.utas.edu.au/
- http://cifa.nic.in/node/47
- http://people.tamu.edu/~tdewitt/wfsc448/index.html
- https://www.ufl.edu/academics/programs/
- https://www.nord.no/en
- https://www.uib.no/en
- http://www.fish.kagoshima-u.ac.jp/efish/field/aqu.html
- https://www.ccac.ca/en/training/modules/fish-stream.html
- https://www.u-tokyo.ac.jp/en/
- https://www.bio.mie-u.ac.jp/en/
- https://www.ntu.edu.tw/english/
- https://en.ctu.edu.vn/
- https://en.uit.no/startsida
- http://www.ncbi.nlm.nih.gov/
- http://www.genome.gov
- http://web.utk.edu/~rstrange/wfs550/html-con-pages/l-heart.html
- Fish Pathology Edition 4 by Ronald J. Roberts https://www.barnesandnoble.com › fish-pathology-ronald-j-roberts
- Fish Vaccines By Alexandra Adams https://www.springer.com › book
- Fish models in behavioural toxicology: Automated techniques, updates and perspectives. semanticscholar.org
- Physiological Methods in Fish Toxicology: Laboratory and Field Studies springer.com
- http://bioinfo.ut.ee/primer3-0.4.0/
- https://all-about-molecular-biology.jimdo.com/
- https://www.molbiolcell.org/
- http://www.web-books.com/MoBio/
- https://npsa-prabi.ibcp.fr/cgi-bin/npsa_automat.pl?page=/NPSA/npsa_sopma.html
- http://www.bioinformatics.nl/cgi-bin/primer3plus/primer3plus.cgi
- https://www.sciencedaily.com/terms/molecular_biology.htm
- https://plato.stanford.edu/entries/molecular-biology/#toc
- https://molbiol-tools.ca/Alignments.htm
- https://molbiol-tools.ca/Phylogeny.htm
- http://evolution.genetics.washington.edu/phylip/software.html
- https://www.addgene.org

Suggested Broad Areas for Master's and Doctoral Research

- Functional significance and mechanism of action of nutraceuticals /micronutrients
- Mechanistic studies with respect to drug delivery
- Pharmacokinetics and pharmacodynamics of functional molecules
- Osmoregulatory challenges in fish and shellfish with respect to altered environments
- Thermal tolerance in commercially important fishes
- Hypoxia tolerance in commercially important fishes
- Salinity tolerance in commercially important fishes
- Tolerance of nitrite of fish and shellfish

- Tolerance of ammonia in fish and shellfish and enhancing tolerance limits
- Interaction of nutrients and anti-nutrients on physiology of fishes
- Development of salinity tolerance in freshwater fishes for rearing in saline affected waters
- Rearing of marine economically important crustacea in low saline water
- Mineral fortification in inland saline water for aquaculture
- Multiple stressor interactions in fish
- Stress physiology during live transportation of fishes and their mitigation
- Waterless transportation of crustacean
- Waterless aquaculture for air breathing fishes
- Physiology of migration in commercially important migratory fishes
- Identifying physiological causes of retardation of growth in migratory fishes in captivity.
- Effect of climate change on fish physiology
- Ontogeny of gut in economically important fishes
- Physio-metabolic responses in fishes on feeding various macro and micro nutrients
- Factors affecting the immune system of fishes
- Interactions of stress and immunity
- Nanotoxicity in fishes and mitigation
- Endocrine disruption in fishes
- Effect of biotic and abiotic factors affecting brood stock and larval development
- Effect of endocrine disrupting compounds in sex determination in fishes
- Production of sterile fish
- Development of surrogate broods
- Sensor development for monitoring physiological distress
- Physio-metabolic response and pharmacodynamics of drugs administered in fishes
- Factors affecting molting frequency in crustacea
- Shell (Gastropod) selection and shell occupation behavior in hermit crab during adverse conditions
- Physiology of crab fattening
- Germ cell isolation and preservation for conservation of threatened/endangered aquatic animals
- Fish as a model for studying Systemic disorders in mammals.
- Development of chemoattractants
- Development of improved inducing systems for spawning aquatic animals
- Development of kits for assessing physiological status viz., maturity status, feeding and nutritional status
- Identifying molecular markers for assessing reproductive activity if fish and shellfish
- Development of In-vitro process of gametes maturation and ovulation.
- Development of in-vitro process for sperm production.
- Development of molecules for accelerating gonad maturity.
- Biochemical markers for evaluating purity of seed of fishes.
- Mitigation strategy of climate change effects through the nutritional intervention

ANNEXURE I

List of BSMA Committee Members for Fisheries Science-2020

(Ref: ICAR File No.7/6/2017 – EQR Dt: 04/04/2018)

Name	Address	Specialization
1. **Dr S. Felix** Vice Chancellor	Tamil Nadu Dr J. Jayalalithaa Fisheries University, Vetter River View Campus, Nagapattinam-611 002 felix@tnfu.ac.in Mobile No: 09443131025	Chairman
2. **Dr N. P Sahu** Dean	ICAR-Central Institute of Fisheries Education, Mumbai-400 061 npsahu@cife.edu.in npsahu1@rediffmail.com Mobile No: 09869120627	Convener
3. **Dr E J Jayaraj** Professor	Department of Aquaculture, College of Fisheries, Kankanady, Mangalore-575 002, Karnataka jayaettigi@yahoo.com jayaraj@fisheriesroundup.com Mobile: 09448033957	Aquaculture
4 **Dr Hukam Singh Dhaker** Dean	Faculty of Fisheries, Shirgaon, Ratnagiri, Maharashtra state, hukamsingh69@yahoo.com Mobile: 09421230257	Aquaculture
5 **Dr P. Jawahar Professor** Dean	Department of Fisheries Biology and Resource Management, Fisheries College and Research Institute, Thoothukudi-628 008, Tamil nadu jawaharphd@gmail.com Mobile: 09487078758	Fisheries Biology and Resource Management

	Name	Address	Specialization
6	**Dr L.L. Sharma** Former Dean	College of Fisheries, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan Residential Address: PN-207,Road - 13, Ashok Nagar, Udaipur-313 001, Rajasthan Ilsharma.206@gmail.com Mobile: 09829230343	Aquatic Environment Management
7	**Dr Raman Kumar Trivedi** Professor	Department of Aquatic Environment Management, West Bengal University of Animal and Fishery Sciences, 37 & 68 Khudiram Bose Sarani, Kolkata, West Bengal-700 037 ramankumart@rediffmail.com Mobile: 09432491149	Aquatic Environment Management
8	**Dr J.J. Abraham** Professor	Department of Aquatic Animal Health Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Chakgaria, Kolkata-700 094, West Bengal abrahamtj1@gmail.com abrahamtj@yahoo.com Mobile: 09432206950 /09433368328	Aquatic Animal Health Management
9	**Dr S. Jahageerdar** Principal Scientist	Department of Fish Genetics and Biotechnology ICAR-Central Institute of Fisheries Education Panch Marg, off. Yari Road, Versova, Andheri West Mumbai, Maharashtra-400 061 jahageerdar@cife.edu.in jahageerdar@rediffmail.com jahageerdar@gmail.com Mobile: 09969300125	Fish Genetics and Biotechnology
10	**Dr K. Karl Marx** Professor	Directorate of Incubation and Vocational Training in Aquaculture (DIVA) ECR Muttukadu Chennai-603 112 kkmarx@gmail.com Mobile: 09444543858	Fisheries Biotechnology

Name	Address	Specialization
11 **Dr G. Sugumar** Professor	Directorate of Incubation and Vocational Training in Fisheries (DIVF) Mandapam Ramanathapuram-614 904 sukumar@tnfu.ac.in Mobile: 09443844820	Fish Processing Technology
12 **Dr M. Rajakumar** Professor	Department of Fisheries Extension Economics and Statistics Dr M.G.R. Fisheries College & Research Institute Tamil Nadu Dr J. Jayalalithaa Fisheries University Thalainayeru, Nagapattinam-611 002 Rajasaro@rediffmail.com Mobile: 09444232349	Fisheries Economics

Additional Technical Team

Name	Address	Specialization
1 **Dr S.A. Shanmugam** Dean (Basic Sciences)	Institute of Fisheries Postgraduate Studies OMR Campus, Vaniyanchavadi, Chennai-603 103. deanipgs@tnfu.ac.in shanmugam@tnfu.ac.in	Fisheries Microbiology & Fish Processing Technology
2 **Dr Sundaramoorthy** Dean	Fisheries College and Research Institute Tamil Nadu Dr J. Jayalalithaa Fisheries University Thoothukudi-628008 Tamil Nadu, India. deanfcrituty@tnfu.ac.in sundaramoorthy@tnfu.ac.in	Fishing Technology & Engineering
3 **Dr Sujath Kumar** Professor and Head	Dept. of Fisheries Extension, Economics and Statistics Fisheries College and Research Institute Tamil Nadu Dr J.Jayalalithaa Fisheries University Thoothukudi-628 008 sujathkumar@tnfu.ac.in	Fisheries Extension

Name	Address	Specialization
4 **Dr Aparna Choudhary** Principal Scientist & Head	Fish Genetics and Biotechnology, Central Institute of Fisheries Education, Versova, Mumbai-400 061 achaudhari67@gmail.com	Fish Biotechnology

ANNEXURE II

Consultation Process
Members of BSMA (Fisheries Science)

Chairman
Dr S.Felix, Vice-Chancellor, TNJFU, Nagapattinam

Convener
Dr N.P.Sahu, Dean, ICAR-CIFE, Mumbai

Members

1. Dr E.J.Jayaraj, Professor,
   Dept. of Aquaculture, College of Fisheries, Mangalore
2. Dr P.Jawahar, Professor,
   Dept. of Fisheries Biology and Resource Management,
   Fisheries College and Research Institute, Thoothukudi
3. Dr L.L.Sharma, Former Dean,
   College of Fisheries, Maharana Pratap University of
   Agriculture and Technology, Udaipur, Rajasthan
4. Dr Raman Kumar Trivedi, Professor
   Department of Aquatic Environment Management,
   West Bengal University of Animal and Fishery Sciences
   Presently working as Director (Students Welfare), BASU,
   Patna, Bihar
5. Dr T.J.Abraham, Professor,
   Department of Aquatic Animal Health,
   West Bengal University of Animal and Fishery Sciences,
   Kolkata
6. Dr S.Jahageerdar, Principal Scientist,
   Department of Fish Genetics and Biotechnology,
   ICAR-CIFE, Mumbai
7. Dr K.Karal Marx, Dean
   Institute of Fisheries Postgraduate Studies,
   TNJFU, Chennai
8. Dr ShyamSundar Dana, Professor
   Department of Fisheries Extension,
   West Bengal University of Animal and Fishery Sciences, Kolkata
9. Dr M.Rajakumar, Professor,
   Department of Fisheries Extension, Economics & Statistics
   Fisheries College and Research Institute, Thoothukudi
10. Dr Human Singh Dhaker, Dean
    Faculty of Fisheries, Shirgaon, Ratnagiri, Maharashtra.
11. Dr G.Sugumar, Dean
    Fisheries College and Research Institute, Thoothukudi

The consultation process was completed after four consultations involving all the stake holders like faculties of different fisheries colleges of the country, scientists of the fisheries research institutes and scientists of other ICAR research institutes, industry personnels,

entreprenuers, students, faculty from overseas universities and alumini. First, third and fourth meeting was conducted among the BSMA members, whereas the 2nd workshop was conducted at ICAR-CIFE, Mumbai by involving all the stake holders for in depth discussion for 2 days. The details are given below:

First Consultation (6th August 2020)

The first meeting of the BSMA (Fisheries Science) Committee was held at ARTP, Madhavaram Campus of Tamil Nadu Dr J.Jayalalithaa Fisheries University, Chennai on 06.08.2018. The first meeting was conducted among the members of BSMA to appraise all the points to be covered while preparing the syllabus revision. It was decided that all the members to take up the task seriously as revision of PG courses is usually conducted once in 10 years and hence members should prepare a curriculum that would stay relevant for the next 10 years giving scope for improving knowledge, skill, entrepreneurship, attitude, competence and confidence of the students. The following points were discussed during the interaction

- Introduction of technology-oriented courses
- Global approach
- Developing common nomenclature for courses with ARS orientation
- Number of PG disciplines.
- Timely completion of the task

Further discussions were held on the following issues:

- Faculty improvement
- New teaching methods
- Infrastructure sharing
- Improving employability
- Bringing all fisheries professionals under one umbrella
- 4T approach (Tradition, Technology, Talent and Trade) in the course curriculum
- Uniformity among all colleges in credit load, duration of Ph.D. course work, examination pattern, supporting and compulsory courses, plagiarism, grading system, etc.
- It was decided to enlist the fisheries colleges with the courses offered
- Lengthy discussion held on bringing the subjects under 5 major disciplines in line with agriculture and animal science
- Revision of syllabus for courses and changes on need basis – A minimum of 20% change in the existing syllabi and industry requirements should be considered.
- No constructive changes be made and all based on need and changes in the field
- Aspects on climate change shall be included in all areas wherever necessary
- UG subjects shall not be repeated in PG courses although some overlap may be allowed if found inevitable
- Molecular and genetic approach should be included
- Recent references should be consulted
- New titles and content development
- Further, one credit load was suggested to be based on 6-9 instructional classes and equals 3 units of syllabus – unitization be revised accordingly.
- The non-credit course (six credits in PG) shall be completed by ICT based open / online courses relevant to fisheries
- Internship may be tried for students in industries
- Regarding admission criteria, UGC guidelines be followed

Instruction to BSMA – subject experts:

- All subject experts are requested to contact their peers in fisheries colleges and research institutes to seek for suggestions and ideas of innovations for revision of syllabus concerned to their subjects

- Any novel and new ideas shall be shared among members of BSMA for adoption
- All experts are to come up with details of
  - New titles
  - New courses
  - Percentage of content revision
  - Need for content revision
- The above details are to be presented by individual member
- All should join in a whatsapp group for fast communication
- All the members should discuss within the group if some new idea clicks, so that all will do the needful if it is accepted.
- The course contents of Animal science may be consulted for churning out any new things to be added. The experts from the overseas universities may also be consulted. All the members should share the link for overseas contact.

2.Second consultation (workshop from 18-19 February, 2019)

The second workshop on "Syllabus Revision and Academic Reformation in Higher Fisheries Education" was conducted at ICAR-Central Institute of Fisheries Education, Versova, Mumbai during 18-19th February 2019. The main objective of this workshop is to prepare a uniform syllabus for Masters and Ph.D. courses all over the country and building the competent human resource in the field of Fisheries Science by making the post-graduate programs at par with the global standard of Fisheries higher education.

Expert from various institutes, especially State Agriculture Universities and other ICAR-research institutes and student representatives from various disciplines of CIFE were attended the workshop. Discipline wise discussion was held among 12 different groups. Each group was allotted with minimum of two external subject experts, faculties of particular discipline and a student representative nominated from the particular discipline. The forenoon session included discussion of addition, deletion or modification of MFSc syllabus and PhD syllabus was covered in the afternoon session.

The second day of the programme was started with the introduction by Dr N.P. Sahu, Dean (Academics), ICAR-CIFE & Convener, BSMA (Fisheries Science) and remarks by Dr S. Felix, Vice-Chancellor, TNFU & Chairman, BSMA (Fisheries Science). Dr C. Gopal, Member Sec., CAA, Chennai, Dr Sanu Jacob, Joint Director, Export Inspection Agency, Mumbai, Dr A.K. Pal, Ex-Joint Director, ICAR-CIFE & Representative from Industry, Mr. Raghavan Sampathkumar, Executive Director, CLEFMA, Mumbai, Sri Vellanki Ravi, President, Shrimp farmers Association of India and Sri Saji Chacku, Vice-president ABG Aquaculture Ltd, Billimora, Gujarat conveyed their remarks including role of industry in framing academic curriculum. Dr G. Venkateshwarlu, ADG-EQR, ICAR and BSMA Coordinator and Dr Gopal Krishna, Director & Vice Chancellor, ICAR-CIFE conveyed their notes and commented on the remarks made by invitees.

A discussion held after the invited talks for three hours emphasizing the importance of practical oriented schemes for students, lessening course work duration for PhD, removal of compulsory non-credit courses, industry internships, graduate assistantship, video classes, improvisation of student exchange programmes and fellowships, credit course by industry, Research Ethics Committee constitution, economical support for data collection and abstract or paper publications, provisions for training to the faculties and PhD students and the reducing number of disciplines etc.

Towards the end of the session BSMA members Dr E.G. Jayaraj, Dr P. Jawahar, Dr L.L. Sharma, Dr R. K. Trivedi, Dr T.J. Abraham, Dr S. Jahageerdar, Dr K. K. Marx, Dr S.S. Dana, Dr M. Rajakumar, Dr H.K. Dhaker, Dr G. Sugumar and Dr S. Dasgupta were presented the major changes made in the syllabus of each discipline. Dr S. Felix,

Dr G. Venkateshwarlu and Dr Gopal Krishna were concluded the session by emphasizing the points discussed and Dr Rupam Sharma thanked the invitees, speakers and students.

Third consultation (6th May 2019)

3rd Consultation was held on 6 May 2019 at TNJFU, Chennai among the members of BSMA (Fisheries). This was the first meeting after major revision of the course curriculum to discuss the following points:

- Semester-wise break-up of courses along with credit hours
- Courses should be breakup under the heading Major, Minor and supporting, Seminar and Research
- There will be two and one semester course work for Master and Ph.D, respectively.
- Filed visit may be kept within the total credit (2 credit) for one month. This is only subject specific. If you feel, it is not required for your discipline may not be kept.
- The Contents under each course should be divided into units and it should be uniformly followed. For example, if a course is 1+0, total units should be 3, which should be covered with 18 classes. Similarly, for 2+1 the units should be 6, which should be covered with 36 classes and for 3+1, it should be 9 units and covered with 54 classes.
- Inclusion of some references and suggest names of books for each courses
- 2-3 objectives should be written for each course, justifying the inclusion of that course
- For framing the academic rules the academic guidelines developed by the Rani Laxmi Bai CAU, Jhansi should be considered as the base with some modification as deemed fit with the consent of core committee members.

Fourth Consultation (14 May 2019)

The DDG -Education organized this meeting at the ICAR complex, New Delhi to finalize the no. of Disciplines for the Fisheries Science. All the committee members along with the Chairman, the Convener and the ADG (Edun.) have attended this meeting.

The Chairman presented all the 15 Disciplines of Fisheries Science currently being offered by institutions in the country. After a long deliberations the DDG permitted to have 12 Disciplines for the BSMA – Fisheries Science which include the following:

i. Aquaculture
ii. Fisheries Resource Management
iii. Aquatic Environment Management
iv. Aquatic Animal Health Management
v. Fish Genetics and Breeding
vi. Fish Nutrition and Feed Technology
vii. Fish Processing Technology
viii. Fish Biotechnology
ix. Fishing Technology & Engineering
x. Fisheries Economics
xi. Fisheries Extension
xii. Fish Physiology and Biochemistry

Fifth consultation (22-23 September, 2019)

The fifth consultation was conducted at TNJFU, Chennai from 22 to 23 September, 2019 to give a final shape with limited members along with Chairman and Convener. The uniformity was checked for all the courses at one go along with some minor corrections. The final draft was ready after 2 days consultation, which was circulated among the members.

Chairman
BSMA (Fisheries Science)

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