N. Jayaraju
G. Sreenivasulu
M. Madakka
M. Manjulatha *Editors*

Coasts, Estuaries and Lakes

Implications for Sustainable Development

Springer

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Editors

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Editors
N. Jayaraju
Department of Geology
Yogi Vemana University
Kadapa, Andhra Pradesh, India

G. Sreenivasulu
Department of Geology
Sri Venkateswara University
Tirupati, Andhra Pradesh, India

M. Madakka
Department of Biotechnology
and Bioinformatics
Yogi Vemana University
Kadapa, Andhra Pradesh, India

M. Manjulatha
Department of Floriculture
National Institute of Horticultural
and Herbal Science
Seonghwan, Republic of Korea

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Dedicated to the family members of the Editors

Foreword

Congratulations on putting together such an impressive set of papers that examine our coasts, estuaries, and lakes! Please accept this brief foreword that aims to synthesize and shine light upon this important book:

Coasts, estuaries, and lakes are critical zones globally where humans interact and often conflict with nature. These Earth features are complex in morphology and inherently dynamic as a result of a multitude of processes that shift their form and change their functioning. Communities depend on the water and shoreline for sustenance, revenue, and countless aspects of life. The challenges of living in coastal zones, of both lakes and marine areas, are ever increasing as shoreline populations continue to climb and demand for food and financial sustainability increases. Moreover, climate change is creating new threats and perturbations that require humanity and governments to react, often rapidly, to water surpluses or shortages or shifting land and seascapes. Research is required to advance our understanding of these complicated systems and human impacts, and around the world, people must strive to share insights and to learn from each other. Beyond research, communities need wise planning and smart public and private action that is rooted in and driven by science. In addition to reading and studying about Earth processes and systems, scientists and students are encouraged to engage with governments and communities to help them understand our evolving world and guide careful decision-making.

The book *Coasts, Estuaries and Lakes: Implications to Sustainable Development* is an excellent collection of 29 chapters in 7 parts that delve into critical science and related challenges. From processes to pollutants, the chapters examine fundamental aspects, but are too numerous and detailed to review or attempt to synthesize succinctly here. Led by Dr. N. Jayaraju from the Department of Geology at Yogi Vemana University, the experienced editorial team includes Drs. Sreenivasulu, Madakka, and Manjulatha. Part I addresses two immediate and important topics, flooding and pollution. Water quality and sedimentary aspects are explored in Parts II and III, respectively. Parts IV and V address biodiversity and climate change which are key concerns for coasts, estuaries, and lakes, and Parts VI and VII examine socioeconomic considerations and geospatial tools that are essential to and will inform sustainable development. The compilation of papers is truly impressive, covering a wealth of information and including examples at varying scales – from local and national studies in India, Kuwait, and elsewhere to global insights from past and recent work.

In summary, the book collection will provide an excellent resource for years to come, and the various chapters will serve as invaluable references for experts and students around the world. The unfortunate reality is that our coasts, estuaries, and lakes are facing unprecedented challenges. Science must be used in partnership with continuous stakeholder engagement and wise governance to allow our shores and seas to sustain society for future generations.

Director, Coastal Resources Center & Professor J. P. Walsh
Graduate School of Oceanography, URI-GSO Bay Campus,
Narragansett, RI, USA

Foreword

Coasts, estuaries and brackish lakes support an important biodiversity and large human populations, and they deliver many ecosystem services from which society gains goods and benefits. However, at the same time, they are the sites of many hazards which give rise to risks and threats to natural and human populations. These threats have been summarised as a “triple whammy” – that the areas are subject to three major threats: an increasing urbanisation and industrialisation; an increasing use of resources such as fish, water and space; and a decreasing resistance and resilience to external, wide-ranging factors such as climate change. These threats and risks may be even greater in developing countries which may have a lesser capability to deal with them.

Given the above features, there is the need to summarise the characteristics of all areas and to gain better information and data to help us manage the areas sustainably. In this way, both nature and society benefit from a healthy environment. This requires natural and social scientists to work together and to work with policymakers and policy implementers. It requires gathering knowledge and data at local, regional, national and global levels and summarising these for a greater benefit. It requires us to be clear about why we need information and how it can be used, often based on studying and monitoring the areas.

Against this background, in its five parts, this book integrates the science and management and gives attention to various features for many Indian areas, including hot spots within those, although other geographical locations are also mentioned. The editors and many authors have done an excellent job of bringing together information and data on local and regional processes and dynamics. These cover sediment contamination and its effects, and coastal flooding, thereby covering physico-chemical interactions, water quality and hydrological processes for the coastal and catchment areas. Using evidence from various regions, and as well as on different spatial scales, it covers temporal scales including long-term natural and anthropogenic forcing on marine, coastal and estuarine ecosystems and multi-year biogeochemical observations.

It is axiomatic that we cannot understand the ecological structure and functioning of an area unless we understand the physical and chemical structure and interactions. Hence the book covers saline water intrusion, and sediment physical, chemical and geochemical features. The seasonal and spatial features of local beaches, the substratum and suspended sediment dynamics and mineral chemistry give a background to a greater understanding. This in turn will enable environmental management which has to be based on fit-for-purpose science and good analytical techniques, which are also described.

The physical and chemical background then allows an interrogation of the biological and ecological features. As such, the contributors give the background with greater information on biodiversity and ecology. The chemical conditions then result in contamination of the biota, reflected here in studies on a range of taxa from foraminifera to molluscs and fishes. This contamination often leads to pollution effects, defined as a decline in the health of organisms, their populations and communities, and indeed a reduction in their fitness-for-survival. Understanding these aspects requires us to define and apply bioindicators and follow this with detailed monitoring. As shown here, chemical contamination can have biochemical effects in organisms and lead to the sequestration of the contaminants in shells and other hard structures of organisms.

As shown in this book, the features of an area may be affected by pressures, defined as the mechanisms of change on the natural and human systems. These may relate to local factors and activities, such as industrial discharges, leading to what may be termed endogenic managed pressures, where the causes and consequences of environmental change both occur in a given area being managed. However, all areas are also exposed to what may be called exogenic unmanaged pressures, in which the causes of change are outside the area being managed but the consequences have to be managed locally. The most important example of this is global climate change which may be manifest as alterations in weather patterns, storminess, sea-level rise, flooding and erosion, all of which increase the vulnerability of our coasts, estuaries and brackish lakes. Hence, although the causes of climate change have to be managed on a global scale, the consequences have to be managed locally.

The editors and contributors summarise these local, regional and global effects and look at the implications of climate change for the geographical regions covered by the book. These features are important and so have an interest beyond the local areas. In particular, it is important for all natural and social scientists and policy-makers to understand such changes in wider global areas. Because of this, the book will be of interest to coastal and estuarine scientists worldwide.

Chair in Estuarine & Coastal Sciences, Research Professor, Mike Elliott
Department of Biological and Marine Sciences
The University of Hull
Hull, UK

Formerly Director, the former Institute
of Estuarine & Coastal Studies (IECS)
Hull, UK

Director, International Estuarine
& Coastal Specialist Ltd
Beverley, UK

Co-Editor-in-Chief, Estuarine Coastal
& Shelf Science
Hull, UK

UNIVERSITY
OF HULL

University of Hull
Hull, HU6 7RX, UK
Mob. +44 (0)7946 533938
University Tel. +44 (0)1482 466773
Email Mike.Elliott@hull.ac.uk
Alternative Email Mike.Elliott@iecs.ltd

Foreword

In 2015, the United Nations General Assembly established its position on Sustainable Development Goals (SDG). These 17 inter-linked global goals are designed to be a "blueprint to achieve a better and more sustainable future for all" and should be in place by 2030. While some of the goals (*e.g.*, gender equality, peace, justice and strong institutions) are exceptionally broad in outlook, several relate to environmental issues, especially No. 13 (Climate Action). This goal is designed to "take urgent action to combat climate change and its impacts". Geoscientists have, for many years, been presenting evidence to the Inter-Governmental Panel on Climate Change (IPCC) that there was a clear separation of "natural climate change" from modern, "anthropogenic" climate change. Meetings, such as COP26 (Glasgow, 2021), have identified a number of changes consequent on a global temperature rise of 1.5–1.8 °C (*e.g.*, sea level rise, coastal erosion, reduction of dissolved O_2 in the oceans, ocean acidification, coral bleaching, loss of biodiversity and extreme weather events). Many of these outcomes of climate change require geoscience awareness to resolve the potential problems, sustain ecosystem services and provide leadership in areas such as flooding and coastal zone management.

Many of these topics feature in this volume, where sustainable development is considered from a geoscience perspective. Our lakes, estuaries, and coastal seas are archives of the Pleistocene, Holocene and "Anthropocene" and provide an understanding of the rates of change involved. This volume is also a contribution to SDG No. 4 (Quality Education) in communicating the sustainability issues.

To some, geoscience *is the problem* (*e.g.*, mining and mining pollution, oil exploration, and coalfield development) but it is also clear that, in many aspects of environmental understanding, *geoscience knowledge will also be part of the solution*.

Malcolm Hart
Emeritus Professor of Micropalaeontology
University of Plymouth
Plymouth, UK

THE GEOLOGICAL SOCIETY
CGeol
CHARTERED GEOLOGIST
Fellow No. 10224

University of Plymouth
Plymouth, U.K.

UNIVERSITY OF PLYMOUTH
School of Geography, Earth and Environmental Sciences

Foreword

This volume titled *Coasts, Estuaries and Lakes: Implications for Sustainable Development* covers a wide range of topics in coastal science, primarily in reference to the Indian subcontinent. The studies cover topics including coastal and estuarine water quality, suspended sediments and trace elements, beach morphology and sediments, biodiversity and marine pollution in coastal waters, the impacts of climate change on coasts in this region, consideration of sustainable development of coastal resources, and the usefulness of geospatial tools for monitoring and investigation in the coastal zone.

The wide range of topics, study locations, methods and authors involved in this volume is indicative of an extremely vibrant community of coastal researchers working in this field and who care deeply about preservation and future management of coastal and estuarine environments around the Indian subcontinent. The editors have done an excellent job in pulling this volume together, and I expect that it will become essential reading for researchers interested in the breadth of work being undertaken within coastal science in this region.

Sarah Woodroffe

President of the INQUA Commission,
(INQUA= International
Union for Quaternary Research)
Coastal and Marine Processes, Department
of Geography, Durham University,
Durham, UK

Durham University
Department of Geography

Inspiring the extraordinary

Foreword

Coastal communities are prone to a range of hazards that can result in the loss of life, damage to infrastructure, economic hardship, and the degradation of ecosystems. While coastal issues of this nature are influenced by a range of biological, chemical, and physical processes, and increasing anthropogenic pressure, many scientific works focus on a subset of these contributors to coastal change. The book *Coasts, Estuaries and Lakes: Implications to Sustainable Development* is a timely and multidisciplinary synthesis of physical and biological processes impacting coastal environments and examines the role they play in sustainable development. The chapters cover a broad, yet well-integrated, spectrum of Earth science disciplines ranging from coastal environments, Earth system processes, and the link between socioeconomics and sustainable development. That sets this volume apart from related books is the multidisciplinary aspect, not only regarding the book as a whole but also the individual chapters. The case studies focus mainly on the vulnerable coastlines of India, but they can be applied globally as they explore issues and solutions that are both relevant and informative to many of the world's coastlines. As co-leader of IGCP Project 725 "Forecasting Coastal Change," I am particularly pleased to see that this book provides a comprehensive understanding of many of the drivers, processes, and scale of coastal change and how this improved understanding enhances a community's ability to manage the coastal zone and better support sustainable development. Researchers, students, practitioners, and enthusiasts alike will find value in this book that is carefully organized and edited by Drs. N. Jayaraju, G. Sreenivasulu, M. Madakka, and M. Manjulatha.

Co-Leader, UNESCO/IGCP 725&, Tier II Canada Research Chair
Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada

Jessica Pilarczyk

Preface

Global warming and climate change continue to pose a severe threat to the coasts and the fragile marine marginal fringes. Coastlines need to be managed effectively and responsibly. Considering the fact that the Earth's surface consists of about 70% water, oceans are crucial for the existence of life on earth. It is indispensable for sustaining all life forms, hence conservation of coastlines is key towards protection of the vulnerable ecosystem as well as human life.

The Earth has around 620,000 km of coastline. With the growing human population and an increasing number of people living near the coasts, it is all the more reason to conserve and look for new ways to protect the natural ecosystems, which is often home to a wide range of spectacular and species-specific biodiversity. On land, they harbor key ecosystems such as freshwater or marine marginal wetlands, which are considered to be vital for migratory bird sanctuaries and other terrestrial biota. In wave-protected zones, they house mangroves, salt marshes, deltas, and sea grasses, among others, all of which can support replenishment and reproduction of aquatic biosphere. Rocky shores along coasts support for a wide range of both benthic and sessile species and several types of seaweed. Colonies of coral reefs are usually found at depths of around 50 m along the shores of tropical regions in clear and warm water.

Other coastal attractions like beaches, tourist islands, and seaside resorts spin a huge economy through coastal tourism. The coastal fragile ecosystems generally provide protection against erosion, rise in sea level, and natural tsunamis, if planted and protected with mangroves and marine vegetation. In several countries, mangroves are the main source of firewood for fuel and domestic usage. Ecosystems such as mangroves and sea grasses have a much bigger ability for carbon sequestration over several well-known terrestrial ecosystems. Thus, they can play a vital role to mitigate, monitor, and manage the impact of climate change by uptake of anthropogenic carbon dioxide pumping. However, because of how economically significant coasts are, many of these communities are susceptible to climate change, which increases the frequency of extreme weather events, sea level rise, and related problems like beach erosion, saltwater intrusion, and marine transgression, which includes flooding. The anthropogenic uses of the coast are further complicated and its vulnerable marginal coastal zones are threatened by a number of additional chronic coastal challenges, including marine trash, microplastic waste, coastal development activities, and marine ecosystem dispersion.

Globally, coastal ecosystems are in decline as a result of the combined effects of climate change, bio habitat imbalance, uncontrolled overfishing, and water pollution (microplastic pollution). This decade (2021–2030) has been designated as the UN Decade on Ecosystem Restoration by the UN. Rare attention has been paid to the rehabilitation of delicate marine habitats. This is due to the fact that coastlines are always changing, making it impossible to calculate their precise perimeter. Today, however, coastal regions are home to the majority of the world's population. Forty-four percent of the world's population, according to the United Nations' atlas, lives about 160 km from the ocean. Many huge cities are situated near harbors and have lavish access to port facilities. Some countries defend and safeguard their coasts against military attacks, marine smugglers, and illegal migrants. This has added a crucial importance to the coasts. Therefore, research on this fragile and economically vital part is mandatory at the present juncture.

The Intergovernmental Oceanographic Commission (IOC) of UNESCO, which focuses on ocean observations, data, services, and associated capacity building. The International Decade of Ocean Science for Sustainable Development, or 2021–2030, has been designated by the United Nations. The 2030 Agenda, which the United Nations endorsed in 2015, was closely related to the idea of an ocean decade. It is intended that the decade would inspire the ocean community to take action on crucial issues including the preservation and usage of the ocean, including research and technology advancements in oceanography. In order to support this sincere and scientific endeavor, we have taken the responsibility of bringing out this edited book to mark the IOC–UNESCO Ocean decade celebrations.

With this background, a humble beginning has been made by us to compile and edit research papers on several burning issues related to the marine marginal bodies including marine pollution. This endeavor has attracted several investigations dealing with the most basic to critical issues like coastal resources, pollution, erosion, restoration, and so on.

We hope that the research, recommended study, and suggestions will provide the needed baseline data for the researchers, stakeholders, policy makers, students, and others who are in constant touch with the coastal zone for science, survival, sightseeing, tourism, economy, and preservation of fragile marine ecosystems. Ocean protection and responsibility at regional and global level is paramount for healthy sustenance of life in the waters. It is imperative to prevent further ecological degradation that in turn affects human well-being and the environment at large.

Kadapa, Andhra Pradesh, India N. Jayaraju
Tirupati, Andhra Pradesh, India G. Sreenivasulu
Kadapa, Andhra Pradesh, India M. Madakka
Jeonju, South Korea M. Manjulatha

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About the Editors

N. Jayaraju is a professor of Geology, Yogi Vemana University, India. His research interests include of environmental geosciences, marine ecology, marine pollution, coastal zone resources, sediments of marine marginal water bodies, viz., lakes and estuaries. He was awarded gold medal for being a university topper in his master's degree course and later received University Merit Fellowship for pursuing PhD. He worked as PDF for UGC, CSIR, DST, and all central government prestigious funding agencies. He has published more than 60 research papers in various national and international journals. Jayaraju has attended more than 50 international conferences abroad and 40 in India. He is an active member in many scientific associations/organizations. Moreover, he is serves on editorial boards and reviewer boards for many prestigious journals. Jayaraju has travelled widely on his research endeavor, visiting over 60 countries like Australia, China, Japan, Germany, France, Italy, Middle East, the UK, and the USA.

G. Sreenivasulu received his MSc (with university top rank and gold medal) and PhD from the Department of Geology, Yogi Vemana University, Kadapa, India. He worked as a Research Associate at the National Centre for Earth Science Studies, Thiruvananthapuram, India. Currently, he is working as Dr. D. S. Kothari Postdoctoral Fellow in the Department of Geology at Sri Venkayeswara University, Tirupati, India. He was awarded DST-INSPIRE, a prestigious fellowship, for 5 years for PhD program by the Department of Science and Technology (DST), Government of India. Thrust areas of his research include micropaleontology, marine pollution, coastal morphodynamics, and application of geospatial tools. He has attended many scientific events related to his relevant area of specialization both within India and abroad. He has published more than 25 papers in international and national journals. He is an active member in many scientific associations/organizations. Moreover, he serves on editorial boards and reviewer boards of many prestigious journals.

M. Madakka is currently an associate professor in the Department of Biotechnology and Bioinformatics, Yogi Vemana University, Kadapa, AP, India. She received her MSc and PhD degrees in microbiology from Sri Krishnadevaraya University, Anatapur, India. Her research interests are in the fields of environmental biotechnology and environmental microbiology. She was awarded Rajiv Gandhi fellowship for PhD from UGC, New Delhi, India. She secured DST-SERB fast track young scientist fellowship during 2012–2015, New Delhi. She has over 17 years of research and 14 years of teaching experience in the university. She has published more than 40 research papers in peer-reviewed national and international scientific journals and presented several papers in national/international conferences.

M. Manjulatha, Senior Research Associate, is currently affiliated to the National Institute of Horticultural and Herbal Sciences, RDA, South Korea. She obtained her PhD from the Department of Biotechnology, Sri Krishna Devaraya University, in collaboration with the Department of Crop Physiology, University of Agricultural Sciences, GKVK, Bangalore. She worked as a research associate in DBT-supported Center of Excellence program and ICAR FIST-DST niche area of excellence for drought research in UAS, GKVK, Bangalore. She has 14 years of research experience in the area of plant molecular biology, biotechnology, transgenics, gene editing, and molecular markers. She has published 25 research papers in peer-reviewed journals and 4 book chapters. She has been a reviewer for various international journals.

Nanotechnology in the Life Sciences

Vishnu Kirthi Arivarasan
Karthik Loganathan
Iddya Karunasagar *Editors*

Nanotechnological Approaches to the Advancement of Innovations in Aquaculture

Springer

Nanotechnology in the Life Sciences

Series Editor
Ram Prasad, Department of Botany
Mahatma Gandhi Central University
Motihari, Bihar, India

Nano and biotechnology are two of the 21st century's most promising technologies. Nanotechnology is demarcated as the design, development, and application of materials and devices whose least functional make up is on a nanometer scale (1 to 100 nm). Meanwhile, biotechnology deals with metabolic and other physiological developments of biological subjects including microorganisms. These microbial processes have opened up new opportunities to explore novel applications, for example, the biosynthesis of metal nanomaterials, with the implication that these two technologies (i.e., thus nanobiotechnology) can play a vital role in developing and executing many valuable tools in the study of life. Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale, to investigating whether we can directly control matters on/in the atomic scale level. This idea entails its application to diverse fields of science such as plant biology, organic chemistry, agriculture, the food industry, and more.

Nanobiotechnology offers a wide range of uses in medicine, agriculture, and the environment. Many diseases that do not have cures today may be cured by nanotechnology in the future. Use of nanotechnology in medical therapeutics needs adequate evaluation of its risk and safety factors. Scientists who are against the use of nanotechnology also agree that advancement in nanotechnology should continue because this field promises great benefits, but testing should be carried out to ensure its safety in people. It is possible that nanomedicine in the future will play a crucial role in the treatment of human and plant diseases, and also in the enhancement of normal human physiology and plant systems, respectively. If everything proceeds as expected, nanobiotechnology will, one day, become an inevitable part of our everyday life and will help save many lives.

Vishnu Kirthi Arivarasan
Karthik Loganathan • Iddya Karunasagar
Editors

Nanotechnological Approaches to the Advancement of Innovations in Aquaculture

Springer

Editors
Vishnu Kirthi Arivarasan
Department of Microbiology
School of Bioengineering and Biosciences
Lovely Professional University
Phagwara, Punjab, India

Karthik Loganathan
Department of Synthetic Biology
Salem Microbes
Salem, Tamil Nadu, India

Iddya Karunasagar
Center for Science Education & Research
Nitte University
Kotekar, Karnataka, India

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Preface

Nanotechnology is a cutting-edge science and technology with numerous scientific and technological applications. Rapid breakthroughs in nanosciences and nanotechnologies have opened up new possibilities for many industrial and consumer sectors, including aquaculture and agriculture and associated fields, which have recently been considered a hotspot of a new industrial revolution.

Aquaculture, or the farming of aquatic organisms in inland and coastal settings, is the world's fastest expanding food-generating sector, thanks to technological advancements and diversification. It is widely perceived that the high-quality proteins found in fish are superior to that found in meat and fowl. Annually, the aquaculture industry generates substantial advances in the creation of technology to boost food production.

Nanotechnology has played an important role in the development of an economic and sustainable pathway for different aspects of aquaculture for benefit of the human race. It has led to the development of new tools for aquaculture, fish biotechnology, fish genetics, fish reproduction, and aquatic health, among other things. The fisheries and aquaculture industries can be changed by integrating nanotechnology with new tools such as rapid disease diagnosis, improving fish's ability to absorb medications such as hormones, vaccinations, and nutrients, and so on.

In this book, we have tried to put together a detailed account of the different roles nanotechnology plays in the fast-developing and progressive path toward aquaculture growth. The different aspects of nanotechnology in aquaculture have been amalgamated into a single book. This book will be beneficial for young researchers, postgraduates, and of course the general populace to know in detail about the topic of nanotechnology and aquaculture.

Phagwara, Punjab, India — Vishnu Kirthi Arivarasan
Salem, Tamil Nadu, India — Karthik Loganathan
Kotekar, Karnataka, India — Iddya Karunasagar

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Shalini Dhyani
Dibyendu Adhikari
Rajarshi Dasgupta
Rakesh Kadaverugu *Editors*

Ecosystem and Species Habitat Modeling for Conservation and Restoration

Springer

Ecosystem and Species Habitat Modeling for Conservation and Restoration

Shalini Dhyani • Dibyendu Adhikari •
Rajarshi Dasgupta • Rakesh Kadaverugu
Editors

Ecosystem and Species Habitat Modeling for Conservation and Restoration

Springer

Editors
Shalini Dhyani
Critical Zone Research Group, Water Technology and Management Division
CSIR-NEERI
Nagpur, India

Dibyendu Adhikari
Plant Ecology & Climate Change Science
CSIR-National Botanical Research Institute
Lucknow, India

Rajarshi Dasgupta
School of Public Policy
Indian Institute of Technology
Delhi, India

Rakesh Kadaverugu
Cleaner Technology and Modeling Division
CSIR-National Environmental Engineering Research Institute
Nagpur, India

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Foreword

Origins

The field of distributional ecology revolves around the question of why a species is where it is, and why is the species not where it is. This question may seem simple, in the sense that ranges of species have been a central focus in biology for more than a century. Now, for many species, it is quite easy to find a range map, or occurrence data, or some source of information about the "where" question. So why should answering this question be so difficult?

These challenges of obtaining high-quality distributional information for species have been approached using myriad frameworks and tools. Early approaches centered on so-called habitat suitability modeling (e.g., Scott et al. 1996), and saw application of several multivariate statistical approaches to the question (e.g., Austin et al. 1990). A next generation of progress brought the many advantages (and disadvantages) of machine learning approaches (Stockwell and Peters 1999; Phillips et al. 2006), which had the in-hindsight-dubious quality of being able to fit more complex response types (Elith et al. 2006).

Curiously, at least in my own humble opinion, a next (and key) major advance was that of bringing a more rigorous conceptual underpinning to distributional ecology. Building on the foundational work of Grinnell (Grinnell 1917a, b) and Hutchinson (Hutchinson 1957, 1978) and a few subsequent authors (Austin 1987; Austin et al. 1990; Austin et al. 1994; Pulliam 2000), a consortium of authors published a first conceptual framework for the field (Peterson et al. 2011). Based on this framework, many additional advances became possible, such as comprehending the importance of accessible areas in fitting models (Barve et al. 2011; Machado-Stredel et al. 2021), establishing appropriate approaches for evaluating models (Peterson et al. 2008), etc.

Key Elements in the Process

The typical niche modeling application is a multi-step process, which (to be honest) is not laid out in any standard methodology in any one textbook or standard reference book. Nonetheless, it is generally a process of (1) assembling point occurrence data for the species in question, (2) assembling relevant environmental data for the region in question, (3) choosing a region over which to fit models, (4) actually fitting the model, and (5) post-processing and interpretation of model outputs to respond to the questions that were originally posed. These steps have been achieved via standard statistical tools (Guisan et al. 2017), modular sets of tools (Cobos et al. 2019), or via standalone platforms that package many or all of the necessary steps (Kass et al. 2018). Beyond these basics, however, a few points remain important to emphasize, as follows.

A key emphasis is on the use of *primary* biodiversity data—i.e., data that document the presence of an individual of a species at a particular place at a particular time—as the basis for these modeling efforts. Although it is certainly tempting to appeal to easier and more readily available sources of occurrence information, such as range maps or atlas summaries, use of secondary sources of biodiversity data for model inputs introduces significant noise into the results. In essence, the primary occurrence data and the environmental data should go hand in hand in terms of spatial grain and resolution, such that neither is too general, and such that discords and mismatches are not pervasive in the modeling effort. The subjectivity introduced by secondary data sources is an additional source of uncertainty and confounding effects for the models, such that important features of the distributional ecology may be lost from the analysis.

A further emphasis should be on the use of methods that are quantitative, repeatable, scalable, and portable, at all points in the process. Although many present-day analyses simply provide general, text-based descriptions of methodological steps, program code (e.g., in R) or full-blown workflows can now be developed or implemented that make the methodology entirely portable, transferrable, and scalable. The code can be shared as part of the publication process, which makes the methodology repeatable, and ready for application in any other analysis by any investigator.

Challenges

Although this methodology has now been used in thousands of analyses and thousands of published papers, its development is not complete. That is, a number of advances remain to be explored and documented, so that the approach is as maximally informative and useful as is possible. The following are several such areas that remain under exploration and development, but that can certainly be seen as fruitful areas for future research.

Estimate the Right Sort of Object Fundamental ecological niches are likely to be relatively simple, convex objects in environmental space (Maguire 1973). Nonetheless, the methods in vogue currently in distributional ecology often estimate objects that are quite a bit more complex, with gaps, holes, and infoldings—in this sense, workers in this field are using inappropriate tools for the task. As such, an important step forward will be to develop and use tools that estimate objects that "look like" fundamental ecological niches, and are simple and convex, and that do not have bimodal environmental responses, or any other such complexities. Some initial steps have been taken toward such a methodology (Jiménez et al. 2019; Jiménez and Soberón 2022), but much work remains to be done.

Use the Right Environmental Information Workers in the field of distributional ecology have long used environmental information in the form of long-term average values to characterize species' occurrences in terms of the environments that are manifested at the site of occurrence. It is well known, however, that an average can be a poor representation of the conditions at any particular moment, and an individual or a population can be extinguished with even a short period of time spent under unsuitable conditions. As such, recent research efforts (Ingenloff and Peterson 2020) have explored the potential for representing environmental conditions associated with occurrences of species as a function of latitude, longitude, *and time*, such that conditions specific to an occurrence are identified more precisely.

Consider Dispersal Ecological niche models, if done well, present a view of the area that is suitable for a species in terms of abiotic conditions (note that the next item in this list refers to the question of suitability in biotic terms). A crucial consideration, however, is that the ability of the species to access those suitable sites is not generally considered. As a consequence, too often, conclusions in ecological niche modeling studies are based on rather simple assumptions about dispersal ability (e.g., no dispersal or universal dispersal). A few efforts have now been made to incorporate dispersal processes more powerfully into these methods (Engler and Guisan 2009; Machado-Stredel et al. 2021), but applications have been relatively few—adding this component into modeling efforts and interpretations is crucial to making this methodology and the resulting conclusions more powerful.

Incorporate Biotic Interactions A further dimension that is too often left out of ecological niche model-based studies is that of biotic dimensions—in essence, the set of biotic considerations that makes a site suitable or unsuitable for a species. As has been pointed out in several conceptual treatments, consideration of the full dynamics of the broad suite of potential biotic interactors for any given species may prove to be impossible. Nonetheless, it is feasible to incorporate at least known interactor species in two- or multi-species models (e.g., Anderson 2017; Ashraf et al. 2021), and network analysis approaches may be relevant to identifying such interactor species more rigorously (Fath et al. 2007).

This Book

This volume, entitled *Ecosystem and Species Modeling for Conservation and Restoration: Mainstreaming Modeling Approaches in Policy Planning*, comprises a set of papers that revolve around models of ecosystems and species, and their niches and distributions, in the context of guiding policy. Although I have not yet had the opportunity to read each of the contributions, the list of titles, topics, and authors is impressive—this volume will create a rich picture of the state of the field and will illustrate many of the possible applications of this methodology. As a consequence, I am so very pleased to have been invited to preface the volume with a few thoughts, ideas, and comments.

University of Kansas Biodiversity Institute A. Townsend Peterson
Lawrence, KS, USA 28 October 2022

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Contents

Editors and Contributors

About the Editors

Shalini Dhyani is a Senior Scientist with the Critical Zone Group of Water Technology and Management Division of CSIR-NEERI, India. She is a seasoned ecologist with two decades of experience. She uses observational, empirical, and modeling approaches to investigate and understand issues related to the environment, loss of natural and urban greenspaces, and interlinkages between ecological and social systems through sustainability science approaches. She is Asia Vice Chair member of CEM (Commission on Ecosystems Management) and also Steering Committee member.

Dibyendu Adhikari is a Principal Scientist at CSIR-National Botanical Research Institute (NBRI), India. He is a seasoned researcher with over 15 years of experience in ecology and environmental science. He is skilled in terrestrial ecosystem restoration, threatened plant conservation, forest carbon assessment, ecological data analysis and modeling.

Rajarshi Dasgupta is Assistant Professor at IIT Delhi. He was previously with the Institute for Global Environmental Strategies (IGES), Kanagawa, Japan. He holds diverse research interests in the field of landscape ecology and planning, which include Ecosystem-based Disaster Risk Reduction (Eco-DRR), spatial quantification of ecosystem services, land change simulation, development of socio-ecological scenarios, participatory conservation, and social forestry.

Rakesh Kadaverugu is a Senior Scientist associated with CSIR-National Environmental Engineering Research Institute. He has more than 10 years of research experience in environmental systems modeling and his is work is focused to better understand the socio-environmental systems at multiple spatial and temporal scales using geospatial, soft-computing, and process-based modeling approaches.

Contributors

Rovshan Abbasov is the head of Khazar University's Department of Geography and Environment. He is a member of the IPBES's Multidisciplinary Expert Panel and ICOMOS National Committee and Coordinating Lead Author in the National Ecosystem Assessments.

C. S. Abhijitha is from WWF, India, with proficiency in the research areas related to biodiversity, conservation and geospatial applications.

Santoshkumar Abujam is currently working as a Research Associate under a DST-funded research project in Rajiv Gandhi University, Rono Hills, Doimukh, Arunachal Pradesh (India).

Prasannajit Acharya is a Ph.D. Scholar at the Institute of Technical Education and Research, Department of Chemistry, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India.

Dibyendu Adhikari works as a Principal Scientist in the Plant Ecology and Climate Change Science Division at CSIR-National Botanical Research Institute, Lucknow.

Peerzada Ishtiyak Ahmad is Assistant Professor cum Scientist at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, India.

Mohammad Alizadeh-Noughani is a graduate from Ferdowsi University of Mashhad-Iran.

G. Areendran works at WWF, India, and is addressing conservation issues occurring in various landscapes, with a high focus on tiger, elephant, and rhinoceros to overseeing several institutional GIS-based projects.

A. Arunachalam is the Director of the ICAR-Central Agroforestry Research Institute, Jhansi. He is also Project Coordinator for the All India Coordinated Research Project on Agroforestry, and Task Force Coordinator for the National Mission for Sustaining Himalayan Ecosystem (NMSHE).

A. Arya is pursuing her Ph.D. in Bits Pilani G BITS, Pilani, Goa campus.

Ratul Baishya is associated with the Department of Botany, University of Delhi, as an Associate Professor.

Aritra Bandopadhyay is pursuing his Ph.D. in Climate Change and Ecology in the Department of Humanities and Social Science in BITS-Pilani, Goa Campus.

Harish Barewar is currently working as project Associate-II in CSIR-National Environmental Engineering and Research Institute (NEERI), Nagpur.

Rajesh Biniwale is a Senior Principal Scientist in CSIR National Environmental Engineering Research Institute, Nagpur.

Milben A. Bragais is a Licensed Forester and Environmental Planner with a background in hydrological modeling, watershed characterization, and vulnerability assessment.

Manish Kuntal Buragohain is currently working as a Project Associate-I in CSIR-National Environmental Engineering and Research Institute (NEERI), Nagpur.

Dhoni Bushi is currently pursuing a Ph.D. in the Department of Geography, Rajiv Gandhi University, Arunachal Pradesh.

Joseph G. Campang is an Assistant Professor at the Institute of Biological Sciences (IBS) of University of the Philippines Los Baños (UPLB) with research specialisation on lakes.

Yves Christian L. Cabillon with a bachelor's degree is an experienced researcher in water quality assessment, plankton taxonomy, environmental impact assessment, and environmental awareness.

Bipin Charles is Consultant at the Institute for Biodiversity Conservation and Training, Bangalore, India.

Sudipto Chatterjee is an Associate Professor at TERI School of Advanced Studies. He is the Principal Investigator of this study supported by UNU ProsperNet. He is the Co-Lead for the South Asia Nitrogen Hub (SANH) project on the study of impacts of pollution on biodiversity with Lichens as an indicator.

Rajiv Kumar Chaturvedi is an Assistant Professor at BITS, Pilani, Goa campus, and is an UN expert on GHG inventory in the land-use and forestry sector.

Arun Chettri is working as an Assistant Professor at Sikkim University.

Shahid Ahmad Dar is working as a postdoctoral fellow at Zoological Survey of India, Kolkata.

Mira Das is a Professor at the Institute of Technical Education and Research, Department of Chemistry, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India.

Vedika Dutta received a Master of Science in Environmental Studies and Resource Management at TERI School of Advanced Studies, New Delhi, India.

Shalini Dhyani is a Senior Scientist in CSIR National Environmental Engineering Research Institute, Nagpur.

Piyali Dias has a Master of Science in Biodiversity and Taxonomy of Plants from the University of Edinburgh, UK.

Wisdom M. D. Dlamini is an environmental and geospatial scientist at the University of Eswatini.

Jennifer D. Edrial is a postgraduate from the University of the Philippines Los Baños and is currently a member of the Sustainability Team of Ayala Land, Inc.

Azita Farashi is Associate professor at the Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad, Iran.

Marlon Flores leads the global sector-centered economic valuation approach Targeted Scenario Analysis (TSA) at UNDP's Food and Agricultural Commodity Systems (FACS) Practice.

S. A. Gangoo is Dean at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, India.

Anjaly George is a Ph.D. scholar at the Kerala University of Fisheries and Ocean Studies.

Sonali Ghosh is a Senior Indian Forest Service Officer with more than 25 years of work experience at state and center and specialization in wildlife. She has also worked at UNESCO C2C on World Natural Heritage Centre at Wildlife Institute of India.

Shailendra Goel is Professor in the Department of Botany, University of Delhi.

Kiran Hungund is a Project Assistant working on air quality changes and their visualization with the Energy, Environment and Climate Change Programme at National Institute of Advanced Studies, Bangalore.

Tanvi Hussain is a Research Scholar in the Department of Environmental Science, Gauhati University, and presently with World Agroforestry (CIFOR-ICRAF).

Nazrul Islam is pursuing his Ph.D. in Eastern Swamp Deer Ecology in Manas National Park from Gauhati University and working as biologist with Wildlife Trust of India in the Greater Manas landscape.

Jonson M. Javier is an Assistant Professor of Agricultural Economics and Environmental Science at the Western Philippines University.

Aroma Caroline John has completed an M.Sc. in Geographical Information Systems and Remote Sensing.

Karun Jose is pursuing his Ph.D. in Climate Change and Forest Phenology in the Department of Humanities and Social Science in BITS-Pilani, Goa Campus.

Shijo Joseph is an Assistant Professor and Coordinator of the Centre for Climate Resilience and Environment Management at the Kerala University of Fisheries and Ocean Studies, Kochi.

Ashok Kadaverugu is Head of Civil Engineering department in a Government Polytechnic college, Nalgonda, Telangana.

Rakesh Kadaverugu is a Senior Scientist in CSIR National Environmental Engineering Research Institute, Nagpur.

Sarbeswar Kalita is the Former Head and expert of seismology, climatology, and meteorology from the Department of Environmental Science, Gauhati University.

Sharanjeet Kaur worked as a DBT Senior Project Fellow in the Department of Botany, University of Delhi.

Siddhartha Kaushal is associated as a Ph.D. research student with the Department of Botany, University of Delhi.

B. S. P. C. Kishore is a Ph.D. scholar in the Department of Geoinformatics, Central University of Jharkhand, Ranchi, India.

Amit Kumar is working as an Assistant Professor in the Department of Geoinformatics, Central University of Jharkhand, India.

Gajendra Kumar is a Ph.D. scholar in the Department of Geoinformatics, Central University of Jharkhand, Ranchi, India.

Sudip Kumar Kundu is a Ph.D. scholar at Manipal Academy of Higher Education (MAHE), Bengaluru.

Bibhuti Prasad Lahkar is a Senior Scientist with Aaranyak, Assam. He has extensively researched grassland ecosystems in the Indian state of Assam.

Suvha Lama is currently working as a Scientist in CSIR-National Environmental Engineering and Research Institute (NEERI), Nagpur.

Felino P. Lansigan is a Professor of Statistics at the Institute of Statistics, UPLB. He specializes in stochastic modeling and crop insurance under climate change.

Jeoffrey M. Laruya is from College of Forestry and Natural Resources, University of the Philippines Los Baños, Laguna, Philippines.

Linda Loffler is an independent consultant with vast experience in botanical research in Southern Africa.

Nethanel Jireh A. Larida holds a Master of Science in Botany degree from the University of the Philippines at Baños (UPLB) and works on diversity of aquatic macrophytes and riparian diversity in freshwater lakes.

Damasa B. Magcale-Macandog is a Professor of Plant Ecology at the Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Baños.

Kristina S. Mago was a Student Assistant at the Ecoinformatics Laboratory of the Institute of Biological Sciences, University of the Philippines Los Baños.

Ranjit Mahato is currently pursuing a Ph.D. in the Department of Geography, Rajiv Gandhi University, Arunachal Pradesh.

Marc Bryan Manlubatan is a Research Associate in the NRCP-Funded project with a degree in Agricultural Engineering, University of the Philippines Los Baños.

Teodorico L. Marquez Jr is Student Assistant at the Ecoinformatics Laboratory of the Institute of Biological Sciences at the University of the Philippines Los Baños.

T. H. Masoodi is Registrar at Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, India.

Abhinav Mehta is CEO at the Geographic Information Lab (TGIS), Gujarat.

Pradipta R. Muduli is presently working as a Scientific Officer at the Wetland Research and Training Centre (WRTC), Chilika Development Authority (CDA), Dept. of Forest and Environment, Govt. of Odisha, India.

Tahir Mushtaq is Assistant Professor cum Scientist at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, India.

Jerry Naayos is Field Guide in the research and survey experiments in Banaue.

Anukul Nath is serving at UNESCO C2C at the Wildlife Institute of India with an extensive experience of work in the Manas landscape.

Gibji Nimasow is Professor in the Department of Geography, Rajiv Gandhi University, Rono Hills, Doimukh, Arunachal Pradesh (India).

Oyi Dai Nimasow is Assistant Professor in the Department of Geography, Rajiv Gandhi University, Rono Hills, Doimukh, Arunachal Pradesh (India).

Mir Muskan Un Nisa is a M.Sc. Forestry student at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, India

Sarath Nissanka is a Professor in Crop Science at the University of Peradeniya, Govt of Sri Lanka. Sarath implements the SANH project in Sri Lanka.

Jaderick P. Pabico is a Professor of Computer Science at the Institute of Computer Science, UPLB.

Vasundhara Pandey has a Master of Science in Environmental Studies and Resource Management at TERI School of Advanced Studies, New Delhi, India.

Ma. Grechelle Lyn D. Perez is Master's in Environmental Science at the University of the Philippines, Los Baños, Laguna, Philippines and affiliated with the University of the Philippines Rural High School handling biology, earth science, field study courses, and capstone research.

John Vincent R. Pleto is an Assistant Professor at the Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Banos and specializes in freshwater ecology.

Randy Porciocula is administrative staff of the NRCP-Funded project at the University of the Philippines Los Baños.

Aditya Pradhan is currently working as an Assistant Professor at SRM University Sikkim.

K. Preeti has a Master of Science in Environmental Studies and Resource Management at TERI School of Advanced Studies, New Delhi, India.

Sarena Grace L. Quiñones is a Development Communication graduate from the University of the Philippines Los Baños (UPLB).

Marc Anthony F. Rabena is an Assistant Professor at the Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Baños.

Krishna Raj is a Specialist in Geospatial Application and has done a Master's in Geography from Banaras Hindu University, Varanasi, India, and has been working in various major research projects of WWF-India.

Shrey Rakholia is Consultant at the Geographic Information Lab (TGIS), Ahmedabad, Gujarat.

Hemanthi Ranasinghe is a Senior Professor in Forestry and Environmental Science at the University of Jayewardenepura, Govt of Sri Lanka.

Kumar Ranjan has completed his postgraduation in GIS and Remote Sensing, and his expertise lies in varied fields of allied disciplines of geospatial analysis.

Kottapalli Sreenivasa Rao is Senior Professor and former Head, Department of Botany, University of Delhi.

Marlon A. Reblora is the Research Associate at the University of the Philippines Los Baños.

Mohan Reddy is Lead in Carbon & Sustainability Division at Nurture Agtech Private Limited, Bellandur, Bengaluru-560103, India.

Uttam Kumar Sahoo is a Professor at the Department of Forestry, School of Earth Sciences and Natural Resource Management, Mizoram University.

Purabi Saikia is working as an Assistant Professor at the Central University of Jharkhand, Ranchi.

Arnold R. Salvacion is an Associate Professor at the Department of Community and Environmental Resource Planning, College of Human Ecology, University of the Philippines Los Baños.

R. Sanil is currently working as an Associate Professor at the Department of Zoology, Government Arts College, Udhagamandalam, India.

Harini Santhanam is an Associate Professor and Head, Department of Public Policy (DPP), Manipal Academy of Higher Education (MAHE) Manipal, Bengaluru Campus, Bengaluru, India.

Thekke Thumbath Shameer is working as a scientist (APO projects) at the Centre for Conservation Education Advanced Institute for Wildlife Conservation, Tamil Nadu Forest Department.

Jahnavi Sharma is an independent researcher working on Energy and Environment policy and is based in Bangalore.

Prachi Sharma is working as a Ph.D. research student in the Department of Botany, University of Delhi.

Shilky is a Ph.D. scholar in the Department of Environmental Sciences, Central University of Jharkhand, Ranchi, India.

Alolika Sinha is Senior Wildlife Biologist with Aarnyak, Assam, with a Ph.D. in endangered cervid—the hog deer.

Anshu Siwach is pursuing her Ph.D. in the Department of Botany, University of Delhi.

P. A. Sofi is Associate Professor at the Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, India.

Radhika Sood is AcSIR PhD at CSIR-NEERI, Nagpur working on ecosystem health and mapping cultural ecosystem services.

Sundaram Suresh Ramanan is a scientist at ICAR-Central Agroforestry Research Institute, Jhansi.

Rajesh Tandon is a senior professor in the Department of Botany, University of Delhi.

Malsha Thejani is doing her BSc at the University of Jayewardenepura, Govt of Sri Lanka.

Keshia N. Tingson is an Assistant Professor at the College of Forestry and Natural Resources, University of the Philippines Los Baños.

Prem Lal Uniyal is Senior Professor in the Department of Botany, University of Delhi.

Kalidas Upadhyaya currently works at the Department of Forestry, Mizoram University. His research interests are agroforestry, soil ecology, and restoration ecology.

S. Varshini is a Project Assistant with the Energy, Environment and Climate Change Programme at National Institute of Advanced Studies (NIYAS), Bangalore.

Buddhika Weerakoon is a Ph.D. scholar at the University of Peradeniya, Govt of Sri Lanka.

Macrina T. Zafaralla is a Professor Emeritus at the University of the Philippines Los Baños. She specializes in freshwater ecology and phytoplankton.

Abbreviations

3-PG	Physiological Processes Predicting Growth
3Rs	Reduce, Reuse, Recycle
AAQMS	Ambient Air Quality Monitoring Station
ABA	Abscisic acid
ACF	Autocorrelation Function
ADB	Asian Development Bank
AEKOS	Australian Ecological Knowledge and Observation System
AHP	Analytic Hierarchy Process
AIC	Akaike Information Criterion
ANN	Artificial Neural Network
ANOVA	Analysis of Variance
AOD	Aerosol Optical Depth
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ASCII	American Standard Code for Information Interchange
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AUC	Area Under the Curve
AZN	Manat (Azerbaijani currency)
BAU	Business as Usual
BBA	Blue to Built-up Area
BCC	Basic Carrying Capacity
BCVs	Bioclimatic Variables
BFAR	Bureau of Fisheries and Aquatic Resources
BGM	Generalized Boosting Model
Bio	Bioclimatic Variables
BIOCLIM	Bioclimatic Models
BNF	Biological Nitrogen Fixation
BoB	Bay of Bengal
BOD	Biological Oxygen Demand

BP	Background Points
BRT	Boosted Regression Trees
BSIP	Birbal Sahni Institute of Palaeosciences
ca.	circa (meaning around)
CAAQMS	Continuous Air Quality Monitoring Stations
CART	Classification and Regression Tree
CASA	Carnegie-Ames-Stanford Approach
CBD	Convention on Biological Diversity
CC	Carrying Capacity
CCi	Actual Carrying Capacity Level
CCimax	Carrying Capacity Limit
CEM	Climate Envelope Model
Chl-a	Chlorophyll-a
CHL-A	Chlorophyll-a
CI	Consistency Index
CLUP	Comprehensive Land Use Plan
CMFRI	Central Marine Fisheries Research Institute
CMIP	Coupled Model Intercomparison Project
CO2	Carbon dioxide
CPCB	Central Pollution Control Board
CPT	Conditional Probability Tables
CR	Consistency Ratio
CR	Critically Endangered
CRD	Completely Randomized Design
CS	Central Sector
C-SDM	Correlative Species Distribution Model
CSi	Carrying Capacity Level
CSI	Consortium for Spatial Information
CSR	Corporate Social Responsibility
CTA	Classification Tree Analysis
CTI	Compound Topography Index
CV	Cross Validations
CWC	Canopy Water Content
CWE	Corrected Taxonomic Weighted Endemism
CWPE	Corrected Weighted Phylogenetic Endemism
DBF	Day Before Fish Kill
DEM	Digital Elevation Model
DENR AO	Department of Environment and Natural Resources
DGVM	Dynamic Global Vegetation Model
DO	Dissolved Oxygen
DOST	Department of Science and Technology
DOT	Department of Tourism
ECC	Ecological Carrying Capacity
EcoSIS	Ecological Spectral Information System
EDA	Exploratory Data Analyses

eDNA	Environmental DNA
ENFA	Environmental Niche Factor Analysis
ENM	Ecological Niche Model
ENM	Ecological Niche Modeling
ERA	European Center for Medium-Range Weather Forecasts Re-Analysis
ES	Ecosystem Services
ESD	Eastern Swamp Deer
ESM	Earth System Model
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FARE	Food Analysis and Research
FARMC	Fisheries and Aquatic Resource Management Council
FDA	Flexible Discriminant Analysis
FF	Favorability Function
FGD	Focus Group Discussion
FHWAR	Fishing, Hunting, & Wildlife-Associated Recreation
FSLF	Friends of the Seven Lakes Foundation, Inc
FvCB	Farquhar, von Caemmerer, and Berry
GA	Gibberellic acid
GAM	Generalized Additive Model
GARP	Genetic Algorithm for the Rule Set Production
GBIF	Global Biodiversity Information Facility
GBM	Gradient Boosting Machine
GBR	Green Blue Ratio
GCM	Global Circulation Model
GCS WGS	Geographical Coordinate System World Geodetic System
GDEM	Global Digital Elevation Model
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GEMS	Global Environment Monitoring System
GHG	Greenhouse Gas
GI	Green Infrastructure
GIOVANNI	Geospatial Interactive Online Visualization and Analysis Infrastructure
GIS	Geographic Information System
GIZ	German International Cooperation
GJAM	Generalized Joint Attribute Model
GLCF	Global Land Cover Facility
GLM	Generalized Linear Model
GLR	Generalized Linear Regression
GNF	Global Nature Fund
GOI	Government of India

GPP	Gross primary production
GPS	Global Positioning System
GSA	Global Sensitivity Analysis
GSI	Geological Survey of India
H+	Hydrogen ion
HCA	Hierarchical Cluster Analysis
HEC	Human-Elephant Conflict
HII	Human Influence Index
HL	Hidden Layers
HN	Hidden Network
HPP	Hydropower Plant
H-SDM	Hybrid Species Distribution Model
IAA	Indole Acetic Acid
IAP	Invasive Alien Plant
IBIS	Integrated Biosphere Simulator
ICAR	Indian Council of Agricultural Research
ICH	Indian Central Himalaya
IHR	Indian Himalayan Region
IL	Input layers
INCOIS	Indian National Centre for Ocean Information Services
INSAT 3D	Indian National Satellite 3D
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IRMS	Isotope-Ratio Mass Spectrometer
ISA	Impervious Surface Area
ISRIC	International Soil Reference and Information Centre
IUCN	International Union for Conservation of Nature
JSDM	Joint Species Distribution Model
JULES	Joint U.K. Land Environment Simulator
KAP	Knowledge, Attitudes, Practices
KARB	Kura-Araz river basin
KfW	German government-owned development bank (Reconstruction Credit Institute)
KII	Key Informant Interview
$kJ\ m^{-2}\ day^{-1}$	kilo joules per square meters per day
km^2	square kilometers
KML	Key Markup Language
KMZ	Keyhole Markup Language
KRC	Knowledge Resource Centre
LAI	Leaf Area Index
LD	Land Degradation
LDN	Land Degradation Neutrality
LGU	Local Government Unit
LID	Low Impact Development

LLDA	Laguna Lake Development Authority
LPI	Largest Patch Index
LPJ-DGVM	Lund Potsdam Jena—Dynamic Global Vegetation Model
LPJ-GUESS	Lund Potsdam Jena—General Ecosystem Simulator
LPJmL	Lund-Potsdam-Jena managed Land
LPX	Land Surface Processes and Exchanges
LULC	Land Use Land Cover
m.s.a.l	meters above sea level
MARPOL	The International Convention for the Prevention of Pollution from Ships
MARS	Multivariate adaptive regression splines
MaxEnt	Maximum Entropy
MAXENT	Maximum Entropy
MDP	Master Development Plan
MDS	Multi-dimensional scale
MF	Mixed Forest
MFA	Marine Fishery Advisories
Mg ha^{-1}	Megagram per hectare
MINARS	National Programme of Monitoring of Indian National Aquatic Resources
MIR	Model Improvement Ratio
MIROC5	Model for Interdisciplinary Research on Climate Version Five
ML	Machine learning
MLP	Multi-Layer Perceptron
MNP	Manas National Park
MODIS	Moderate Resolution Imaging Spectroradiometer
MOEFCC	Ministry of Environment, Forest and Climate Change
MOSES	Modular Observation Solutions for Earth Systems
MPA	Marine Protected Area
MPCA	Minnesota Pollution Control Agency
MRF	Material Recovery Facility
M-SDM	Mechanistic Species Distribution Model
MSE	Mean of squared residuals
MT	Metric Ton
MUSIC	Model for Urban Stormwater Improvement Conceptualization
MV	Market value
MVLR	Multivariate linear regression
N2	Nitrogen Gas
NASA	National Aeronautics and Space Administration
NAT	NbS Aiding Technologies
NBM	Naive Bayesian Model
NbS	Nature-Based Solutions
NCAP	National Clean Air Program
NCP	Nature’s Contributions to People
NDVI	Normalized Difference Vegetation Index

NFF	Nature Future Framework
NGO	Non-Governmental Organization
NH3-	Ammonia
NMPB	National Medicinal Plants Board
NMSHE	National Mission for Sustaining Himalayan Ecosystem
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxide
NP	National Park
NPK	Nitrogen, Phosphorus and Potassium
NPP	Net Primary Production
NPP	Nuclear Power Plant
Nr	Nitrogen
NRCP	National Research Council of the Philippines
NS	Northern sector
NSM	Niche Suitability Models
O3	Trioxygen
OC	Outer channel
OCM	Ocean Color Monitor
OECD	Organization for Economic Cooperation and Development
OLI	Operational Land Imager
OM	Organic Matter
OOB	Out-of-bag
ORCHIDEE	Organizing Carbon and Hydrology in Dynamic Ecosystems
p	probability value
P10	10 percentile training presence
PA	Presence-Absence
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PAUC	Partial Area Under ROC curve
PB	Presence-Background
PBL	Planetary Boundary Layer
PBM	Process-Based Model
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PCC	Percent of Sites Correctly Classified
PCC	Potential Carrying Capacity
PD	Phylogenetic Diversity
PET	Potential Evapotranspiration
PFT	Plant Functional Type
PFZ	Potential Fishing Zone
pH	Potential of Hydrogen or Power of Hydrogen
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PK	Pundasyon ng Kalikasan
PM	Particulate Matter
PM10	Particulate matter having size less than 10 μm and more than 2 μm

PM2.5	Particulate matter having size less than 2 μm
PNET (C.N)	Photosynthetic/Evapotranspiration model (Carbon Nitrogen)
PPM	Parts Per Million
ppmv	parts per million by volume
PRA	Participatory Rural Appraisal
pROC	partial area under the Receiver Operating Curve
PSA	Philippine Statistics Authority
p-value	Probability Value
QGIS	Quantum Geographic Information System
R&D	Research and Development
RA	Republic Act
RC	Rotation Coefficient
RCC	Real Carrying Capacity
RCI	Random Consistency Index
RCM	Regional Circulation Model
RCP	Representative Concentration Pathways
RET	Rare Endangered Threatened (Species)
RF	Random Forest
RF	Regularization Factor
RMSE	Root Mean Squared Error
RoA	Republic of Azerbaijan
ROC	Receiver Operating Characteristic
RS	Remote Sensing
RSFs	Resource selection functions
RTI	Right to Information
SAFAR	System of Air Quality and Weather Forecasting and Research
SCLWMC	Seven Crater Lakes and Watershed Management Council
SCS	State Committee of Statistics of Azerbaijan
SD	Secchi Disk Depth
SD	Standard Deviation
SDBM	Simple Diagnostic Biosphere Model
SDG	Sustainable Development Goals
SDGVM	Sheffield Dynamic Global Vegetation Model
SDM	Spatial Distribution Modeling
SDM	Species Distribution Model
SDMs	Species distribution models
SDVD	Secchi Disk Visibility Depth Index
Se	Sensitivity
SECC	Socio-economic Carrying Capacity
SEDAC	Socio-economic Data and Applications Centre
SEIB-DGVM	Spatially Explicit Individual Based-Dynamic Global Vegetation Model
SEM	Sustainable Ecosystem Management
SES	Social-ecological systems
SESAM	Spatially explicit species assemblage modeling

SFSLR	Step-wise Forward Selection Logistic Regression
SHPP	Small Hydropower Plant
SIMWAL	Simulated Walnut
SMLP	Samahang Mangingisda ng Lawa ng Pandin
SOC	Soil Organic Carbon
SOI	Survey of India
SOx	Sulfur Oxide
Sp	Specificity
SPCB	State Pollution Control Board
SpThin	Spatial Thinning
SR	Species Richness
SRE	Surface Range Envelop
SRES	Special Report on Emission Scenarios
SROCC	Special Report on the Ocean and Cryosphere in a Changing Climate
SRTM	Shuttle Radar Topography Mission
SS	Southern Sector
SSDM	Stacked-SDMs
SSE	Sum of Square Error
SSP	Shared Socio-economic Pathway
SST	Sea Surface Temperature
SVAT	Surface Vegetation Atmosphere Transfer
SVM	Support Vector Machine
SWM	Solid Waste Management
TAR	Third Assessment Report
TCC	Tourism Carrying Capacity/Total Carrying Capacity
TDS	Total Dissolved Solids
TECM	Terrestrial Ecosystem Carbon Model
TEEB	The Economics of Environment and Biodiversity
TERN	Terrestrial Ecosystem Research Network
TIRS	Thermal Infrared Sensor
TL	Total Length
TLI	Trophic Level Index
TN	Total Nitrogen
TOF	Trees Outside Forests
TP	Total Phosphorus
TPP	Thermal Power Plant
TRIFFID	Top-down Representation of Interactive Foliage and Flora Including Dynamics
TS	Total Sensitivity
TSA	Targeted Scenario Approach
TSPCB	Telangana State Pollution Control Board
TSS	Total Suspended Solid
TSS	True Skill Statistic
TSS	True Skill Statistics

TURB	Turbidity
UC ANR	University of California Agriculture and Natural Resources
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UPLB-FEWS	University of the Philippines Los Baños—Fish Kill Early Warning System
USAID	United States Agency of International Development
USD	United States Dollar
USDM	Uncertainty Analysis for Species Distribution Models
USGS	United State Geological Survey
UT	Union Territory
UTM	Universal Transverse Mercator
UYRDC	Uttarakhand Youth Rural Development Centre
VIF	Variance Inflation Factor
WB	Water Body
WE	Taxonomic Weighted Endemism
WECC	Water Ecological Carrying Capacity
WG	Western Ghats
WGS84	World Geodetic System 1984
WHO	World Health Organization
WPE	Weighted Phylogenetic Endemism
WQBCC	Water Quality and Biodiversity Carrying Capacity
WT	Water temperature
WTO	World Tourism Organization
WTTC	World Travel and Tourism Council
WWF	World Wildlife Fund
XGB	XGBoost Model

Immunomodulators in Aquaculture and Fish Health

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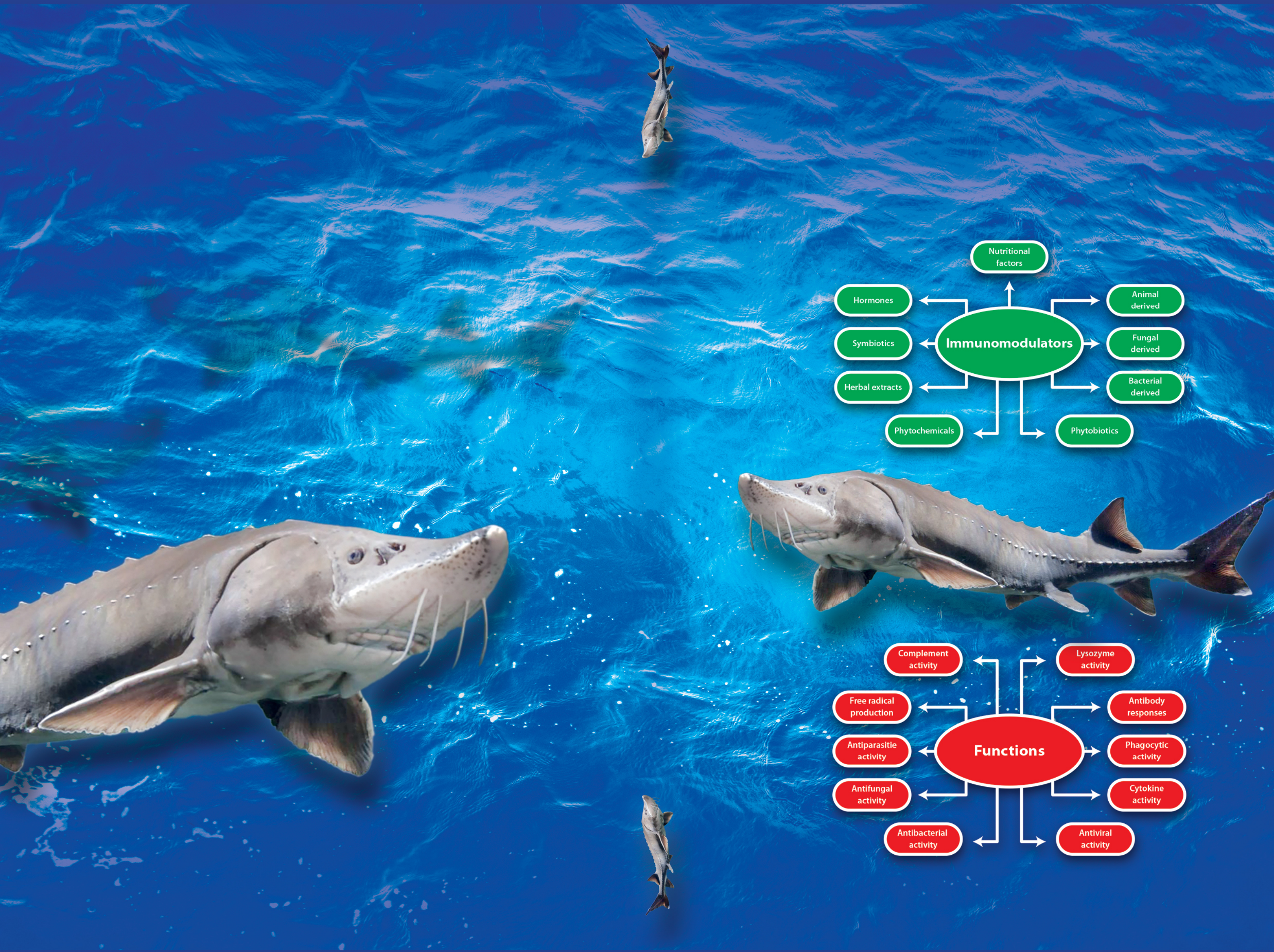

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Foreword

It is my great pleasure to write this foreword for a very timely book, "**Immunomodulators in Aquaculture and Fish Health,**" edited by my colleagues, Preetham Elumalai, Mehdi Soltani, and Sreeja Lakshmi.

As a believer in identifying opportunities and linking scientific evidence, innovation with improved sustainable aquatic production, together with my professional commitment in the aquaculture industry of over 40 years, I have found this volume of work to be a very extensive review. The wealth of information on the potential therapeutic and preventative roles of immunomodulators, in combating diseases in farmed aquatic species is truly insightful.

The importance of this book defines an era, where the performance of aquatic foods has been greatly recognized and concerted efforts have been initiated to enhance production and to bridge the ever-expanding supply-demand gap, for aquatic blue foods worldwide.

The burden of disease is high in aquatic production and currently estimated as $10 billion USD annually. With the decades of experience and lessons learned in aquatic animal health management, it is convinced that prevention is better than cure for aquatics and investing in prevention is more cost-effective than investing in therapy.

In this regard, I believe we should be aiming for more tools and procedures such as vaccines and vaccination and more research efforts should be supported, both at academic and commercial levels.

I congratulate the editors for this comprehensive volume and hope it will serve the purpose of increasing awareness of immunomodulators towards the implementation within aquatic animal health management.

Dr Rohana Subasinghe
Founder + Director,
FUTUREFISH Co. Ltd.
www.futurefish.org

Aquaculture plays a vital role in global food security and economic development. It is the fastest-growing food production sector in the world and has been for some considerable time, with an average annual growth rate over the last 50 years of 8%. The latest FAO State of the World Fisheries and Aquaculture Report (2022) estimated global aquaculture production of aquatic animals at a record 87.5 million tonnes, with a value of USD 264.8 billion; this equates to 49% of total aquatic animal supply by volume and 65% by value. Approximately 2.5 million people are directly employed in the aquaculture sector around the world, with most of these in Asia, followed by Africa and Latin America. Women comprise 28% of these employment figures, slightly more than the average of 25% for the agriculture sector as a whole.

Infectious diseases represent a major constraint to the continued growth of global aquaculture, with estimated annual losses of at least USD 6 billion. The industry is particularly prone to disease outbreaks because of high stocking densities which increase pathogen transmission rates and reduce water quality, and also because of low genetic diversity in many breeding stocks, which may compromise the immune response to infection of cultured animals. Antimicrobials and antiparasitics are used therapeutically and prophylactically, but these treatments are often expensive and there is concern over the potential adverse effects of their widespread use, particularly the promotion of antibiotic resistance. Vaccination is another option for disease control, but vaccines often have limited efficacy, particularly for juvenile fish which do not have a fully developed immune response. There is therefore increasing interest in alternative approaches to disease control in aquaculture.

Immunomodulators are substances that affect the functioning of the immune system. A range of natural and synthetic products have been used or proposed, with varying degrees of scientific evaluation, to control infectious diseases in aquaculture. This book provides a very comprehensive and timely exploration of their efficacy and potential role in an aquatic animal health management system. The various sections of the book provide an overview of immunomodulators and their mode of action; the potential of immunomodulators to provide a more sustainable approach to disease control; the current use of immunomodulator products in aquaculture; and finally, their efficacy, limitations, and future prospects for the aquaculture industry. The book will be of great benefit to researchers in aquatic animal health, aquatic veterinarians, aquaculture managers, and all of us who wish to promote an economically viable and environmentally sustainable aquaculture industry.

Professor Alan Lymbery
Director, Centre for Sustainable Aquatic Ecosystems
Harry Butler Institute, Murdoch University
Australia

Editors

Preetham Elumalai, PhD, is an associate professor at the Department of Marine Biology, Cochin University of Science and Technology, Kochi, Kerala, India. He earned a master's degree from the University of Madras and a PhD in biochemistry and molecular immunology from the Institute for Immunology, University of Regensburg, Germany. His research practice includes bioassay-guided identification of novel marine compounds, unveiling fish lectins in innate immune defense, aquatic vaccine development, evaluation of cost-effective feed additives and nutrigenomics, and effects of environmental pollutants on marine ecosystems. He has been a partner in numerous EU-, Indian-, and UK-funded projects (e.g., IVVN, BactiVac). He has written more than 70 peer-reviewed articles and has two patents in his name apart from editing five books (Springer, CRC Press) and has presented his work at more than 60 national and international conferences. He has been awarded the prestigious INSA fellowship (2018); MASTS, Fellowship (2019); IVVN award, UK (2020); FRSB award (2021); and BactiVac award, UK (2022).

Mehdi Soltani, PhD, is a distinguished professor at the University of Tehran and an adjunct professor at Murdoch University, Australia. He earned a DVM from the University of Tehran and PhD in aquatic animal health from the University of Tasmania, Australia. Professor Soltani has an international reputation for research on aquatic animal health, with 290 published scientific papers, collaborations with researchers throughout the world, and editorship of scientific journals in fisheries and veterinary science. He chaired government advisory committees in fisheries and aquaculture and has also worked closely with the aquaculture industry. He developed and patented a number of fish vaccines, which are registered throughout the Middle East. He also taught numerous undergraduate courses and supervised many higher degree students. His research interests include vaccine development for fish pathogens; immunopathogenesis of infectious agents in fish/shellfish; and development of alternative therapies such as immunostimulants, probiotics, and phytobiotics for disease control in farmed fish and shellfish.

Sreeja Lakshmi, PhD, is a postdoctoral research scientist in collaboration with Moredun Research Institute (MRI), UK. She graduated from Calicut University and earned a PhD in biochemistry and functional genomics from the Institute for Molecular Biology, University of Regensburg, Germany. She has published research articles in peer-reviewed international journals and authored books and book chapters. She has been awarded prestigious research grants from the Bavarian Research Foundation (Bayerische Forschungsstiftung), Government of Bavaria, Germany; an HRD-Fellowship for Women Scientists from the Department of Health Research, Government of India; and a MASTS (Marine Alliance Science and Technology, Scotland) Award for Postdoctoral and Early Career Research Exchanges (PECRE). She has visited the University of Aberdeen, Scotland, and received an IVVN Fellowship grant from the International Veterinary Vaccinology Network (IVVN), UK.

Contributors

Maram H. Abduljabbar
Department of Pharmacology and Toxicology, College of Pharmacy
Taif University
Taif, Saudi Arabia

Catherine Alexander
Jayaraj Annapackiam College for Women
Thamaraikulam, Periyakulam, Tamil Nadu

Manal E. Alosaimi
Department of Basic Science, College of Medicine
Princess Nourah Bint Abdulrahman University
Riyadh, Saudi Arabia

Babitha Rani A.M.
Aquaculture Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Yaser Arafath
Department of Microbiology, School of Life Sciences
Pondicherry University
Puducherry, India

Palanichamy Ayyappan
Department of Botany
Government Arts College
Melur, Madurai, Tamil Nadu, India

Paulraj Balaji
PG and Research Centre in Biotechnology
MGR College
Hosur, Tamil Nadu, India

Ramalakshmi Balasubramanian
Department of Zoology
Lady Doak College
Tallakulam, Tamil Nadu

Sajna Beegum
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology (CUSAT)
Lakeside Campus, Fine Arts Avenue, Cochin, Kerala, India

Ankeet Bhagat
Aquatic Toxicology Lab, Department of Zoology
Guru Nanak Dev University
Amritsar, Punjab, India

Faggio C
Department of Chemical, Biological, Pharmaceutical and Environmental Sciences
University of Messina
Messina, Italy

Thongam Ibemcha Chanu
Aquaculture Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Hethesh Chellapandian
PG and Research Department of Biotechnology and Microbiology
National College (Autonomous)
Tiruchirappalli, Tamil Nadu, India

Azubuike V. Chukwuka
National Environmental Standards and Regulations
Enforcement Agency (NESREA)
Nigeria

Owias Iqbal Dar
Aquatic Toxicology Lab, Department of Zoology
Guru Nanak Dev University
Amritsar, Punjab, India
and
Department of Biosciences
Chandigarh University
Gharuan, Punjab, India

Sweta Das
Department of Aquatic Animal Health Management
Kerala University of Fisheries and Ocean Studies
Panangad, Kochi, Kerala

Maderi Velayutham Dassprakash
Department of Biochemistry
Sri Sankara Arts and Science College
Enathur, Kanchipuram, Tamilnadu, India

Ashutosh D. Deo
Fish Nutrition, Biochemistry and Physiology Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Dipanjan Dutta
Aquaculture Laboratory, Department of Zoology
The University of Burdwan
Golapbag, Burdwan, West Bengal, India
and
Post Graduate Department of Zoology
Hooghly Mohsin College
Chinsurah, Hooghly, West Bengal, India

Hiam Elabd
Aquatic Animals' Medicine Department, Faculty of Veterinary Medicine
Benha University
Moshtohor, Toukh, Egypt

Gehad E. Elshopakey
Department of Clinical Pathology, Faculty of Veterinary Medicine
Mansoura University
Mansoura, Dakahlia, Egypt

Preetham Elumalai
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology (CUSAT)
Lakeside Campus Fine Arts Avenue, Cochin, India

Falco F
Institute of Marine Biological Resources and Biotechnologies, National Research Council (CNR)
Mazara Del Vallo, Italy

Caterina Faggio
Department of Chemical, Biological, Pharmaceutical and Environmental Sciences
University of Messina
Messina, Italy

Aifa Fathima
Department of Microbiology, School of Life Sciences
Pondicherry University
Puducherry, India

Femi John Fawole
Fish Nutrition and Biochemistry Unit, Department of Aquaculture and Fisheries
University of Ilorin
Ilorin, Nigeria

S. Ferosekhan
Department of Aquaculture
ICAR – Central Institute of Freshwater Aquaculture
Bhubaneswar, Odisha, India

Koushik Ghosh
Aquaculture Laboratory, Department of Zoology
The University of Burdwan
Golapbag, Burdwan, West Bengal, India

M. Divya Gnaneswari
Department of Zoology
Gargi College
New Delhi, India

Tamilselvan Gokul
PG and Research Department of Zoology
Vivekananda College
Tiruvedakam (West), Madurai, Tamil Nadu, India

Aseem Grover
Department of Chemistry, Biochemistry and Forensic Sciences, Amity School of Applied Sciences
Amity University Haryana
Panchgaon, Haryana, India

Saqib Hassan
Department of Biotechnology, School of Bio and Chemical Engineering
Sathyabhama Institute of Science and Technology
Chennai, Tamilnadu, India
and
FutureLeaders Mentoring Fellow
American Society for Microbiology
Washington, USA

Ramchandran Ishwarya
Mandapam Regional Centre, ICAR – Central
Marine Fisheries Research Institute
Mandapam, Tamil Nadu, India

Rengarajan Jayakumar
ICAR – Central Institute of Brackishwater Aquaculture (CIBA)
MRC Nagar, Chennai, Tamil Nadu, India

Ramaraj Jayakumararaj
Department of Botany
Government Arts College
Melur, Madurai, Tamil Nadu, India

Manish Jayant
Fish Nutrition, Biochemistry and Physiology Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Sivakamavalli Jeyachandran
PG and Research Department of Biotechnology and Microbiology
National College (Autonomous)
Tiruchirappalli, Tamil Nadu, India

Divya Jyoti
School of Biological and Environmental Sciences
Shoolini University
Solan, India

Mian Adnan Kakakhel
MOE Key Laboratory of Cell Activities and Stress Adaptations, School of Life Sciences
Lanzhou University
Lanzhou, P.R. China

Gbadamosi Oluyemi Kazeem
Department of Fisheries and Aquaculture Technology
Federal University of Technology
Akure, Ondo State, Nigeria

Tejaswini Kinnera
Fish Nutrition, Biochemistry and Physiology Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

George Seghal Kiran
Department of Food Science and Technology, School of Life Sciences
Pondicherry University
Puducherry, India

Arathi Kollath
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology (CUSAT)
Lakeside Campus, Fine Arts Avenue, Cochin, India

Devasree Ganesh Kumar
The Madura College (Autonomous)
Vidya Nagar, Madurai, Tamil Nadu

Kamatchi Ramesh Kumar
PG and Research Department of Zoology
Vivekananda College
Tiruvedakam (West), Madurai, Tamil Nadu, India

Sreeja Lakshmi
Kerala University of Fisheries and Ocean Studies, Panangad
Kochi, India

Banaee M
Aquaculture Department, Faculty of Natural Resources and the Environment
Behbahan Khatam Alanbia University of Technology
Behbahan, Khuzestan Province, Iran

Mauro M
Department of Biological, Chemical and Pharmaceutical Sciences and Technologies (STEBICEF)
University of Palermo
Palermo, Italy

Heba Mahboub
Fish Diseases and Management Department, Faculty of Veterinary Medicine
Zagazig University
Zagazig, Sharkia, Egypt

R. Dinakaran Michael
Centre for Fish Immunology
Vels Institute of Science, Technology, and Advanced Studies (VISTAS)
Pallavaram, Chennai, Tamil Nadu

Shamna Nazeemashahul
Fish Nutrition, Biochemistry and Physiology Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Hussain Nottanalan
Fish Nutrition, Biochemistry and Physiology Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Neha Omgy
Kerala University of Fisheries and Ocean Studies, Panangad
Kochi, India

Lokesh Pawar
College of Fisheries (Central Agricultural University – Imphal)
Agartala, Tripura, India

Nikhila Peter
Fish Nutrition and Feed Technology Laboratory, Department of Aquaculture
Kerala University of Fisheries and Ocean Studies
Panangad, Kochi, Kerala

Chinnathambi Pothiraj
Department of Botany
Government Arts College
Melur, Madurai, Tamil Nadu, India

Chiranjiv Pradhan
Fish Nutrition and Feed Technology Laboratory, Department of Aquaculture
Kerala University of Fisheries and Ocean Studies
Panangad, Kochi, Kerala

S. Kalaivani Priyadarshini
Department of Biotechnology
Lady Doak College
Hakim Ajmal Khan Rd, Tallakulam, Tamil Nadu

Neha Qureshi
Fisheries Economics, Extension and Statistics Division
ICAR-CIFE, Mumbai, Maharashtra, India

Priyatharsini Rajendran
Department of Zoology
Lady Doak College
Tallakulam, Tamil Nadu, India

Akshay Thuruthiyil Rajesh
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology (CUSAT)
Lakeside Campus, Cochin, Kerala, India

Subramanian Ramya
Department of Zoology
Yadava College (Men)
Madurai, Tamil Nadu, India

Einar Ringø
Norwegian College of Fishery Science, Faculty of Biosciences, Fisheries and Economics
UiT, The Arctic University of Norway
Tromsø, Norway

Nimai Chandra Saha
University of Burdwan
Purba Barddhaman, India

Shubhajit Saha
Fisheries and Ecotoxicology Research Laboratory
Department of Zoology
The University of Burdwan, Burdwan
West Bengal, India

Parimal Sardar
Fish Nutrition, Biochemistry and Physiology Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Joseph Selvin
Department of Microbiology, School of Life Sciences
Pondicherry University
Puducherry, India

Arun Sharma
Aquatic Animal Health Management Division
ICAR – Central Institute of Fisheries Education
Mumbai, Maharashtra, India

Sunil Sharma
Aquatic Toxicology Lab, Department of Zoology
Guru Nanak Dev University
Amritsar, Punjab, India

Reshma Sinha
Department of Animal Sciences
Central University of Himachal Pradesh
Kangra, India

Subramaniam Sivakumar
Department of Biochemistry
Sri Sankara Arts and Science College
Enathur, Kanchipuram, Tamilnadu, India

Hamed Mousavi Sabet
Department of Fisheries, Faculty of Natural Resources
University of Guilan
Sowmeh Sara, Iran

Mehdi Soltani
Centre for Sustainable Aquatic Ecosystems, Harry Butler Institute
Murdoch University
Perth, Australia
and
Department of Aquatic Animal Health Faculty of Veterinary Medicine
University of Tehran
Tehran, Iran

Parasuraman Aiya Subramani
Centre for Fish Immunology
Vels Institute of Science, Technology, and Advanced Studies (VISTAS)
Pallavaram, Chennai, Tamil Nadu

C. Shanmuga Sundaram
Department of Microbiology
Hindustan College of Arts and Science
Kelambakkam, Chennai, Tamilnadu, India

Baskaralingam Vaseeharan
Biomaterials and Biotechnology in Animal Health Lab, Department of Animal Health and Management
Alagappa University
Karaikudi, Tamil Nadu, India

Karthikeyan Venkatachalam
Faculty of Innovative Agriculture and Fishery Establishment Project, Prince of Songkla
University Surat Thani Campus
Makham Tia, Mueang, Surat Thani, Thailand

Rantham Subramaniam Venkatesan
Lakshmi Bangaru Arts and Science College
Melmaruvathur, Chengalpet, Tamilnadu, India

Section I

Immunomodulators: An overview

1

Immunomodulators: An Introduction

Falco F[1], Banaee M[2], Mauro M[3], Faggio C[4], Arathi Kollath[5], and Preetham Elumalai[5]
[1]*Institute of Marine Biological Resources and Biotechnologies, National Research Council (CNR), Mazara Del Vallo, Italy*
[2]*Aquaculture Department, Faculty of Natural Resources and the Environment, Behbahan Khatam Alanbia University of Technology, Behbahan, Khuzestan Province, Iran*
[3]*Department of Biological, Chemical and Pharmaceutical Sciences and Technologies (STEBICEF), University of Palermo, Palermo, Italy*
[4]*Department of Chemical, Biological, Pharmaceutical and Environmental Sciences, University of Messina, Messina, Italy*
[5]*Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology (CUSAT), Lakeside Campus, Fine Arts Avenue, Cochin, India*

1.1 Introduction

Before going into detail about immunomodulators, it's important to understand how immune systems work and how different variables can stimulate the immune system in different ways. Many substances are known to exist in our environment, and they are always capable of affecting the immune systems of living beings. For example, it has been shown that the immune system plays an important role in aquatic organisms subjected to various physical stress conditions (Mauro et al. 2021), noise pollution (Mauro et al. 2020), drug pollution (Mauro et al. 2022), or bacterial activity (Vizzini et al. 2021). Several biomarkers are also used to evaluate the health status of important animals in aquaculture (Mauro et al. 2022). In addition, aquatic organisms are also an excellent source of molecules with antimicrobial and antitumor activity (Mauro et al. 2022). In this chapter, we briefly introduce the function and role of immunomodulators, especially in the fish immune system. Fish have an immune system that is similar to that of higher vertebrates. As a result, every living entity must preserve its integrity and health status when challenged and must be able to recognise and distinguish between "self" (its molecules, cells, and tissues) and "non-self" (all other organisms or substances). The purpose of the immune system is to recognise the millions of non-self organisms that are potentially harmful to the self and to eliminate them or reduce their impact so that no damage occurs to the self (Takx-Köhlen 1992). This chapter does not explain self-immunity or self-tolerance phenomena that lead to suppression of the immune system and the spread of many autoimmune diseases in fish. We prefer to divide the immune system into two broad categories based on function, namely the innate immune system (non-specific immune system) as the first line of defence against pathogens (Carbone & Faggio 2016) and the adaptive immune system (specific or acquired immune system) (Marshall et al. 2018).

1.2 How Do the Immunostimulants Work in Fish?

Since their embryonic life stage, fish have relied on their innate immune system, and their survival depends on it. The skin is the principal non-specific defence in fish and plays a key role in protecting and preventing the entry of pathogens into the epithelium through the secretion of a mucus layer involved in the immunity system (Salinas et al. 2011). The cells and mediators involved will differ depending on the time, the trigger, the anatomical location (inflammation can affect any tissue), and the severity of the inflammation (Calder et al. 2013). Teleosts have a cellular defence system that includes macrophage-like phagocytic cells, neutrophils, and natural killer (NK) cells, as well as T and B lymphocytes, as well as various humoral defence components like complement (classical and alternative pathways), lysozyme, natural hemolysin, transferring factor, and C-reactive protein (Watts et al. 2001). Furthermore, teleosts and elasmobranchs are the most primitive groups that possess the major histocompatibility complex (MHC) and T-cell receptors, which are the primary components of the immune response against

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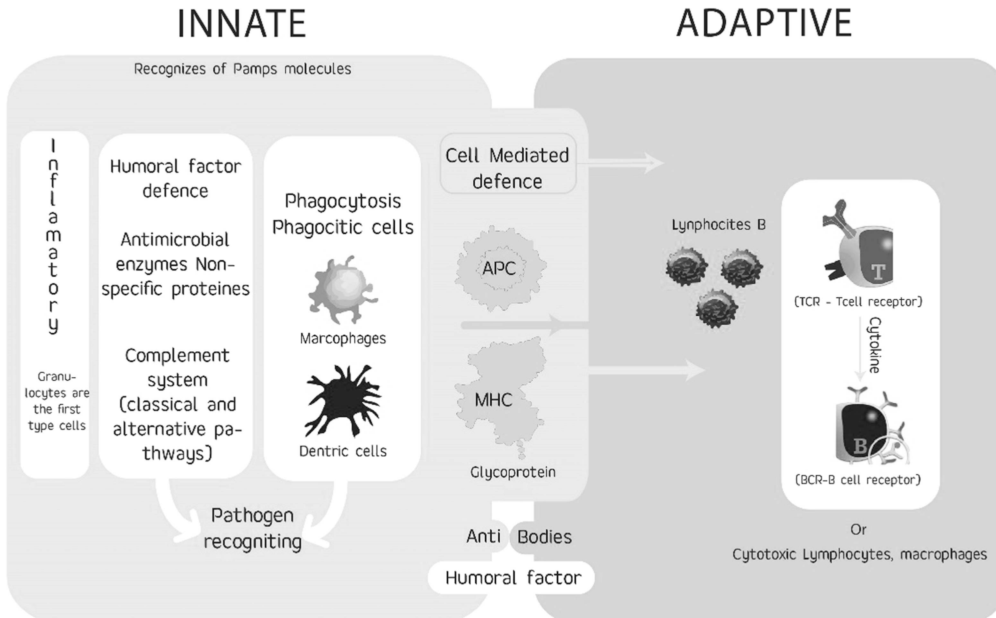

FIGURE 1.1 The immune system assumption in teleostfish.

The above figure represents types of immune system in fish. Innate immunity provides primary defence against pathogens by activating phagocytosis and antimicrobial, complement activation. On the other hand, adaptive immune system functions by stimulating specific lymphocytes.

pathogenic organisms (Zou & Secombes 2016). Sakai et al. (2021) investigated the role and function of cytokines in fish (interferon, interleukin 2, and macrophage activating factors), whereas among the lymphoid organs found in fish to mediate the responses have been the thymus, spleen, and kidney (Zapata 1996). The collaboration of fish innate and adaptive (memory) immune systems to eliminate intruders or activate defensive mechanisms is now well recognised; these two systems are classified into cell-mediated defence and humoral components (soluble substances). Figure 1.1 describes their main functions.

The innate system is made up of three parts: the tegument (skin and mucus), cellular components (granulocytes, monocytes, macrophages, and natural killer cells), and humoral components (granulocytes, monocytes, macrophages, and natural killer cells) (the complement system, antimicrobial enzyme system, and non-specific mediators such as interferon and interleukin). Furthermore, inflammation is thought to be an innate immune response driven by complex interactions between cellular and humoral components. Granulocytes are the first cells to arrive at the site of inflammation and are responsible for killing infections. Innate and adaptive immune systems normally work in concert, with innate responses serving as the host's first line of defence and enabling adaptive responses by antigen-specific T and B cells to produce antibodies in the presence of specific humoral components called histocompatibility molecules and glycoprotein receptors encoded by genes in the major histocompatibility complex (MHC).

1.3 Immunomodulators

The immunomodulators are all antigens (chemical or physical) that manage to vary the immune system's activities. When an agent depresses the immune system, also known as an immunosuppressant, they can cause a negative response. Immunosuppression is described by Dohms and Saif (1984) as "a state of transient or persistent dysfunction of the immune response resulting from insults to the immune system and increasing susceptibility to disease," and the qualifier "and frequently a suboptimal antibody response." Otherwise, if an immunomodulator can increase or promote activity, it is called an immunostimulant. Finally, another category is immune adjuvants, which hold the promise of being the actual modulators (De Paula Barbosa 2014) of the immune response, especially to enhance the vaccine's efficacy. An example in this regard is Freund's complete adjuvant, which is being used to enhance the potency of poor immunogenic substances (Tengjaroenkul & Yowarach 2011). Very often, the same agent can have both immunostimulant and immunosuppressive effects on an organism. Studies showed that the physiological response of fish to different doses of immune system stimulants could be different (Petit 2019). In other words, in some cases, excessive use of several immunostimulants simultaneously may cause immunosuppression in fish (Raa 1996).

1.4 Immune Suppressors

Immunosuppressive compounds are chemical, biochemical, and physical agents that suppress, decrease, or disrupt the immune system functions in fish. Studies show that all immunosuppressant compounds carry a severe risk of infection. Various types of immunosuppressive materials may change the immune response in fish when challenged by pathogens (Hidasi 2017). Most immunosuppressants may weaken the immune system by altering the gene expression of immune parameters. However, some immunosuppressive materials may decrease the absorption of vitamins and dietary supplements. Furthermore, immunosuppressive compounds reduce the ability of fish's innate and specific immune systems to respond to foreign objects. The interaction of immune suppressants with drugs may also reduce their effectiveness. The following part explains some immune suppression effects on the fish immune system.

1.4.1 Environmental Stressors

The functions of the immune system of fish depend on nutrition, environmental conditions, health, gender, and ontogeny. Temperature, dissolved oxygen, salinity, pH, and hardness ranges may also differ between fish species. Therefore, environmental fluctuations could alter the fish's physiological status and immunological response. For example, hyperosmotic stress could decrease the immune system response of *Scatophagusargus* to bacterial infection (Lu et al. 2022). In hostile biological conditions, fish may not be able to feed properly. As a result, they will not have enough energy to allocate to the immune system (Estensoro et al. 2012). Moreover, breeder malnutrition may lead to epigenetic changes in the offspring's immune and metabolic genes. Improper fish nutrition under stressful conditions can also lead to impaired immune priming by dendritic cells and monocytes and impair the function of effective memory T-cells. Acute and chronic stress are critical agents in suppressing the immune functions of fish (Guo et al. 2021).

Environmental stress can suppress the immune response in fish. As a result, fish that live in stressful environments may have a weaker immune system than fish that live in normal conditions. Guo et al. (2022) discovered that exposing Wuchang Bream (Megalobramaamblycephala) to ammonia nitrogen reduced immunoglobulin M (IgM), interleukin 1 (IL-1), and tumour necrosis factor (TNF-) levels while decreasing TLR mRNA expression. Following exposure to ammonia, there was a considerable drop in IgM and component C3 levels and lysozyme activity in the spleen and head kidney of Pelteobagrusvachellii (Qi et al. 2017). Moreover, those latter authors showed that high ammonia concentrations in the environment could disrupt the expression of immune-related genes in crucian carp (*Carassius auratus)* (Mazini et al. 2022). It was observed that the immune system's response would be decreased when fish were exposed to the stress of transporting between different farms. They discovered that an increase in corticosteroids was linked to immunological suppression in fish. Corticosteroids may affect the effectiveness of the immune system by altering mRNA expressions implicated in immunological parameters. Therefore, to better understand the impact of environmental stressors, each of the stressors has been discussed separately.

1.4.1.1 Agrochemicals

Agrochemicals include fertilisers, phytohormones, and pesticides (e.g., insecticides, pesticides, herbicides, and fungicides) used in the agriculture industry. Agrochemicals also include medications, disinfectants, hormones, and growth stimulants used in cattle, poultry, and aquaculture. Suppression of the immune system in fish exposed to agrochemicals can increase the susceptibility and vulnerability of fish to various pathogens (Banaee et al. 2019; Farag et al. 2021). Changes in intrinsic and specific immunological indices are perhaps the most important reason for suppressing the immune system of fish exposed to agrochemicals (Hassan et al. 2022). This section explains the reasons for the decay of the fish immune system after exposure to agrochemicals.

Due to their lipophilic nature, most pesticides easily cross biological barriers and enter the aquatic body. Pesticides can suppress the immune system by interacting with immune agents or causing oxidative damage in tissues involved in the immune system (Farag et al. 2021). Previous studies have shown that fish exposure to pesticides can cause changes in haematological parameters, including a decrease in leucocytes and an alteration in the differential count of white blood cells (Banaee et al. 2008). In fish treated with pesticides, decreased total immunoglobulin, C3, and C4 complement activities have also been reported (Hatami et al. 2019). A significant decrease was reported in lysozyme activity, respiratory burst activity, and total immunoglobulin levels in Nile tilapia (Oreochromis *niloticus*) exposed to cypermethrin (Abdel-Tawwab et al. 2020). Exposure to pesticides can also lead to changes in the gene expression of inflammatory cytokines such as TNF-, IL-1, and IL-6 (Acar et al. 2021; Wang et al. 2020).One study found that glyphosate exposure altered the levels of interferon- (IFN-) and IL-1 in the hematopoietic tissues of common carp (*Cyprinus carpio*).

1.4.1.2 Heavy Metals

Exposure to heavy metals at levels higher than the accepted dosages could suppress the immune response in fish. Also, the transmission of heavy metal contamination through the food chain can affect fish immune systems (Mohiseni et al. 2017). A significant decrease in immune functions of Vardar chub (*Squalius vardarensis,* Karaman) may be due to histopathological damage to the kidney and spleen (Jordanova et al. 2017). Bernier et al. (1995) demonstrated that bioaccumulation of heavy metals could cause suppression of the immune system, autoimmune diseases, increased susceptibility to pathogens, and inflammation reactions in fish. Banaee et al. (2019) demonstrated that alterations in humoral immune parameters in fish exposed to heavy metals indicated quenching of innate immune responses. Manganese reduced lysozyme activity and IgM levels while increasing the expression of tlr3, tnf-, il-1, and il-6 in juvenile yunlong groupers (*Epinephelus maureus* and *E. lanceolatus*) (Wang et al. 2022). Heavy metals were exposed to *Centrarcus lal.rax.* changes in bactericidal activity in the skin mucosa of gilthead seabream (*Sparus aurata*) after heavy metal exposure have also been reported (Guardiola et al. 2015). A significant decrease in HK-B cell proliferation, IgM level, and serum bactericide potential was observed in catfish exposed to arsenic (Ghosh et al. 2007). Heavy metal exposure in fish may affect leucocyte counts. Furthermore, changes in the granulocyte/granulocyte ratio suggest that heavy metals trigger the fish immune system. A significant increase in monocyte and neutrophil numbers and a significant decrease in lymphocyte numbers were reported in goldfish (*C. auratus*) after exposure to manganese (Aliko et al. 2018).

Genotoxicity may be linked to oxidative stress, DNA damage, and changes in mRNA expression. Indeed, Ghazy et al. (2017) found that the gene expression in the immune system changed in Nile tilapia that lived in waters contaminated with heavy metals. Heavy metals altered the expression of IL1, TNF-, IFN, Mx, Lyz, C3B, and CXCL-Clc in zebrafish (*D. rerio*) embryos (Cobbina et al. 2015). Moreover, significant changes in the mRNA transcription of immune-related genes were observed in the leucocytes of European sea bass exposed to cadmium, lead, and mercury (Morcillo et al. 2015).

1.4.2 Other Xenobiotics

Segner et al. (2021) showed that xenobiotics could bind to the aryl hydrocarbon receptor (AhR) as a vital transcription factor. Then, complex AHR and xenobiotics were set on sequence response elements and changed immune-related gene expression. Suppression of the immune system in aquatic animals exposed to xenobiotics may be due to energy shifts for detoxification. Decreased energy allocated to the immune system may reduce its performance.

1.4.3 Natural Toxins

Qiao et al. (2013) investigated the immunotoxicity of cyanobacteria in Crucian carp. The immunological fish response might be boosted by blood cyanobacteria, according to authors Rymuszka and Adaszek (2013), who assessed the effects of microcystin derived from cyanobacteria on carp leucocyte proliferation under *in vitro* conditions. They showed microcystin could increase apoptosis rates in white blood cells. Rymuszka and Sieroslawska (2018) showed that carp leucocytes' half-life decreased after exposure to nodularin, a cyanobacteria toxin. Contamination of food with aflatoxin toxins can reduce the potency of non-specific immune systems in fish (Bitsayah et al. 2018). In common carp fed with aflatoxins-contaminated feed, Bitsayah et al. (2018) found a substantial shift in complement C3, C4, and CH50, lysozyme activity, and total immunoglobulin content.

1.4.4 Anti-nutritional Agents

Some antinutritional compounds in the diet can suppress the immune system in aquatic animals. However, the immunodepressive effects of anti-nutritional compounds on the immune system depend on their bioavailability and their dosages in feed. By generating cytotoxicity, anti-nutritional substances may have an impact on immune function. Furthermore, by producing inflammation or modifying the quantity of inflammatory markers in the blood, these substances may impair immunological function. Inhibiting the absorption of micronutrients in the intestine by anti-nutritional compounds can also play a role in suppressing the aquatic immune system (Abdel-Tawwab et al. 2018). The immune system may be harmed by phytotoxins such as cyanogenic glycosides (Cho et al. 2013). Glycinin is a dietary allergen in soy, which can harm an animal's immune system (Sun et al. 2008). Gossypol, an anti-nutritional compound found in cottonseed, can cause apoptosis by activating caspase-3 (Sadahira et al. 2014).

1.4.5 Diseases

Increased inflammatory cytokines in chronic diseases may be a reason to suppress the immune system. Furthermore, toxins and enzymes secreted by the primary pathogen can reduce the immunity of fish against secondary pathogens (Ilgová et al. 2021). Simultaneous fish infection with two or more pathogens can weaken the immune system (Shameena et al. 2021). Ilgová et al. (2021) found that chronic pathogen infections could significantly delay the immune system response of fish. They showed that infection with monogeneans could increase the susceptibility of fish to secondary pathogens. Ilgová et al. (2017, 2020) demonstrated that infection with *Eudiplozoon nipponicum* reduced TNF-gene expression in common carp macrophages in vitro.

1.4.6 Sex Hormones

Hormone manipulation and changes in the steroid hormones may affect gene expression in a fish's immune response. Therefore, a decrease in the immune system capacity of adult fish may be related to changes in sex hormones. Szwejser et al. (2017) found that fish leucocytes have receptors and cytochrome P450 aromatase. As a result, oestrogen levels in the blood might affect the fish's immune system. Cabas et al. (2018) found a link between oestrogen levels and autoimmune illness and chronic inflammation in fish and discovered that fluctuations in sex steroids affected the immune systems of spotted snakeheads (*Channa punctatus*). They found that increased sex steroids could mitigate innate and cellular immune responses. Dietrich et al. (2021) showed that hormone therapy in common carp could change mRNA expression in hematopoietic tissues.

1.4.7 Drugs and Antibiotics

Antibiotics can suppress the fish immune system by disrupting the regulation of NF-B signalling and immunotoxic pathways (Qiu et al. 2020). Yang et al. 2020 indicated that antibiotics are toxic to fish at high dosages. They also showed that treatment with a high dose of antibiotics would suppress the fish's immune system. Increased mortality and an inflammatory response were observed in zebrafish treated with 260 ng of L-1 sulfamethoxazole (Zhou et al. 2016). Common carp exposed to sulfamethoxazole has reportedly seen a similar outcome (Iftikhar et al. 2022). Liu et al. (2020) found that exposure of zebrafish larvae to high doses of sulfamethoxazole could change the mRNA expression of cytokines such as IL-1, IFN-, IL-11, and TNF-. The genotoxicity effects of antibiotics on leucocytes could mitigate the efficiency of cellular immunity in fish (Grondel et al. 1985).

1.5 Immunostimulants

Immunostimulants have a crucial role in activating the non-specific defence mechanism in fish protection against pathogens, and they are valuable for controlling fish diseases. Previous studies have shown that numerous immunostimulants may be useful to fish cultures in aquafeed. Particularly for enhancing and improving the immunity and disease resistance in fish, increasing non-specific defence mechanisms immune stimulants may also be an effective strategy to increase fish performance. Although the use of immunostimulants in the aquaculture industry has been successful in some cases, research in this field is still ongoing (Jadhav et al. 2006).

Chemical agents, bacterial components such as probiotics (Abdel-Latif et al. 2022), polysaccharides (e.g., from plants) (Faggio et al. 2016, 2015), animal or vegetable extracts (plant-based) (Rashidian et al. 2021), feed additives and herbal extract (Elumalai, as pointed out above, immunostimulants) might mainly facilitate the function of phagocytic cells and increase their bactericidal activities (Abarike et al. 2019). Moreover, natural killer cells, complement, lysozyme, and other antibody responses may be stimulated by different types of immunostimulants. Immunological function and activation are associated with improved protection against infectious diseases in aquaculture due to their ability to serve as an alternative and supplement to vaccination. Moreover, they also have additional effects on growth performance and the survival rates of the fish under stress (Heo et al. 2001) (Figure 1.2).

1.5.1 Chemical Agents

Since immune system stimulants contain many chemical compounds that may affect the function of the aquatic immune system, they can be administered alone or in combination with vaccination. Some immunostimulants have been shown in studies to improve vaccination efficiency. Shahbazi and Bolhassani (2016) found that some biochemical compounds such as vitamin C and E, lactoferrin, interferon, growth hormone, prolactin, and recombinant cytokines can act as immunostimulants. The chemical agents could disrupt immunological structures and functions, making animals more susceptible to both infections and non-infectious agents. A wide range of substances target the immune system and prolonged exposure to these compounds can result in immunological dysfunction (Koller 2001). For example, levamisole is the most useful chemical agent used and is a

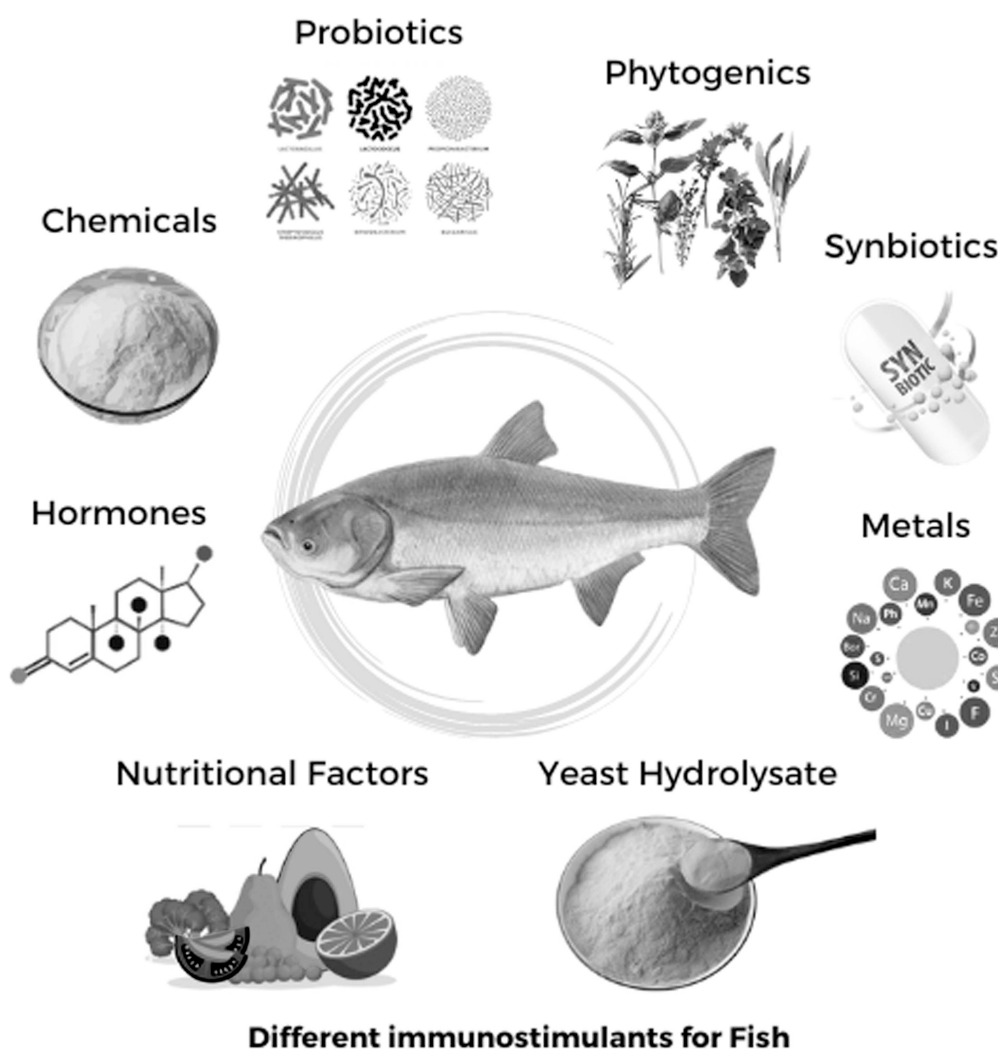

FIGURE 1.2 Different categories of immunostimulants for fish.

Various natural and synthetic agents that enhance immunological activity in fish are depicted in the figure. Bacterial agents, specifically prebiotics and probiotics are of high potential, along with immensely used phytochemicals, yeast derivatives, chemical agents and metals.

levo-isomer of tetramisole (Findlay & Munday 2000). It is a polysaccharide that can increase macrophage activity and provide resistance to specific harmful microorganisms. On the other hand, chitosan is a de-N-acetylated version of chitin. Both chitin and chitosan have the potential to be significant components in aquaculture. Chitosan treatment by injection or immersion was found to enhance brook trout (*Salvelinus fontinalis*) resistance to an *A. salmonicida* infection. Chitosan treatments had a substantial influence on the non-specific immunity and immunological response of both healthy and cortisol-treated *Labeo rohita* (Barman et al. 2013).

1.5.2 Biological Substances and Bacterial Derivates

The most common biological substances are bacterial derivatives, also known as killed pathogens, and their products. The use of immunostimulants such as probiotics and prebiotics has always been considered (Bachère 2003). Probiotics are a collection of non-pathogenic microorganisms often found in aquatic animal digestive systems. Oral administration of probiotics can change bacterial flora, boost the immune system, and stimulate growth performance (Villamil et al. 2002). Previous studies show that the administration of probiotics can significantly increase antibody production and non-specific immune parameters in fish (Abareethan & Amsath 2015). Therefore, it is essential to identify and isolate different strains of microorganisms to produce probiotics. Among the different probiotic strains commonly used in fish are *Bacillus,* e.g., *B. subtilis* and *B. licheniforms*; *Lactobacillus* sp. such as *L. delbrueckii subsp., L. bulgaricus, and L. acidophilus*; and *Bifidobacterium* sp. Numerous reports on the use of probiotics in aquatic environments have been published (Van Doan et al. 2020; Jahangiri & Esteban 2018; Chauhan & Singh 2019), and for more details, readers are referred to Chapter 10.

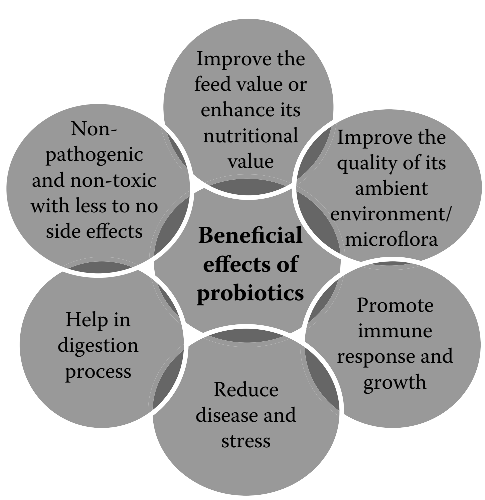

FIGURE 1.3 Benefits of probiotics.

Figure 1.3 illustrates the functions of probiotics as an immunostimulant in aquaculture. Probiotics promote immunity, growth, digestion, reduce stress and improve the feed value and quality of microflora in fish.

1.5.3 Lipopolysaccharide

Lipopolysaccharide (LPS) is the main component of the outer membrane of gram-negative bacteria such as *Salmonella typhimurium* and *Escherichia coli* (Miura & Mizushima 1968), and its preparations include O-antigens and endotoxins. The biological activity of LPS is a consequence of both hydrophobic domains known as lipid A (or endotoxin), a "core" oligosaccharide, and a distal polysaccharide (or O-antigen) (Neidhardt 1996). Moreover, LPS has been used as a potential immunostimulant. Toll-like receptor (TLR)-4 is mainly involved in the activation of the immune system by LPS through the specific recognition of its endotoxin (lipid A) moiety. LPS studies were made on fish both in vitro and in vivo, and they reported that LPS influences the growth and health status of fish. (Guttvik et al. 2002) showed that Atlantic salmon fry fed with LPS-coated feed (0.1% LPS) for 63 days had a reduced survival rate when challenged with a virulent strain of *A. salmonicida.* Furthermore, Paulsen et al. (2003) discovered that LPS stimulates plasma lysozyme activity originating from macrophages in various organs (e.g., blood polymorphonuclear and cells isolated from the head, kidney, and intestine) in their experiment on *Salmo salar*. In an in vitro experiment, Paulsen et al. (2001) in *Salmo salar* found that in head kidney macrophages grown in the presence of LPS, there was an increase in lysozyme production in the culture supernatants, which coincided with an accumulation of lysozyme gene transcript in stimulated cells.

1.5.4 Hormones and Cytokines

Hormones and cytokines are part of the neuroendocrine system. Their role as immunomodulators in the immune system has been studied in recent years. Acute stress may often be associated with fish life stages and have an impact on fish immunity and health (Figure 1.4). An example could be stress (resulting in potential advantages), thus involving short-term challenges resulting in immune activation or enhancing processes. Hormones generally can directly affect macrophages, lymphocytes, NK cells, and mitotic activity. Cortisol, growth hormone (GH), prolactin (PRL), reproductive hormones, melanin-concentrating hormone (MCH), and pro-opioid melanocortin (POMC)-derived peptides have all been shown to affect immune function in many fish species (Harris & Bird 2000). The growth hormone (GH, or somatropin) is a hormone from the family of prolactin and somatostatin; the main role of GH and insulin-like growth factor-I (IGF-I) is in the regulation of body size in growing animals. Previous studies showed that the administration of exogenous growth hormone (GH) improves many aspects of immune function, for example, cytotoxic (Sakai et al. 1996), phagocytic (Yada et al. 2006), haemolytic (Kim et al. 2013), and lysozyme activities (Harris et al. 2000) as non-specific defences, and immunoglobulin production as specific defences Yada (2007) observed that the activation of immune function during seawater adaptation was closely associated with increased plasma GH levels in some euryhaline fishes. Moreover, a previous study (Yada et al. 2006) showed that ghrelin (an important regulator of GH

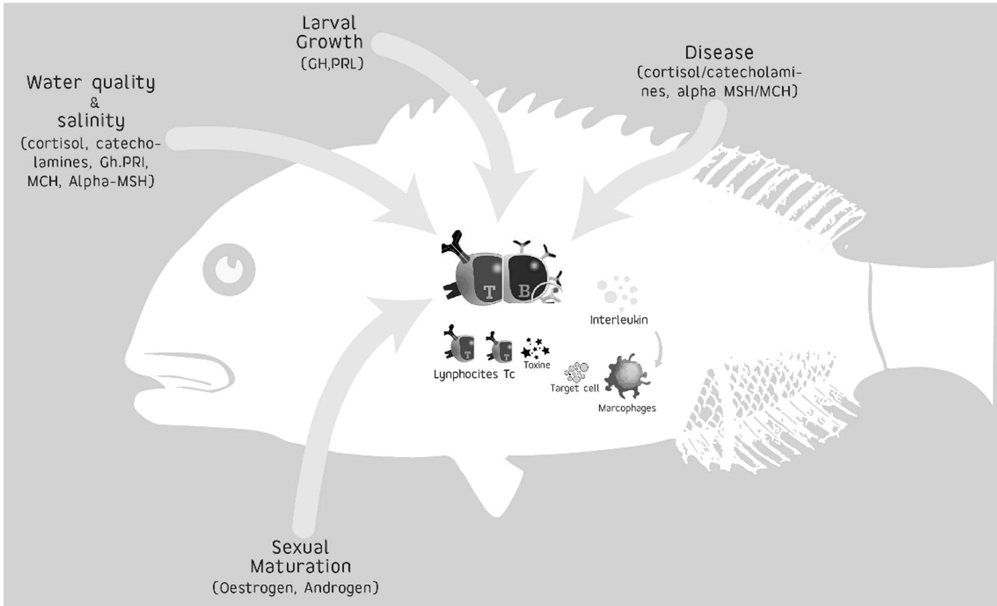

FIGURE 1.4 Interconnections between the general immune system and the endocrine system about environmental processes and fish life stages.

secretion) stimulates superoxide production associated with phagocytosis in trout leucocytes. While GH increased the mRNA levels of superoxide dismutase, which catalyses the dismutation of superoxide into oxygen and hydrogen peroxide, Also, Pontigo & Vargas-Chacoff (2021) found that GH may modulate the immune response in the SHK-1 cell line and leucocyte cultures of the head kidney in Atlantic salmon. Therefore, their work points out the independent action of GH on the immune system and the GH/IGF axis.

Cytokines are low-molecular-weight glycoproteins involved in regulating the immune system. These molecules are mainly secreted by cells of the innate and adaptive immune systems, but they play an important role in the innate immune response in fish. Kono et al. (1996) reported that IL-1 plays an essential role in fish immunity by activating lymphocytes and phagocytic cells and increasing resistance to *A. hydrophila* infection. Type I IFNs (homologs to human IFN- and IFN-) also have antiviral activity. Secombes & Belmonte (2016) discovered that type II IFN (IFN-) had bactericidal activity against intracellular parasitic bacteria. Studies to elucidate cytokines' functions in fish have recently begun. Still, more work is needed to select their appropriate functions, such as immunostimulants and vaccine adjuvants, to prevent infection in farmed fish. Sakai et al. (2021) developed a multiplex reverse transcription-polymerase chain reaction assay to investigate the immune response of fish when activated by an immunostimulant. Moreover, cytokines are also defined as biological response modifiers because of their ability to enable communication between different cell populations, in agreement with what was reported by Wilson et al. (2002).

Conforming to changes in environmental factors such as water quality, salinity and diseased conditions, the T-cell proliferation and cytokine expression also range, which is mediated through hormonal regulations. Hormones expressed during sexual maturation and larval growth enhance the expression of these immunological mediators.

1.5.5 Phytogenic Immunostimulants

(Plant extracts, herbals, garlic, ginger, triterpenic acid, polyphenols, olive oil, seaweeds)

Phytogenics are plant-derived natural products characterised by their richness in biologically active compounds that are mainly incorporated into the feed to enhance the innate immunity, health status, and growth performance of the animals. In farmed fish, phytogenics have been reported to contribute as antimicrobials, antioxidants, anti-inflammatory agents, immunostimulants, and sedatives. They work as promoters of growth and appetite stimulators, and they could influence the bile secretion and several enzymes associated with digestion (Chakraborty et al. 2011, Firmino et al. 2021, and Caipang et al. 2021). Botanicals, including herbs and spices, contain aromatic compounds and essential oils (extracted from parts of plants such as leaves, flowers, roots, and fruits), and many other medicinal plants come under phytogenics (Caipang et al. 2021). Plant extracts are active substances with desirable properties that are extracted from plant tissue for specific purposes, such as immunostimulant use. They have been known to have increased lysozyme activity, complement activity, phagocytic activity, an antibody response, elevated respiratory burst activity, and higher plasma protein (albumin and globulin) (Reverter et al. 2014; Harikrishnan R et al. 2011a). Saponin compounds, herbs, ginger, triterpenes from fungi and plants and seaweeds, etc. are some of the compounds and products which have an immunostimulatory effects on fish health and welfare and are discussed in detail in this book.

1.5.6 Nutritional and Dietary Factors

(Dietary amino acids, vitamin C, vitamin E, dietary nucleotides, organic acids, polysaccharides, probiotics, and food waste)

Nutrition plays a crucial role in maintaining the body's functioning and health. It provides all the essentials required by the

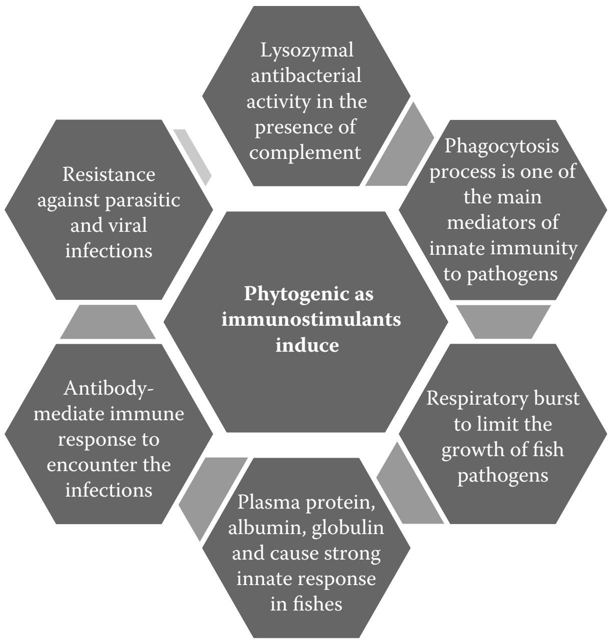

FIGURE 1.5 Activities of plant extract as an immunostimulant.

Figure 1.5 represents the role of plant extracts in enhancing immunity in fishes. Plant extract stimulate immunity by different cellular mechanism like phagocytosis, respiratory burst, antibody mediated responses, lysosymal antibacterial activity, and stimulate immunogenic plasma proteins.

body to maintain life, like metabolic energy and elements and compounds that act as co-factors for various physiological processes. When we talk about immunostimulants, dietary nutritional components include dietary amino acids (AA), vitamin C, vitamin E, dietary nucleotides, organic acids, polysaccharides, probiotics, food waste, etc. Dietary amino acids are essential acids that can improve the haemocyte count, phagocytic activity, respiratory burst in haemolymph, and lysozyme activity in cell-free haemolymph (CFH). Moreover, they can remarkably downregulate the malondialdehyde content (Luo et al. 2021). In addition to these, AAs are necessary for endogenous synthesis of protein and act as important energy substrates. These can also modulate the necessary metabolic pathways (Dawood et al. 2021) (Figure 1.6).

Vitamins are organic compounds necessary for animal growth and development. They are required in small quantities and must be provided with food, as they cannot be synthesised in the body. At present, vitamins C and E have gained popularity as immunostimulants (Kono et al. 1996). Vit E (tocopherols) are bioactive phenolic compounds, and a proper dose of this can (i) promote the differentiation and proliferation of lymphocytes and cytokines, (ii) enhance the production of antibodies and enhance complement activity when encountered with an antigen, and (iii) it can also improve phagocytosis activity and cytotoxicity. In channel catfish and turbot, VE enhances macrophage phagocytosis (Barman et al. 2013). Vitamin C (ascorbic acid) is involved as a cofactor in many bioactive processes, like neuromodulation, collagen synthesis, and cellular activities related to hormones, and the immune system.

Dietary nucleotides, chitin, and organic waste do also have compounds with immunostimulatory effects and are discussed in subsequent chapters. Bacterial and yeast cell walls mostly consist of glucans. When glucan was given to feed, it activated phagocytic cells in fish, and they also demonstrated an increase in the development rate of *Litopenaeus vannamei* juveniles, enhancing phagocytosis and the capacity of the cells to eliminate harmful pathogens. Additionally, they increase complement and lysozyme activity (Kono et al. 1996). Additionally, glucans improve the non-specific defence mechanisms of fish and shellfish and offer defence against bacterial infections (Barman et al. 2013). Prebiotic compounds called fungal polysaccharides are commonly regarded as a dietary component for controlling growth and health issues. Higher fungi are excellent providers of a variety of crucial natural compounds (Mohan et al. 2019). More details are discussed in subsequent chapters (Figure 1.7).

1.5.7 Trace Elements and Metals

Minerals that are less abundantly present in living tissues are referred to as trace elements (or trace metals). They are considered to be nutritionally essential, although if consumed at sufficiently high levels, they may prove toxic. Copper, chromium, iron, iodine, fluoride, manganese, molybdenum, selenium, and zinc are considered as essential trace elements. General functions of minerals include structural constituents of tissues, formation of the exoskeleton, osmotic pressure balance, muscle contractions, and nerve impulse transmission. They are

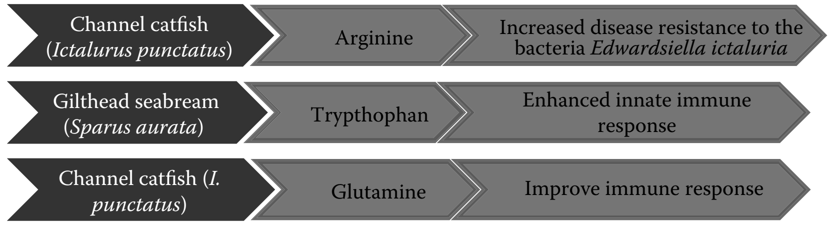

FIGURE 1.6 Effects of different amino acids on fish health.

Essential amino acids such as arginine and tryptophan and non essential aminoacid like glutamine have increased effect on fish immunity. Arginine, in channel catfish improve the resistance in fish against *Edwardsiella ictaluria.* Tryptophan in Gilthead seabream has a transient immune enhancement activity in the fish. Similarly, glutamine improve the immune response in channel catfish.

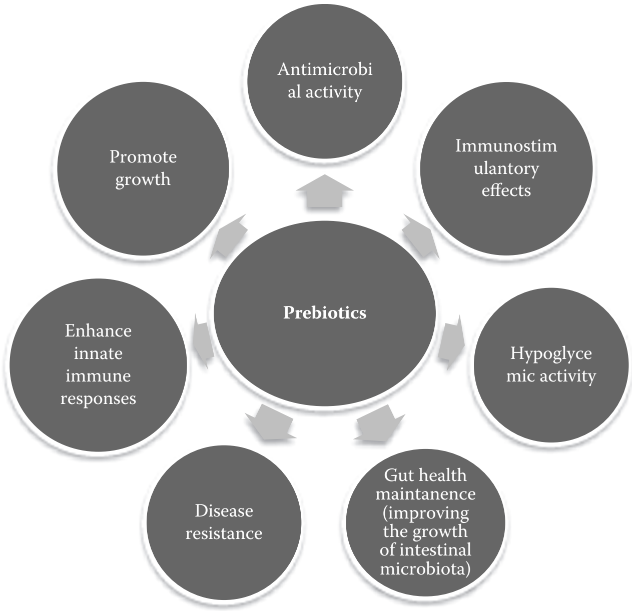

FIGURE 1.7 Functional properties of prebiotics.

Prebiotics have an enhancing effect on fish growth, antimicrobial activity, and disease resistance. They improve favourable intestinal microbiota and stimulate immune system in teleost.

also prime components for co-factors in metabolism, catalysts, enzymes, enzyme activators, hormones, pigments, and vitamins.

1.5.8 Synbiotics

Synbiotics are a combination of both prebiotics and probiotics and work as growth and immunity promoters. These have been used in aquaculture for over a decade, but the functional mechanism is still not very clear. Prebiotics, which are parts of synbiotics when hydrolysed to simpler mono- or disaccharides, show an exceptional increase in biomass and colonisation of probiotic bacteria on the surface of intestinal epithelial cells in the host. By releasing extracellular bacterial enzymes and bioactive substances from their metabolic activities, they also contribute to the growth of aquatic animals. These enzymes also improve the nutrient absorption capacity, which in turn help in effective utilisation of feed. Synbiotics stimulate the immune system's synthesis of nitric oxide, phagocytosis, and respiratory burst activity in fish.

1.5.9 Yeast Hydrolysate

Yeast is known for keeping the digestive system of an animal's body healthy and in balance; hence, it is widely used as a supplement in aquatic feeds. Yeast has a high protein and energy content, as well as high micronutrient content. Aside from being high in amino acids and proteins, yeast products also have immunomodulatory compounds like mannan oligosaccharides (MOS), chitin, glucans, and nucleic acids. Mannan oligosaccharides are well known to enhance the growth performance of rainbow trout (*Oncorhynchus mykiss*), *Aespeciallyes cerevisiae* is a well-known yeast from which glucan is extracted and purified, and an intraperitoneal injection of this improves both specific and non-specific immune responses in carp *(Cyprinus carpio) to* the bacterial challenge posed by *A. hydrophila.* Yeast hydrolysate is a hydrolysate of yeast cells obtained through various methods like acids, enzymes, or other hydrolysis. The extract may be obtained through autolysis, where the enzymes found in yeast itself are used to break down the protein, or through hydrolysis, where enzymes are added from external sources as depicted in Figure 1.8 (Gong et al. 2019).

1.6 How to Administer the Immunomodulators to Fish?

Overall, the immunostimulants could be administered through different routes. Although injection methods are the best strategy to enhance non-specific immune system responses, this method is costly and time-consuming. Furthermore, injection methods are only performed by experts. Therefore, it is applied in experiments where the fish are intended as brook stock in genetic studies. Another method is immersion, but its efficiency is less than that of injection; however, it requires crowding and an increase in the handling of fish stocks. Immune system stimulants may be prescribed as oral supplements. However, the immunostimulants' concentration in the diet depends on the size, ontogeny stages, and initial weight of the fish. This method consists of oral ingestion, produces a suitable non-specific immune response, and can be the most cost-effective method of administration. Top dressing can help you achieve these. The surface of the food is treated with the pure immunostimulant in this case. This is comparable to employing a layer of fish oil to top-dress antibiotic granules. This technique produces variable results depending on how well the immunostimulant adheres to the feed. At last, one method that is much more advanced is bio-encapsulation.

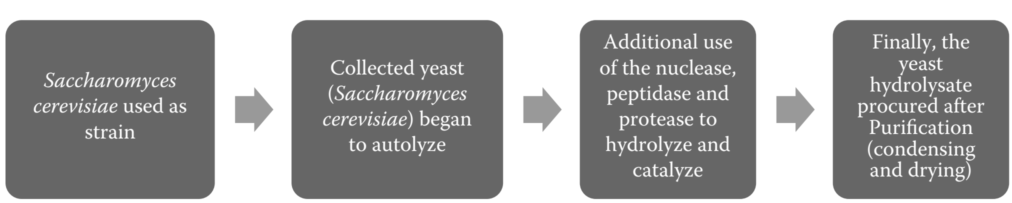

FIGURE 1.8 Extraction of hydrolysate.

Demonstrate the pathway for the extraction of hydrolysate from yeast to use as an immunostimulant for fishes. The yeast (*Saccharomyces cerevisiae*) are collected, autolyzed yeast is subjected to nuclease, peptidase, and protease to get the hydrolysed product, which is subsequently purified using condensing and drying.

1.7 Limitations of Immunostimulants

- Though showing extraordinary growth in the field of aquaculture, one of the important disadvantages of some immunostimulants is their high cost.
- The administration of the drug is important to consider as it depends on its efficacy. Immunostimulants show limited efficiency upon parental administration.
- Immunostimulants are not completely effective against all diseases.
- Overdoses of immunostimulants in feeds may cause immunosuppression.
- In some cases, aquatic animals may also fail to provide enhanced protection or an increase in immunity.
- Immunostimulants are successfully used in aquaculture against various infections and pathogens; however, the ability to improve innate resistance against many diseases (e.g., columnaris disease) has not been studied.

1.8 Factors Affecting the Efficiency of Immunostimulants

The effectiveness of an immunostimulant can depend on various factors, as follows:

- Solubility: Laminaran is an algal extract that can boost respiratory burst activity in leucocytes of the anterior kidney and activate macrophages in Atlantic salmon because it is more soluble than the fungal and yeast glucans. It has also been demonstrated to be a potential chemical for diet usage due to its greater solubility, so the solubility is considered an important aspect for immunostimulants.
- Duration of dose: Salmon that received M-glucan injections only took 2 days to produce their peak leucocyte responses. After 4–7 days of therapy with yeast beta-glucan, the respiratory burst activity increased. This demonstrated how immunostimulants might improve non-specific immunity with very brief dosages.
- Dosage: A high dose or overdose certainly does not seem to have an enhancing effect and can, in turn, inhibit the immune responses. At concentrations of 0.1–1 g/mL, the respiratory burst activity of glucans-treated macrophages increased. Whereas glucan had no effect at a concentration of 10 g/mL, it was inhibitory at a concentration of 50 g/mL. Very high vitamin E levels in feed, such as those of a >1,000–5,000 IE/kg diet, have an immunosuppressive effect. So, the dose per unit weight has a significant effect on efficacy.
- Time of administration: applying immunostimulants at the right time is very important in aquaculture. Mostly, application is needed before the outbreak of disease so that losses due to disease can be reduced.
- Method of Administration: The administration of immunostimulants through injection has been reported to be most effective against a range of pathogens. Vaccination seems to be impractical for small fish. Immersion is commonly used in intensive culture systems, despite the fact that it is less expensive than injection, produces a less non-specific immune response, and stresses the fish during handling. It is most effective during the acclimation of juveniles to ponds in field conditions. Oral ingestion is good for extensive aquaculture systems. It is cost-effective and enhances non-specific immune responses (Barman et al. 2013).

1.9 Evaluating the Efficacy of Immunostimulants

In vivo and in vitro methods can be used to assess the efficacy of an immunostimulant. The in-vivo method employs fish pathogens to assess the efficacy of immunostimulants, whereas the in-vitro method examines cellular and humoral immune mechanisms. In-vivo and in-vitro methods should be performed together to check the basic mechanisms for providing protection. In preliminary studies, in vitro methods are preferred. In vitro evaluation is based on lymphocyte proliferation, complement activation, total erythrocyte and leucocyte counts, chemokinesis, chemotaxis, lysozyme activity, and RBA phagocytosis. Other parameters include monitoring natural cytotoxic activity, macrophage-activating factor (MAF) levels, and C-reactive protein levels. However, these tests are too expensive to be conducted to check the efficacy of immunostimulants. A deep level of research is required to check the efficacy of various compounds for aquaculture species and their pathogens and to ultimately decrease the cost of the immunostimulants.

1.10 Timing of Administration

It is very important to use immunostimulants at the correct time and in the right concentration to boost the immune system. Anderson proposed in 1992 that it is best to use immunostimulants prior to the possibility of disease outbreaks in order to minimise disease-related loss. Furthermore, the effective dose and timing of exposure have a significant impact and are complicated by the culture system and feeding scenario. Studies in Atlantic salmon showed that the maximum non-specific disease resistance is attained only after the third week of injecting glucan at 10 mg/100 g, whereas the effects of low dosing at 1 mg/100 g last only for 1 week. Similarly, in African catfish, administration of glucan led to a maximum increase in the phagocytic cells at 7 days but not after 14 days. So, it is preferable to use them well in advance and at regular intervals (Barman et al. 2013).

1.11 Detection of Immunostimulants

Detection of immunostimulants in fish body is detected by using 'omic' technologies.

Methods of detection of immunostimulation are as follows and it is discussed in further chapters in detail:

- In vitro measurement
- In vivo measurement
- Phagocytic activity

1.12 Attributes of Immunostimulants

The most important attribute of an immunostimulant is that it directly influences the animal's health. It is biodegradable and biocompatible, and therefore safe for the environment. It enhances the immune system of animals, promoting good health, and is non-toxic to both fish and shellfish with no side effects observed. In aquaculture, it provides disease resistance to animals against a broad spectrum of pathogens and reduces mortality caused by opportunistic pathogens. It can also keep the host safe by providing enhanced immune stimulation to fight viral diseases. It increases the effectiveness of many antimicrobial substances, vaccines, and antibiotics. Moreover, it is cheap, easily available, and most importantly, an eco-friendly method for immune stimulation (Barman et al. 2013).

1.13 Vaccine

A vaccination is a biological treatment that increases immunity to a specific disease. Vaccine often comprises an agent that resembles a microorganism that causes a disease and is frequently created from weaker or dead versions of the pathogen. In order for the immune system to more quickly identify and eliminate any further interactions with this disease-causing microorganism, The agent prompts the body's immune system to identify the agent as foreign, eliminate it, and "remember" it so that the immune system will be better able to identify and eliminate any of these microorganisms that it comes into contact with in the future. "Prevention is better than cure" is the core tenet of a vaccination. The name "vaccine" originated from Edward Jenner's usage of the phrase "cow pox" in 1796 (Latin "variolvaccin," which was borrowed from the Latin "vaccn-us," from "vacca" cow). He was a pioneer in the use of cowpox vaccinations to stop the spread of smallpox.

FIGURE 1.9 Vaccination via injection.

Figure 1.9 represents vaccine administration through injection via intramuscular or intraperitoneal method to increase resistance against pathogens by stimulating immune system.

Fish immunisation started in 1942 when David C. B. Duff successfully immunised trout orally against the bacteria *Aeromonas salmonicida* (the first fish vaccine). He is known "Father of Fish Vaccination". The first commercially approved fish vaccination was a dead *Yersinia ruckeri* vaccine against enteric redmouth disease that was administered by immersion in 1976.

1.14 Immunostimulants vs Vaccine

Table 1.1 is the comparison of immunostimulants and vaccines (Dawood et al. 2021).

1.15 New Paradigm

1.15.1 Nutrigenomics

Nutrigenomics is a branch of science that integrates bioinformatics, nutrition, genomics, molecular biology, and epidemiology. It links the relationship between nutrients and cellular processes and shows how the dietary components alter the genetic makeup. Although the relationship between nutrition and the immune system is generally known, it is still unclear

TABLE 1.1

The Comparison of Immunostimulant with Vaccines

Immunostimulants (IS)	Vaccine
• More treatments are required as the prophylactic effect is short term	• One or two treatments are enough as prophylactic effect is long
• Efficacy of immunostimulants is good	• Efficacy of vaccine is excellent
• IS possess wide spectrum of activity	• Vaccine possess limited spectrum of activity
• Nontoxic with less side effects	• Nontoxic with less side effects
• No toxic residue accumulation	• No toxic residues accumulation
• Positive/no environmental impact	• No environmental impact
• Mainly enhance non-specific immune system before specific immune system matures.	• Enhance specific and nonspecific immune response
• Can be used at any stage of life cycle	• Cannot be used at any stage of life cycle
• Easy to supply to larvae of fish and shrimp	• Difficult to supply to larvae of fish and shrimp
• Cost-effective	• Costly

how nutrition, animal energy status, and immune function are linked together. The effects of diet on the immune system are becoming more transparent because of emerging omics technologies like transcriptomics (microarray and RNA-seq) and proteomics. Modules of genes can reveal changes in both local (intestinal) and systemic immune function by applying molecular pathway enrichment analysis. Using the omics, researchers can now investigate the effects of dietary manipulations such as fasting, feed additives, and protein replacement on gene expression, protein synthesis, and immune functions. It is a relatively new approach in aquaculture, but the scope it provides to understand the mechanism behind gene alteration through nutrition may lead to more intense research and the development of aquaculture (Samuel and Martin 2017).

1.15.2 Trained Innate Immunity

It is a concept that argues that not only can adaptive immunity provide immunity by memorising the pathogen, but an innate immune response can also recognise the pathogen and adapt to provide an immune response after exposure. It stimulates defence and increases nonspecific resistance to infection. One such example is the prophylactic effects of glucan injection in fish against *Vibrio salmonicida*. Though technological advancements and research have revealed the mechanism responsible for such immune responses to be effective programming of cells like monocytes, NK cells, macrophages, etc. through pattern recognition (MAP kinase dependent), we are still far from knowing the actual effectiveness, mechanism, and potential side effects it may cause. The approach is opening doors of application in various aquaculture fields like brood stocking, larval rearing, and first-feeding fish; however, assessments of this approach using modern tools like transcriptomics, epigenetics, proteomics, and metabolomics are needed (Zhangzuobing et al. 2019).

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Prebiotics and Probiotics as Effective Immunomodulators in Aquaculture

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Edited by

Meththika Vithanage
University of Sri Jayewardenepura
Sri Lanka

and

Majeti Narasimha Vara Prasad
University of Hyderabad (an Institution of Eminence)
India

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Contents

List of Contributors

Muthumali U. Adikari
Department of Food Science and Technology
Wayamba University of Sri Lanka
Makandura, Sri Lanka

Mansoor Ahmad Bhat
Department of Environmental Engineering
Eskişehir Technical University
Eskişehir, Türkiye

Balram Ambade
Department of Chemistry
National Institute of Technology Jamshedpur
Jharkhand, India

Luís Peres de Azevedo
Materials Engineering DsC
Federal University of Ouro Preto
Ouro Preto, Minas Gerais, Brazil

Arunima Bhattacharya
Centre National de la Recherche Scientifique
Institut National de la Santé et de la Recherche
Médicale, ARNA, Institut Européen de Chimie et
Biologie, Université de Bordeaux
Pessac, France

Nanthi Bolan
School of Agriculture and Environment
UWA Institute of Agriculture
University of Western Australia
Perth, Western Australia, Australia

Alfredo Jorge Palace Carvalho
Chemistry and Biochemistry Department
LAQV-REQUIMTE, School of Sciences and Technology
University of Évora
Évora, Portugal

Cláudia C.N. de Carvalho
Department of Biology, State University of Alagoas
Santana do Ipanema
Alagoas, Brazil

Bimal Bhusan Chakraborty
Centre for Soft Matter, Department of Chemistry
Assam University
Silchar, India

Sudip Choudhury
Centre for Soft Matter, Department of Chemistry
Assam University
Silchar, India

Asitha T. Cooray
Department of Chemistry; Instrument Centre, Faculty
of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Kuheli Deb
Centre for Soft Matter, Department of Chemistry
Assam University
Silchar, India

Donia Dominic
Department of Botany, St. George's College
Aruvithura, Erattupetta
Kerala, India

Ana V. Dordio
Chemistry and Biochemistry Department;
MARE – Marine and Environmental Sciences Centre
School of Sciences and Technology
University of Évora
Évora, Portugal

Fatma Nur Eraslan
Department of Environmental Engineering
Eskişehir Technical University
Eskişehir, Turkey

Denise Crocce Romano Espinosa
Chemical Engineering Department
Polytechnic School of University of São Paulo
São Paulo, Brazil

Jorge M.S. Faria
National Institute for Agrarian and Veterinarian Research
INIAV
Oeiras, Portugal

Teresa Ferreira
Chemistry and Biochemistry Department, School of Sciences and Technology; HERCULES Laboratory
University of Évora
Évora, Portugal

Eftade O. Gaga
Department of Environmental Engineering and Environmental Research Center (ÇEVMER)
Eskişehir Technical University
Eskişehir, Türkiye

Sanchala Gallage
Department of Aquaculture and Fisheries, Faculty of Livestock, Fisheries & Nutrition
Wayamba University of Sri Lanka; University of Sri Lanka
Makandura, Sri Lanka

Kadir Gedik
Department of Environmental Engineering
Eskişehir Technical University
Eskişehir, Turkey

Anu Gopinath
Department of Aquatic Environment Management
Kerala University of Fisheries and Ocean Studies
Cochin, India

Sunayana Goswami
Department of Zoology
Biswanath College
Assam, India

Sedat Gundogdu
Department of Basic Sciences, Faculty of Fisheries
Cukurova University
Adana, Turkey

Nurani Ikhlas
Department of Environmental Engineering
Faculty of Engineering
Institut Teknologi Pembangunan Surabaya
Indonesia

Marta Jaskulak
Department of Immunobiology and Environment Microbiology
Medical University of Gdańsk
Gdańsk, Poland

Jasintha Jayasanka
Department of Biosystems Technology, Faculty of Technology
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Chamila V.L. Jayasinghe
Department of Food Science and Technology
Wayamba University of Sri Lanka
Makandura, Gonawila, Sri Lanka

Sharmila Jayatilake
Department of Food Science and Technology
Wayamba University of Sri Lanka
Makandura, Gonawila, Sri Lanka

Lander de Jesus Alves
Postgraduate Program in Biology and Biotechnology of Microorganisms
State University of Santa Cruz (UESC)
Ilhéus, Bahia, Brazil

Priya Jose
Department of Botany, St. George's College
Aruvithura, Erattupetta
Kerala, India

Dinushi Kaushalya
Department of Food Science & Technology, Faculty of Livestock, Fisheries & Nutrition
Wayamba University of Sri Lanka
Gonawila, Sri Lanka

Santhirasekaram Keerthanan
Ecosphere Resilience Research Centre, Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Farhan R. Khan
Norway Norwegian Research Centre (NORCE)
Bergen, Norway

N.K. Sandunika Kithmini
Department of Food Science and Technology
Wayamba University of Sri Lanka
Makandura, Gonawila, Sri Lanka

Pabasari A. Koliyabandara
Department of Civil and Environmental Technology
Faculty of Technology
University of Sri Jayewardenepura
Homagama, Sri Lanka

K.M. Prakash M. Kulathunga
Department of Food Science and Technology
Wayamba University of Sri Lanka
Makandura, Gonawila, Sri Lanka

Anna Kwarciak-Kozłowska
Faculty of Infrastructure and Environment
Częstochowa University of Technology
Częstochowa, Poland

Carlos Alberto Ferreira Lagarinhos
Metallurgical and Materials Department
Polytechnic School of University of São Paulo
São Paulo, Brazil

Magdalena Madeła
Institute of Environmental Engineering
Czestochowa University of Technology
Czestochowa, Poland

Dhammika N. Magana-Arachchi
Molecular Microbiology & Human Diseases Unit
National Institute of Fundamental Studies
Kandy, Sri Lanka

Mehdi Mahbod
Department of Water Sciences and Engineering
College of Agriculture
Jahrom University, Jahrom, Iran

Laura A.T. Markley
Department of Civil and Environmental Engineering
Syracuse University
Syracuse, NY United States

Florin-Constantin Mihai
CERNESIM Center, Department of Exact Sciences and Natural Sciences
Institute of Interdisciplinary Research "Alexandru Ioan Cuza" University of Iași
Iași, Romania

Manju P. Nair
Department of Aquatic Environment Management
Kerala University of Fisheries and Ocean Studies
Cochin, India

Ayanthie Navaratne
Department of Chemistry
University of Peradeniya
Peradeniya, Sri Lanka

Fábio C. Nunes
Academic Department
Federal Institute Baiano (IF BAIANO)
Santa Inês, Bahia, Brazil

Yudith Vega Paramitadevi
Environmental Engineering and Management Study Program
Vocational Studies of IPB University
Indonesia

Amir Parnian
National Salinity Research Center (NSRC)
Agricultural Research Education and Extension Organization (AREEO)
Yazd, Iran

Aleena Maria Paul
Department of Botany
St. George's College
Aruvithura, Erattupetta, Kerala, India

Saurav Paul
Centre for Soft Matter, Department of Chemistry
Assam University
Silchar, India

Kalani Imalka Perera
International Program in Hazardous Substances and Environmental Management
Chulalongkorn University
Bangkok, Thailand

Ana Paula Pinto
Mediterranean Institute for Agriculture Environment and Development, MED & Global Change and Sustainability Institute, CHANGE Institute for Advanced Studies and Research; Chemistry and Biochemistry Department, School of Sciences and Technology, University of Évora
Évora, Portugal

Majeti Narasimha Vara Prasad
School of Life Sciences
University of Hyderabad (an Institution of Eminence)
Hyderabad, Telangana, India

Nirmala Prasadi
Department of Food Science
Ontario Agriculture College, University of Guelph
Guelph, Ontario, Canada

K.S.D. Premarathna
Ecosphere Resilience Research Centre, Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

H. Umesh K.D.Z. Rajapakse
Department of Food Science and Technology
Wayamba University of Sri Lanka
Makandura, Gonawila, Sri Lanka

Anushka Upamali Rajapaksha
Ecosphere Resilience Research Centre
Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Bimastyaji Surya Ramadan
Environmental Sustainability Research Group (ENSI-RG), Department of Environmental Engineering, Faculty of Engineering
Universitas Diponegoro
Indonesia

Sammani Ramanayaka
Lancaster Environment Centre
Lancaster University
Lancaster, United Kingdom

Beata Ratnawati
Environmental Engineering and Management Study Program
Vocational Studies of IPB University
Indonesia

Ersa Rishanti
Department of Geophysics and Meteorology
Faculty of Mathematics and Natural Science of IPB University
Indonesia

Aryadeep Roychoudhury
Discipline of Life Sciences, School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi, India

Sarika Sasi
Department of Botany
St. George's College
Aruvithura, Erattupetta, Kerala, India

Gobishankar Sathyamohan
Department of Chemistry
National Institute of Technology Jamshedpur
Jharkhand, India

Abin Sebastian
Department of Botany
St. George's College, Aruvithura
Erattupetta, Kerala, India

Kirk T. Semple
Lancaster Environment Centre
Lancaster University
Lancaster, United Kingdom

Samanthika Senarath
Department of Food Science & Technology, Faculty of Livestock, Fisheries & Nutrition
Wayamba University of Sri Lanka
Gonawila, Sri Lanka

Madushika Sewwandi
Ecosphere Resilience Research Centre
Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Misriya Shaji
Department of Botany
St. George's College, Aruvithura
Erattupetta, Kerala, India

Sheenu Sharma
Soil Ecosystem and Restoration Ecology Lab
Department of Botany
Panjab University
Chandigarh, India

Anand Narain Singh
Soil Ecosystem and Restoration Ecology Lab
Department of Botany
Panjab University, Chandigarh, India

Siril Singh
Department of Environment Studies; Soil Ecosystem and Restoration Ecology Lab, Department of Botany
Panjab University
Chandigarh, India

José R. de Souza Filho
Academic Department
Federal Institute Baiano (IFBAIANO)
Catu, Bahia, Brazil

Sasimali Soysa
Department of Physical Sciences and Technology
Faculty of Applied Sciences
Sabaragamuwa University
Belihuloya, Sri Lanka

Ishara U. Soyza
Instrument Centre, Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Giuseppe Suaria
National Research Council (CNR)
Institute of Marine Sciences (ISMAR)
Lerici, Italy

Jorge Alberto Soares Tenório
Chemical Department
Polytechnic School of The University of São Paulo
São Paulo, SP, Brazil

Ana Turyanti
Department of Geophysics and Meteorology
Faculty of Mathematics and Natural Science of
IPB University
Indonesia

Meththika Vithanage
Ecosphere Resilience Research Centre, Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Janitha Walpita
Department of Multidisciplinary Studies, Faculty of Urban and Aquatic Bioresources; Instrument Centre
Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Rasika P. Wanigatunge
Department of Plant and Molecular Biology
University of Kelaniya
Kelaniya, Sri Lanka

Hasintha Wijesekara
Department of Natural Resources, Faculty of Applied Sciences
Sabaragamuwa University
Belihuloya, Sri Lanka

Madhuni Wijesooriya
Department of Botany, Faculty of Science
University of Ruhuna
Matara, Sri Lanka

Rajni Yadav
Soil Ecosystem and Restoration Ecology Lab
Department of Botany
Panjab University
Chandigarh, India

Iwona Zawieja
Faculty of Infrastructure and Environment
Institute of Environmental Engineering, Czestochowa University of Technology
Czestochowa, Poland

Hao Zhang
Lancaster Environment Centre
Lancaster University
Lancaster, United Kingdom

Katarzyna Zorena
Department of Immunobiology and Environment Microbiology
Medical University of Gdańsk
Gdańsk, Poland

Preface

Microplastics (MPs) are emerging global contaminants, and the scientific community is becoming increasingly interested in this topic. This book discusses recent developments in multidisciplinary research on MPs, including their distribution in the soil, hydrosphere, and aerosphere, as well as their sources, fates, distribution, toxicity, and management. Particularly during the SARS-CoV-2 pandemic, there has been tremendous production and consumption of single-use MPs. But although most MPs are produced on land, they are eventually deposited in the marine environment. This book reviews the state of single-use plastics and MPs in the atmosphere, the ocean, soil systems, and the food chain and food web along with treatment technologies and management.

The sampling, processing, and analytical procedures employed to date to identify MPs are complex. Leaching MPs from landfills and industrial wastewater, vector transport of pollutants, and MPs found on beaches and in marine settings are all evaluated in the hydrosphere. Additionally, MPs in sewage sludge, soils fertilized with sludge, and soils irrigated with wastewater are explored, as well as any potential consequences for plants and human health. Important management strategies are also covered, including suggestions for useful information for policymakers, non-experts, environmental researchers, ecologists, and toxicologists. The interplay of MPs at the macro and molecular levels with the human, animal, and environmental domains is highlighted (Figure 1). As MPs enter or accumulate in the food chain or participate in the food web, their fate in the ecosystem is crucial. It is well-recognized that MPs have a significant capacity for adsorbing a wide range of pollutants, particularly organic toxins. Therefore, it is anticipated that all of the findings will contribute to the establishment of necessary environmental laws and policies as well as pinpoint knowledge gaps regarding MP pollution and contamination.

MPs in the environment originate from a variety of sources and are distributed worldwide. Sources include abrasion of synthetic textiles during laundry, tire abrasion while driving, city dust, spills, road markings, weathering and abrasion by vehicles, marine coatings, etc., in addition to domestic items such as personal care products and industrial uses such as plastic pellets in manufacturing, transport, and recycling. MPs also come from marine accidents such as the X-Press Pearl maritime disaster in 2021, which released thousands of tons of plastic nurdles and other polymers into the marine environment, contaminating coral reefs, seagrass beds, and the food chain. The pathways of global MP cycling include the road runoff pathway, wastewater pathway, wind pathway, and ocean pathway. The fate of MPs in the environment is particularly important because they are transferred to and accumulate in the food chain and become part of the food web.

Management of plastics and MPs is critical for many reasons:

1) Every year, several million tons of primary and secondary MPs leak into the oceans.
2) Discarded plastics could wrap around the earth four times in a single year.
3) Disposable plastic items represent 50% of marine litter.
4) About 95% of disposable plastic packing is wasted.
5) Plastics can survive in the environment for up to 500 years.
6) Recycling plastics takes 88% less energy than making new plastic. We can save a huge amount of gasoline by recycling plastics.

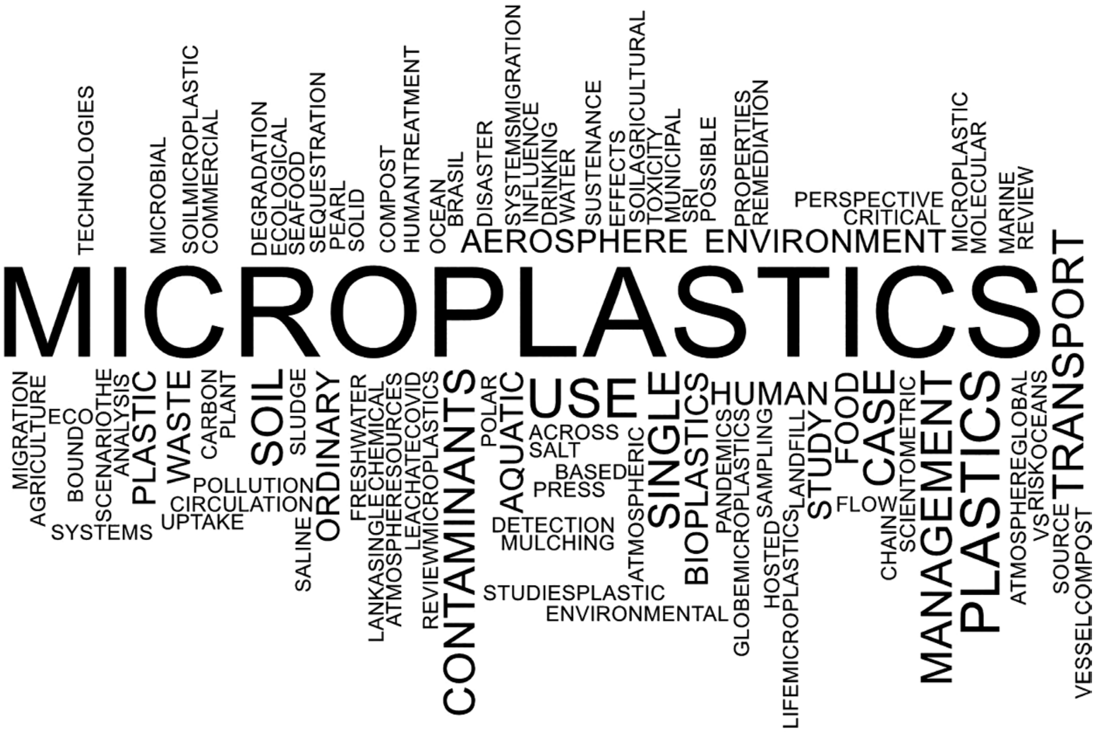

Figure 1 The word cloud map generated from the titles and keywords of the chapters in this book.

"Mission Starfish 2030: Restore Our Ocean and Waters" is a document prepared by an independent commission of the European Union for Healthy Oceans, Seas, and Coastal and Inland Waters. Its overall goal is to restore the earth's oceans and waters by 2030. More concretely, inspired by the shape of a starfish, the Mission highlights four interdependent challenges – unsustainable footprint; climate change; lack of understanding, connection, and investment; and inadequate governance – by proposing five overarching objectives for 2030:

a) Filling the knowledge and emotional gap
b) Regenerating marine and water ecosystems
c) Zero pollution
d) Decarbonizing our waters, ocean, and sea waters
e) Revamping governance

This book is relevant for helping to achieve the Mission Starfish goals via plastic abatement.

Maritime Climate Change: Physical Drivers and Impact

Climate Change and Geodynamics in Polar Regions

Edited by

Neloy Khare

CRC Press
Taylor & Francis Group

Climate Change and Geodynamics in Polar Regions

Climate Change and Geodynamics in Polar Regions covers most of the scientific aspects of geoscientific investigation undertaken by Indian researchers in the polar regions: the Antarctic, Arctic, and Himalayan regions. A firm understanding of the cryosphere region's geological perspectives helps students and geoscientists evaluate important scientific queries in the field.

This book will help readers understand how the cryosphere's geoscientific evolution took place in the geological past, as well as how the climate changed throughout history, and how polar regions were affected by global warming. It also discusses how we might expect polar climate to change in the future. A firm understanding of the cryosphere region's geological perspectives helps students and geoscientists answer some of the most puzzling scientific queries and generate new ideas for future research in this field.

The book is edited by **Dr Neloy Khare**, presently Adviser to the Government of India with a very distinctive acumen in quality science and research in his areas of expertise covering a large spectrum of geographically distinct locations like the Antarctic, Arctic, Southern Ocean, Bay of Bengal, Arabian Sea, Indian Ocean etc. He obtained a doctorate (PhD) in tropical marine region and Doctor of Science (DSc) in Southern High latitude marine regions towards environmental/climatic implications.

Maritime Climate Change: Physical Drivers and Impact

Series Editor: Neloy Khare

As global climate change continues to unfold, the two-way links between the tropical oceans and the poles will play key determining factors in these sensitive regions' climatic evolution. Now is the time to take a detailed look at how the tropical oceans and the poles are coupled climatically. The signatures of environmental and climatic conditions are well preserved in many natural archives available over land and ocean. Many efforts have been made to unravel such mysteries of climate through many natural geological archives from tropics to the polar region. This series makes an effort to cover in pertinent time various depositional regimes, different proxies- Planktic, benthic, pollens and spores, invertebrates, geochemistry, sedimentology etc. and emerged teleconnections between the poles and tropics at regional and global scale, besides sea-level changes and neo tectonism. This book series will review theories and methods, analyze case studies, and identify and describe the evolving spatial-temporal variations in climate and providing a better process-level understanding of these patterns. It will discuss significantly, generalizable insights that improve our understanding of climatic evolution across time—including the future. It aims to serve all professionals, students and researchers, scientists alike in academia, industry, government, and beyond.

Climate Change in the Arctic
An Indian Perspective
Neloy Khare

Climate Change and Geodynamics in Polar Regions
Edited by Neloy Khare

Climate Change and Geodynamics in Polar Regions

Edited by Neloy Khare

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Contents

Foreword

The Paris Accords in 2015 is an outcome of global concern about climate change, which plays a pivotal role to determine whether the UN mandated Sustainable Development Goals will be achievable by 2030. The polar regions of the Earth are best suited for studying the cause-and-effect relationships of climate change. Geodynamics is one of the many natural factors of climate change, and a broad understanding of the inter-relationships between deep Earth processes and their surface manifestations is a significant advancement in our knowledge. Viewed in these contexts, this book presents a collection of studies related to climate change and geodynamics with a focus on the polar regions. The Arctic polar region situated in the northernmost part of the Earth with the North Pole is characterized by distinctively polar conditions of climate, plant and animal life, and other physical features. Likewise, the spectacular "icy continent" of Antarctica is the southernmost continent with the South Pole being a virtually uninhabited and largely ice-covered landmass. The main distinction between these two polar regions is that the Arctic is an ocean surrounded by land whereas, the Antarctic is the land surrounded by an ocean. The Himalayas, considered to be the Third Pole, aroused general interest to generate field and laboratory data for a better understanding of the geodynamic evolution of these spectacular features and to assess the impacts of global warming on the Himalayan glaciers along with other two polar regions.

Over the past 30 years, the Arctic has warmed at roughly twice the global rate. It is attributed to a phenomenon known as Arctic amplification, enhanced by anthropogenic factors. Similarly, new data indicates that climate change is negatively impacting Antarctica and the Himalayas (e.g. melting of glaciers).

Evidence suggests that the West Antarctic Peninsula is one of the fastest-warming areas on Earth, since Antarctica is large, climate change is not having a uniform impact. It has been observed that some areas experience increases in sea ice extent, on the contrary, in other regions, sea ice is decreasing. The unprecedented warming in the Arctic, Antarctic and the Himalayan region is severely causing changes not only to the physical environment but to the entire ecosystem. It is believed that understanding climate change impacts on all these three poles (the Arctic, the Antarctic, and the Himalayas) is a matter of critical importance not only for the region alone but globally.

The Arctic region is an element of a geodynamic system that includes the ancient Eurasian continent and intensely developing younger Arctic Ocean. The Circum-Arctic terrains comprise a series of complex geological structures, with fragments of Archaean to Paleoproterozoic shields and platforms, remains of orogenic belts of Neo-Proterozoic to Cenozoic ages. Recent seismicity indicates ongoing geodynamic processes. New surveys and data provide insights into Arctic continental terrains, basins and tectonic structures. Antarctica has geometric significance for global plate kinematic studies owing to its linkage to the seafloor spreading systems of the Indian, Atlantic Oceans and the Pacific. On the contrary, the Himalayan region, a site of continent-continent collision and disappearance of the Tethys is yet another site to understand various climate change impacts and geodynamical events apart from the Arctic and the Antarctic. The great mountain ranges of the Himalayas are the Earth's unique features. This region came into existence mainly due to the successive accretions of various isolated continental and arc terranes with the converging Indian and Eurasian land masses during Late Mesozoic-Early Tertiary.

Therefore, the Arctic, Antarctic and the Himalayan region are the hotspots of climate change assessment and are sites for understanding geodynamical processes. **The** present book, *Climate Change and Geodynamics in Polar Regions*, aptly provides a comprehensive account of Indian efforts to help understand the impact of climate change and the geodynamics of the Arctic, Antarctic, and the Himalayas.

The book begins with the Arctic through an assessment of the Geomorphology around the Kongsfjorden and Krossfjorden system, Svalbard, by **Pattanaik et al**. Interestingly the significance of the Antarctic Climates and glacial dynamics using mass balance over the Antarctic ice sheet has been highlighted by **Kumar et al**. On the other hand, **Singh et al**. have detailed the Antarctic Climate history and its relationship with global climate changes gleaning clues from ice core records. Significant attempts have been made to study the glacial geomorphology around Schirmacher oasis, Antarctica by **Pattanaik and Baba**. Similarly, **Chaturvedi and Khare** highlighted the significance of foraminiferal studies from the southern high latitudes in assessing global climate change coupled with **Sunil et al.'s** ionospheric response over Antarctica during the Total Solar Eclipse on December 4, 2021. On the contrary, **Reshmi et al**. dealt with the isotope hydrochemistry of Antarctic lakes and ponds while a limnological assessment of water bodies of extreme Antarctic climatic conditions has been made by **Khare et al**.

In a significant attempt, **Singh et al**. focused on the glacial morpho-sedimentology and processes of landscape evolution in the Himalayan region with special emphasis on the Gangotri Glacier area, Garhwal Himalaya.

Altogether, this book provides a comprehensive, up-to-date account of how climate changes and various geodynamical processes occur in the poles (the Arctic, the Antarctic, and the Himalayas). The book provides a holistic picture of the impacts of rising temperatures over the cryosphere region with a highly cross-disciplinary approach to reflect the importance of the Arctic, Antarctic, and the Himalayas in addressing the global issues of climate change.

It will be of immense value to all researchers keen to understand the science of climate change in these sensitive regions. It will also help the Decision Support System and the development of climate models.

Somnath Dasgupta
INSA Senior Scientist at Indian Statistical Institute, Kolkata and Honorary Professor at Indian Institute of Science Education & Research, Kolkata

Date: May 2022
Place: Kolkata

Preface

The polar regions are the center stage of the evolution of all surrounding continental bodies separated millions of years ago. The entire world is experiencing the looming danger of global warming where the Arctic, Antarctic, and Himalayas have again emerged as the keystone in a changing world. It reinforces the importance of continual changes in these cryosphere regions, their history, and the impact of these changes on global climates.

Geodynamics and environmental geodesy cover the entire gamut of research activities on the deformation of the solid Earth including its fluid envelope. It also encompasses the modelling of the past ice history of the Earth, climate change and its impact on polar ice sheets, and sea-level variations. Similarly, the studies on elastic tidal deformation of the Earth and seismogenic tectonic deformation are also significant components of the research activities which can easily be addressed through geoscientific instrumentation such as Interferometric Synthetic Aperture Radar, GPS etc. Recently introduced space-geodetic techniques such as the Gravity Recovery and Climate Experiment (GRACE) and satellite altimetry provide new observations of the changing nature of our mother planet

Such tools play a significant role to investigate how climate change is affecting the environment, of these cryosphere regions (the Arctic, the Antarctic, and the Himalayas)

It is a fact that many glaciers have retreated and ice shelves have either collapsed severely or are being retreated that formerly fringed the peninsula. Such visible signs of the climate changes over the Arctic, Antarctic and Himalayas are responsible for causing physical changes and the living environment by bringing notably changes in sea level, rates of melting of polar ice caps and even ground water storage. Consequently, the melting of ice sheets has the reverse effect, causing uplift of continents and increases in ocean volumes.

Undoubtedly the study of climate change in the Arctic, Antarctica, and Himalayas is important to enabling researchers to prepare the predictive models accurately and put forth future climate change scenarios and help contribute to the decision support systems for the policy makers.

We need to understand and recognize the warming pattern. If global warming continues, it may not be uniform. In the context of global warming, we must address the more significant issue of climate change and geodynamics in polar regions on which the present book places emphasis.

The book begins with the Arctic regions which are important in geomorphological studies as the region is characterised by the lowest sediment fluxes. While assessing the Geomorphology around Kongsfjorden and Krossfjorden systems, Svalbard, **Pattanaik et al**. pointed out that the Arctic region is characterised by a large sediment store and a favorable topography for sediment transport. The Svalbard archipelago in the Arctic has been widely studied in terms of its landscape, glacial dynamics, sediment transports and paleoclimatic studies. The fjord system is the transition zone between the terrestrial and marine environment, acting as an important archive that will have geomorphological features that have been formed as a result of both terrestrial and marine processes. It is a potential site to study paleoenvironmental changes as the region provides a high-resolution sedimentary archive. Diverse geomorphological features developed in Svalbard are due to the interplay of climate and surficial processes active in that region. A study on these features will provide an opportunity to understand the sequence and mechanism of the surficial processes.

The polar regions act as a sensitive barometer to the climate changes occurring on the global scale. **Kumar et al**. present a snapshot of glaciological studies carried out in Schirmacher Oasis and the Nivlisen ice shelf in Central Dronning Maud Land (cDML), East Antarctica during Indian Antarctic Expeditions. Systematic observations have been meticulously carried out since 1996 to document the changes in the ~9 km long Polar Ice Front along the southern margin of the Schirmacher Oasis. Ice stakes have been installed to monitor the accumulation/ablation and estimation of surface mass balance over a 14000-sq.-km area. Ice dynamics and estimation of velocity using differential GPS were done to calculate the surface mass balance. Ice thickness data using ground penetrating radar is used to calculate the net mass balance in the area. According to them, the Dakshin Gangotri Polar Ice Front (DGPIF) shows an annual retreat of 1.32 m during 2018–19 and a cumulative retreat of 14.9 m since 1996. The polar ice front at Schirmacher Oasis shows an annual retreat of 2.79 m during 2018–19 and a cumulative retreat of 42.08 m since 2001. The average annual accumulation of 0.98 m is observed in the high Polar ice sheet area which is equivalent to 394.01 kg/m^2 Snow Water Equivalent (SWE). Impeded Polar Ice sheet area shows an average ablation that ranges from 133.12 kg/m^2 to 183.25 kg/m^2 SWE. The ice velocity during 2018–19 varies from 1.98 m/y to 51.65 m/y with an average velocity of 21.16 m/y in parts of the High Polar Ice sheet area, whereas the ice velocity was 4 m/y to 97 m/y for the same time during 2017–18. The ice sheet movement with an average of 6.78 m/y in parts Impeded Polar Ice sheet area has been recorded, whereas the ice sheet movement over DGPIF is found to be of the order of 5.23 m/y which reveals a total 6.55 m annual degeneration of DGPIF wall during 2018–19, which is equivalent to 6006.35 kg/m^2 loss of ice mass at DGPIF area. Out flux of ice mass for estimation of mass balance in the region shows 1.7504 gigatonnes of ice mass loss from the out-flux gate at Nivlisen ice shelf during 2017–2018, as compared to 1.66 gigatonnes during 2016–17. An increase in the ice loss is attributed mainly to a faster rate of movement of the ice sheets during that period. The cumulative ice loss from the area would have contributed to a rise in mean sea level by about 0.0045 mm and 0.0048 mm during 2017–18 and 2018–19, respectively.

On the other hand, **Singh et al**. have provided an overview of the Antarctic Climate history through ice core records. They highlighted that the Ice core studies in the last two decades have made important conceptual advancements in our understanding of the climate forcing factors and climate response at millennial time scales. Antarctic climate and its variability in the last 800 kyr have been revealed through the study of long ice core records obtained from a few important strategic localities in Antarctica. According to them, Ice cores have many advantages over the marine and continental sedimentary records in terms of their completeness; ability to calibrate actual and measured temperature data through proxies. Ice core records have truly preserved the signatures of variations in the rate of snowfall, and temperature, of the region where they are located. In addition, the wind-blown dust and sea salt record, and the trapped air bubbles containing major and trace gases of the prevailing atmosphere, all provide us clues to the climate changes through ages and over wide regions. The ice cores have improved our understanding to our understanding of the various forcing factors and their mutual impact on the climate system. The nonlinearity of the climate system involves an important threshold of some of the forcing factors like greenhouse gas concentration and Meridional Ocean Circulation. The long ice core records have thrown light on such threshold which gave rise to abrupt climate events. Also, the comparison of the Antarctic and Greenland ice core records led to important concepts like bipolar seesaw and lag and lead of the north and south They also opined that while climate change in the low latitude region is governed by a multitude of factors including land use, anthropogenic activities, ocean circulation, greenhouse gas emission and the external forcing like sun's radiation, the climate change at the poles, particularly Antarctica are mainly controlled by greenhouse concentration, orbital forcings, and feedback processes. That probably is a key factor for Antarctic amplification which is a manifestation of a climate signal two to three times the global average. For a clear understanding of the Antarctic amplification, the ice core records provide an excellent opportunity. One of the most significant findings from the long Antarctic ice core has been to understand the nature of the glacial and interglacial intervals including their amplitude and profile. Their comparison of the paleoclimate record of the Antarctic ice cores with mid-latitude marine sedimentary records reveals teleconnections in the climate through the ocean and atmospheric circulation. Also, the abruptness of the climate change in the north pole is not so evident in Antarctica where the changes are rather gradual. The Antarctic Ice core record compared with the Greenland Ice Core record enables us to understand the interhemispheric coupling at the millennial scale. The ice core studies have revealed that during the last glacial period, the Dasngaard-Oeschger events in Greenland and millennial-scale warm events in Antarctica are strongly coupled with a time lag through the Atlantic meridional overturning circulation showing teleconnections between north and south. The bipolar seesaw is to a great extent proved by comparing Byrd (Antarctica) and Greenland ice core records. In addition, the Antarctic climate is connected to the climate of the tropics. They highlighted that the Antarctic sea ice extent is related to the Indian and African monsoon. The Antarctic ice expansion and sea ice extension are related to enhanced summer monsoon. Well, dated stalagmite δ^{18}Orecord between 88 and 22 kyr BP from Yongxing Cave in central China characterizes changes in Asian monsoon (AM) strength and the studies have shown that the record is strongly anti-phased with Antarctic temperature variability on sub-orbital timescales during the Marine Isotope Stage (MIS) 3, thus establishing teleconnections between monsoon and Antarctic climate. Another major contribution to the ice core record has been the Antarctic Isotope Maxima Events (AIM). During MIS 3, the Antarctic climate is marked by some warming events when the temperature has gone up to 1 to 3 degrees Celsius and a high oxygen isotope value. These warming events are known as Antarctic isotopic Maxima (AIM) events and are characterized by gradual warming and cooling. This is in contrast to the Dansgaard—Oeschger events in the North where rapid warming (8–16 degrees Celsius) is followed by gradual cooling to Greenland Stadials. This shows a distinct difference in the pattern of the warming events in the north and south. Several theories have emerged to explain the bipolar seesaw including the development of a southern heat reservoir during Greenland stadials. Thus we see that the Antarctic Ice core records provide us with a great understanding of the climate system, feedback, forcing factors, response system, and global Tele connectivity from north to south and from polar to tropical latitudes. Though the oldest record goes back only to 800 Kyrs, it provides conceptual advancements in our understanding of the cause and effect relationship and physical processes of linkages, that can be applied for time beyond 800 Kyrs.

On the other hand, **Pattanaik and Baba** provided an exhaustive account of the glacial geomorphology around Schirmacher oasis which is an ice-free area of Dorning Maud Land, East Antarctica. This area is sandwiched between a continental ice sheet in the south and an ice shelf in the north. The ice-free region provides opportunities to study lithology, paleoclimate, glacial process and glacial geomorphology of Antarctica. The landscape and the glacial-geomorphological features found in the Schirmacher oasis help to understand the glacial process active in the region. Striations on bedrocks and erratics indicate the glaciers' movements and deglaciation phases of the Oasis. A considerable amount of sediments found in the oasis as till, pattern ground, moraines, block fields, and outwash plains witnessed the past glacial processes. Retreat and advancement of polar ice have resulted in the formation of various landforms such as valleys, glacial troughs, cliffs, moraines, and *roche moutonnées*. Sediment archives from the lakes provide paleoclimatic information about the oasis. Permanent Indian research station Maitri and Russian research station Novolazarevskaya provide a platform for the researchers for conducting various research works in the Schirmacher oasis.

In view of the significant influence of the southern high latitudes on global climatic change, it is important to understand the role of the Southern Ocean and Antarctica (SOA) in climatic change both at present as well as during the geologic past. The role of the southern high latitudes in climatic change during the geologic past can best be evaluated by using foraminiferal characteristics in sediments from beneath the ocean, from lakes, and uplifted on land. Numerous studies have been carried out in which foraminiferal characteristics have been used to assess paleoclimatic/paleoceanographic changes at southern high latitudes. **Chaturvedi and Khare** aim at reviewing the findings of major foraminiferal studies carried out on sediments from southern high latitudes. The changes in foraminiferal characteristics can help to understand the present and past Physicochemical aspects of the high-latitude Southern Ocean. The application of advanced and recently developed techniques on foraminifera recovered from the SOA enabled the reconstruction of the seawater temperature and the extent of the continental ice sheets during the geologic past. The foraminiferal studies from the Antarctic Circum-polar Current and the regions north of it vastly helped to understand the past variations in productivity as well as changes in the positions of the various polar fronts and the production of deep and intermediate waters. Although the surface distribution of foraminifera has been studied from many regions of the Southern Ocean, there still are several gaps in coverage. In addition, the potential of foraminifera recovered from the Antarctic lake sediments has not been fully explored.

Interestingly the total solar eclipse that occurred on December 4, 2021, generated significant electron density variations over Antarctica. **Sunil et al**. tracked and observed the ionospheric responses over Antarctica during this important period. They observed clear electron density depletions are observed along the eclipse totality path followed by gradual recoveries. Total Electron Content (TEC) derived from 35 Global Positioning System (GPS) stations located over West Antarctica was used to study the ionospheric electron density variations during the eclipse. They found that the absence of solar radiations following the eclipse onset resulted in the drop of charged particle density at various ionospheric layers, which in turn resulted in the decrease of TEC values.

Among the major features of the Antarctic landscape, water bodies stand as a potential source of information as most of these water bodies are of glacial origin, relatively small and date from the Pleistocene epoch of the Quaternary Period. During warmer austral spring and summer periods when the ice melts, the Antarctic water bodies receive the majority of their sediment supply. It is, therefore important to understand that the climatic changes influence the sediments and fauna/flora of the Antarctic water bodies. Hence these water bodies could emerge as an important source of paleoclimatic and global change information. To understand the inter-relationship between various aquatic communities, the study of the physical, chemical and biological conditions of the ambient water is significant. Similarly, the detailed study of biotic communities of the Antarctic water bodies is essential because the biota inhabiting the region today is of relatively recent re-colonization, which undoubtedly accounts for some of the distinctive species distribution. Furthermore, the Oasis and Hills in East Antarctica host many lakes and transient ponds in the ice-free regions formed by the advection heat and differential albedo promoting increased melting of Polar ice. **Reshmi et al**. studied one such Oasis, the Schirmacher and Larsemann Hills areas of the East Antarctica region to probe the chemical and isotopic evolution of the lake waters. They noticed that lake water in the Schirmacher Oasis is fed by the glacial melt water with a relatively low ionic load, whereas the lakes from the Larsemann Hills had a high concentration of dissolved ions. Inter ionic variability showed that weathering of silicate rocks is the prime source of ions in these lakes, followed by ion exchange and evaporation. According to them, Isotopic ratios were also distinctly different in the lake water in both regions. Diffusion controlled kinetic effect at the liquid-ice interface for different water isotopologues is the prime determinant of the isotopic composition in Schirmacher Oasis lakes, whereas, in addition to it, evaporative enrichment of heavier isotopes from open water bodies affects the lakes in Larsemann Hills.

Indubitably, any modification of the catchment region gets reflected in the lake system, which is more easily studied from the lake sediments, than the catchment itself because water bodies are natural sumps of large catchment areas. It is important to mention that the limnological studies can also reveal the structural features and geomorphology of the region in which they are situated. Being the largest and one of the deepest water bodies of the Schirmacher Oasis, central Dronning Maud Land region, of East Antarctica, the sediments of Priyadarshini water body provide a continuous record of high-resolution paleoclimatic information. To retrieve the long sediment core the need to get the information about lake bathymetry, bottom topography and an estimation of the distribution, thickness and stratigraphy of the sediments underlying the lake floor utilizing acoustic techniques such as echo-sounding and sub-bottom seismic reflection profiling of the Antarctic lakes is emphasized in the present study. The preparation of a detailed map of the Priyadarshini water body will help to understand the potential pathways for the sediment and water influx to the waterbody. The results of the present study coupled with the results of the sub-bottom profiler will help in marking potential coring locations. Having realised such importance of the Antarctic's water bodies, **Khare et al**. undertook a detailed morphometric assessment of Priyadarshini water body and also attempt to assess the limnological parameters of the water body (Priyadarshinin Lake) under the extreme Antarctic climatic conditions.

While addressing the danger of ongoing global warming on the Himalayan glaciers, **Singh et al**. focused on the paleo-depositional and paleo-climatic conditions. Glacier dynamics and resulting geomorphic features are the characteristics of various stages of glacial fluctuations. Various geomorphic features/landforms such as Lateral Moraines (LM), Terminal/Recessional Moraines (RM), Outwash Plain Deposits (OWP) and Kame Terraces were identified in the field. The field observations and lithological analysis reflect that these morphological features are evolved by the glacial (Gl), glacio-fluvial (Gf), and mass movement activities. The sediment size decreases whereas sorting, roundness and percentage of matrix increase from the Gl-Gf process. These geomorphic features are modified by catastrophic events such as Landslide Lake Outburst Flooding (LLOF) and Glacier Lake Outburst Flooding (GLOF). Therefore, the geomorphic features/landforms are evolved by glacial processes under the direct control of tectonics and climate and further reshaped by LLOF and/or GLOF.

Thus, the present book emphasizes deciphering the climate records in ice cores, geologic cores, and those inferred from rock outcrops. Its chapters on scientifically significant and addressing a specific issue of climate change and geodynamics over the polar region will be of interest to policy makers, researchers, and scientific institutions

Neloy Khare

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Place: New Delhi

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Neloy Khare

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Place: New Delhi

Contributors

K. K. Ajith
National Atmospheric Research Laboratory
Gadanki, India

Waseem Ahmad Baba
Department of Geology
School of Environment and Earth Sciences
Central University of Punjab
Bathinda, Punjab, India

Vikash Chandra
Polar Studies Division
Geological Survey of India (GSI)
Faridabad, Haryana, India

Subodh Kumar Chaturvedi
Institute of Hydrocarbon
Energy and Georesources
ONGC Centre for Advanced Studies
University of Lucknow
Lucknow, India

A. Dharwadkar
Polar Studies Division
Geological Survey of India (GSI)
Faridabad, Haryana

Prabhu Prasad Dash
ACOAST, Amity University Haryana (AUH)
Gurugram, India
and
Department of Geology
Maharaja Sriram Chandra Banja Deo University, Keonjhar Campus
Keonjhar, Odisha, India

Chetan Anand Dubey
Department of Geology
University of Lucknow
Lucknow, India

Deepak Y. Gajbhiye
Polar Studies Division
GSI
Faridabad, Haryana

Pawan Kumar Gautam
Department of Geology
University of Lucknow
Lucknow, India

Girish Gopinath
Kerala University of Fisheries and Ocean Studies
Kochi, India

Amrutha K.
Department of Geology
School of Environment and Earth Sciences
Central University of Punjab
Bathinda, Punjab, India

Tushar Kaushik
Biodiversity and Paleobiology
Agharkar Research Institute
Pune, India

Rajni Khare
Department of Environmental Sciences & Limnology, Bakatullah University
Bhopal, India (Formerly)

Dhirendra Kumar
Department of Geology
University of Lucknow
Lucknow, India
and
Department of Geology
Central University of South Bihar
Gaya, Bihar, India

Pradeep Kumar
Polar Studies Division
Geological Survey of India (GSI)
Faridabad, Haryana, India

Kirtiranjan Mallick
Department of Geology
Utkal University, Vani Vihar
Bhubaneswar, Odisha 751004

Jitendra Kumar Pattanaik
Department of Geology
School of Environment and Earth Sciences
Central University of Punjab
Bathinda, Punjab, India

M. Praveenbabu
Centre for Water Resources Development and Management
Kozhikode, India

Rahul Rawat
Indian Institute of Geomagnetism
Mumbai, India

T. R. Resmi
Centre for Water Resources Development and Management
Kozhikode, India

Ankush Shrivastava
Department of Geology
Mohanlal Sukhadia University
Rajasthan, India

S. P. Shukla
Polar Studies Division
Geological Survey of India (GSI)
Faridabad, Haryana

Anoop Kumar Singh
Department of Geology
University of Lucknow
Lucknow, India

Ashutosh K. Singh
Department of Geology
Centre of Advanced Studies
University of Delhi
Delhi, India

Dhruv Sen Singh
Department of Geology
University of Lucknow
Lucknow, India

Vikram Pratap Singh
Department of Geology
Indira Gandhi National Tribal University
Amarkantak, India

Devesh K. Sinha
Department of Geology
Centre of Advanced Studies
University of Delhi
Delhi, India

A. S. Sunil
CUSAT-NCPOR Centre for Polar Sciences
Department of Marine Geology and Geophysics
School of Marine Sciences
Cochin University of Science and Technology
Kochi, India

P. S. Sunil
CUSAT-NCPOR Centre for Polar Sciences
Department of Marine Geology and Geophysics
School of Marine Sciences
Cochin University of Science and Technology
Kochi, India

A. K. Swain
State Unit: Odisha, Geological Survey of India (GSI)
Bhubaneswar, Odisha, India

Dhanya Thomas
CSIR Fourth Paradigm Institute
Bangalore, India

Balkrishan Vishawakarma
Department of Geology
University of Lucknow
Lucknow, India

Ashwani Wanganeo
Department of Environmental Sciences & Limnology
Bakatullah University
Bhopal, India (Formerly)

Rajni Wanganeo
Department of Zoology
Government Benzeer College of Commerce & Science
Bhopal, India (Formerly)

Editor

Dr Neloy Khare, presently Adviser/Scientist "G" to the Government of India at MoES has a very distinctive acumen not only in administration but also in quality science and research in his areas of expertise covering a large spectrum of geographically distinct locations like the Antarctic, Arctic, Southern Ocean, Bay of Bengal, Arabian Sea, Indian Ocean etc. Dr Khare has almost 30 years of experience in the field of paleoclimate research using paleobiology Paleontology)/teaching/science management/administration/coordination for scientific programs (including Indian Polar Programme) etc. Having completed his doctorate (PhD) in tropical marine region and Doctor of Science (DSc) in Southern High latitude marine regions towards environmental/climatic implications using various proxies including foraminifera (micro-fossil), have made significant contributions in the field of Paleoclimatology of Southern high latitude regions (the Antarctic and the Southern Ocean) using Micropaleontology as a tool. These studies coupled with his paleoclimatic reconstructions from tropical regions helped understand causal linkages and teleconnections between the processes taking place in Southern high latitudes with that of climate variability occurring in tropical regions. Dr Khare has been conferred Honorary Professor and Adjunct Professor by many Indian Universities.

He has a very impressive list of publications to his credit (125 research articles in national and international scientific journals: three special issues of national scientific journals as guest editor; edited special issues of *Polar Science* (Elsevier), *Journal of Asian Earth Science* (Elsevier), *Quaternary International* (Elsevier), and *Frontiers in Marine Science* as its managing/guest editor. He has authored/edited many books, and has contributed 130 abstracts to various seminars, as well as writing 23 popular science articles and five technical reports). The government of India and many professional bodies have bestowed him with many prestigious awards for his humble scientific contributions to past climate changes/oceanography/polar science and Southern Oceanography. The most coveted award is the Rajiv Gandhi National Award of 2013, conferred by the Honourable President of India. Others include the ISCA Young Scientist Award, Boyscast Fellowship, CIES French Fellowship, Krishnan Gold Medal, Best Scientist Award, Eminent Scientist Award, ISCA Platinum Jubilee Lecture, IGU Fellowship, and many more. Dr Khare has made tremendous efforts to popularize ocean science and polar science across the country by way of delivering many Invited lectures, radio talks, and publishing popular science articles.

Dr Khare sailed in the Arctic Ocean as a part of "Science PUB" in 2008 during the International Polar Year campaign for scientific exploration and became the first Indian to sail in the Arctic Ocean.

1 Geomorphology around Kongsfjorden-Krossfjorden System, Svalbard

Jitendra Kumar Pattanaik,[1] Amrutha K.,[1] and Prabhu Prasad Dash[2]

[1] Department of Geology, School of Environment and Earth Sciences, Central University of Punjab, Bathinda, Punjab, India

[2] ACOAST, Amity University Haryana (AUH), Gurugram, India; Department of Geology, Maharaja Sriram Chandra Banja Deo University, Keonjhar Campus, Keonjhar, Odisha

CONTENTS

1.1 INTRODUCTION

Polar environments are distinctly sensitive to climatic changes as it belongs to the lower end of the energy spectrum of our planet. Hence, it is susceptible to ecosystem variation, landscape evolution and anthropoid influence. The Arctic region has its characteristic geomorphic features which indirectly indicate the geology, climatic condition and different geomorphic forces that are/were active in the area. The abundance of standing waters is a characteristic feature of the Arctic region (Pienitz et al., 2008). Presence of certain geomorphological features can be used to understand the climatic conditions and geomorphological

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agents prevalent in the area. Periglacial land forms such as ice-wedges, rock glaciers, pingos, solifluction, avalanches, debris flows, rockfalls and nivation; glacial land forms like surge glaciers and different aeolian land forms are few example to this. Compared to other coastlines, Arctic coasts have experienced substantial modifications (Overduin et al., 2014). Since the LGM (Last Glacial Maximum), there has been a large degree of glacial retreat from the coastal tract resulting in the predominance of paraglacial processes (Bourriquen et al., 2018; Gjermundsen et al., 2013). Considering the geomorphological studies from the Arctic region, it is important to note that despite having the 30% of the global coastline in the Arctic, only 1% of Arctic coasts have been studied (Lantuit et al., 2010). Arctic mountains are always been important in geomorphological studies as the region is characterized by the lowest sediment fluxes, even though it is characterized by a large sediment store and a favorable topography for sediment transportation (Mithan et al., 2019). The Svalbard archipelago in the Arctic circle has been widely studied in terms of its glacial dynamics and its implications for climate change. However, a wide variety of geomorphological features formed as a result of a single major (ice) geomorphological agent, make it difficult to interpret the underlying geomorphological processes. Svalbard is located in the Arctic sea between latitudes of 74° to 81°N and displays a vast expanse of ice caps (≈ 60%) and valley/fjord glaciers (Hagen et al., 1993). Spitsbergen is the largest island of Svalbard archipelago (Miccadei et al., 2016). Kongsfjorden-Krossfjord systems are located between 78° 40´ and 77° 30´ N latitudes and 11° 3´ and 13° 6´ E longitudes (Svendsen et al., 2002). Kongsfjorden is aligned from southeast to northwest and the orientation of Krossfjorden is from North to South. The coast of Kongsfjorden is defined by the Blomstrandbreen area in the North, Broggerhalvoya toward the South, Ossian Sarsfjellet and Colletthogda in the East (Miccadei et al., 2016). Fjord systems and the lowland areas in the Arctic are important as they experience both terrestrial and coastal processes. Fjords are semi-enclosed marine basins that are deepened by glacier activity and generally represent a transition region between terrestrial and marine environments (Howe et al., 2010).

Numerous fjords of different dimensions are present in the Svalbard archipelago and the longest fjords, Storfjorden, separate Spitsbergen from Barentsøya and Edgeøya. The major fjords of Svalbard are listed in Table 1.1. Krossfjorden-Kongsfjorden system together constitute a basin area of 3074 km^2 and 74% of the area is covered by ice (i.e. 1651 km^2) and 2257 km^2 area island. The system has a glacier volume of 308 km^3 (Svendsen et al., 2002). Kongsfjorden-Krossfjorden systems are located near Arctic and Atlantic water mass and it is influenced by the west Spitsbergen current and freshwater from glacier runoff (Kumar et al., 2018). Seasonal sea ice-rafted, across gravity-driven and the glacier generated sediments control the sedimentation process in the Kongsfjorden-Krossfjorden fjord system. The sediments deposited in the fjords and the landforms formed by glaciers in the region are less modified and hence this is an ideal location for climatic research (Trusel et al., 2010). Geomorphology of the Kongsfjorden-Krossfjorden system is studied by the systematic appreciation of geology and geomorphic processes responsible for landscape evolution.

TABLE 1.1
Major Fjords of Svalbard Based on Length

Sl. no	Name of the fjords	Region in Svalbard	Length (km)	S. N.	Name of the fjords	Region in Svalbard	Length (km)
1	Storfjorden	Spitsbergen	132	19	Lady Franklinfjorden	Nordaustlandet	25
2	Wijdefjorden	Spitsbergen	108	20	St. Jonsfjorden	Spitsbergen	21
3	Isfjorden	Spitsbergen	107	21	Bellsund	Spitsbergen	20
4	Van Mijenfjorden	Spitsbergen	83	22	Brennevinsfjorden	Nordaustlandet	20
5	Woodfjorden	Spitsbergen	64	23	Raudfjorden	Spitsbergen	20
6	Wahlenbergfjorden	Spitsbergen	46	24	Smeerenburgfjorden	Spitsbergen	20
7	Tjuvfjorden	Edgeøya	45	25	Ekmanfjorden	Spitsbergen	18
8	Rijpfjorden	Nordaustlandet	40	26	Grønfjorden	Spitsbergen	16
9	Duvefjorden	Nordaustlandet	35	27	Sassenfjorden	Spitsbergen	15
10	Lomfjorden	Spitsbergen	35	28	Tempelfjorden	Spitsbergen	15
11	Austfjorden	Spitsbergen	32	29	Lilliehöökfjorden	Spitsbergen	14
12	Billefjorden	Spitsbergen	30	30	Vestfjorden	Spitsbergen	12
13	Hornsund	Spitsbergen	30	31	Adlersparrefjorden	Nordaustlandet	10
14	Krossfjorden	Spitsbergen	30	32	Möllerfjorden	Spitsbergen	9
15	Liefdefjorden	Spitsbergen	30	33	Magdalenefjorden	Spitsbergen	8
16	Van Keulenfjorden	Spitsbergen	30	34	Recherche Fjord	Spitsbergen	7
17	Dicksonfjorden	Spitsbergen	30	35	Fuglefjorden	Spitsbergen	6
18	Kongsfjorden	Spitsbergen	26	36	Kobbefjorden	Spitsbergen	3.5

Note: The locations of the fjords are indicated. Some of the branches/tributaries/distributaries of the major fjord system are also included here.

1.2 GEOLOGY AROUND KONGSFJORDEN-KROSSFJORDEN SYSTEM

The Kongsfjorden-Krossfjorden fjord system is located near a major tectonic boundary and hence the region has diverse petrology (Streuff, 2013). This tectonic boundary separates the Northwestern Basement Province to the northeast and the Cenozoic fold- and thrust belt of western Spitsbergen to its southwest (Bergh et al., 2000). Igneous, metamorphic, and sedimentary rocks are reported from the Kongsfjorden-Krossfjorden system**.** According to the Norwegian Polar Institute, the eastern boundary of the island is dominated by sandstone, siltstone and shale with small patches of gabbro or metagabbro rock type. These layered rocks are of the Devonian age. The southern boundary of the island has the maximum diversification and exhibits sedimentary rocks such as chert, silicified limestone and sandstone and metamorphic rocks like marble alternating with other metasediments. Sandstone, siltstone and shale with gabbro or metagabbro patches are also present here along with bituminous shale, phyllite and metapelites schists. Phyllites and quartzites are often found locally with layers of other rocks. These rock types are of Paleogene to Neogene, Middle Jurassic–early Cretaceous, Triassic–Middle Jurassic, and Carboniferous and Permian sequences. The southwest boundary of the island is characterized by limestone and/

or dolostone, conglomerate, tilloid rocks, garnet-mica schist, calc-pelitic schist and marble, quartzite, and other high-pressure metamorphic rock types. The northwestern boundary is majorly occupied by gneisses and schists. Patches of marble with phyllite and metapelitic schist are often observed along this boundary with granite or granodiorite patches. The bedrocks in this region belong to Mesoproterozoic. The Kongsfjorden-Krossfjorden fjord system is surrounded by phyllite and meta-pelitic schist with patches of marble. Quaternary continental and coastal deposits overlie the bedrock sequences. Surficial continental deposits include till and diamicton, talus, rockfalls, fluvial and beach deposits.

1.3 LANDSCAPE TYPES

Landscape in the Svalbard region can be divided into several categories depending upon the geomorphological processes and the localities where it is found. As per the scheme adopted by the Norwegian Polar Institute, landforms are classified into various categories as listed in Table 1.2, Sl. No. 1, under terrestrial landforms. Other landscape types are listed under glacial landforms and surface deposits (Table 1.2). Depending on the landforms that found in the different localities, these features can be grouped under coastal landforms, landforms developed in the slope, mountain ranges and valleys.

1.3.1 Coastal Landforms

Sediment distribution by retreating glaciers and the efficiency of the fluvial system to transport sediment towards the shoreline controls the overall evolution of the coastal region (Bourriquen et al., 2018). Coastal zones with continuous sediment supply have undergone coastal progradation and the areas that lost the sediment supply experienced coastal recession (Bourriquen et al., 2018). Most of the coastal part of the system is

TABLE 1.2
Different Landscape Types and Geomorphological Features Found in Svalbard

Sl. No	Landscape types	Geomorphological feature
1	Terrestrial landforms	Coastal low land, sandur, or river flat within coastal lowland or U-shaped valley, moraine field, ice field and ice cap, valley glacier and glacier cirque, glacial denudation flat, open, and hilly landscape, mountainous landscape with rounded shapes, plateau mountainous landscape, edge dominated and alpine mountainous landscape
2	Glacial landforms	Fjord, Pingo, pattern ground, glaciers, U-shaped valley, moraine field, Drumlins, and glacial flutes
3	Surface deposits	Ice, recent moraines, moraine and till, glacial-fluvial and fluvial deposits, marine deposits, gelifluction deposits, slope deposits, weathering materials
4	Other features	Thermal spring, karst or thermo-karst landforms, exposed bedrocks

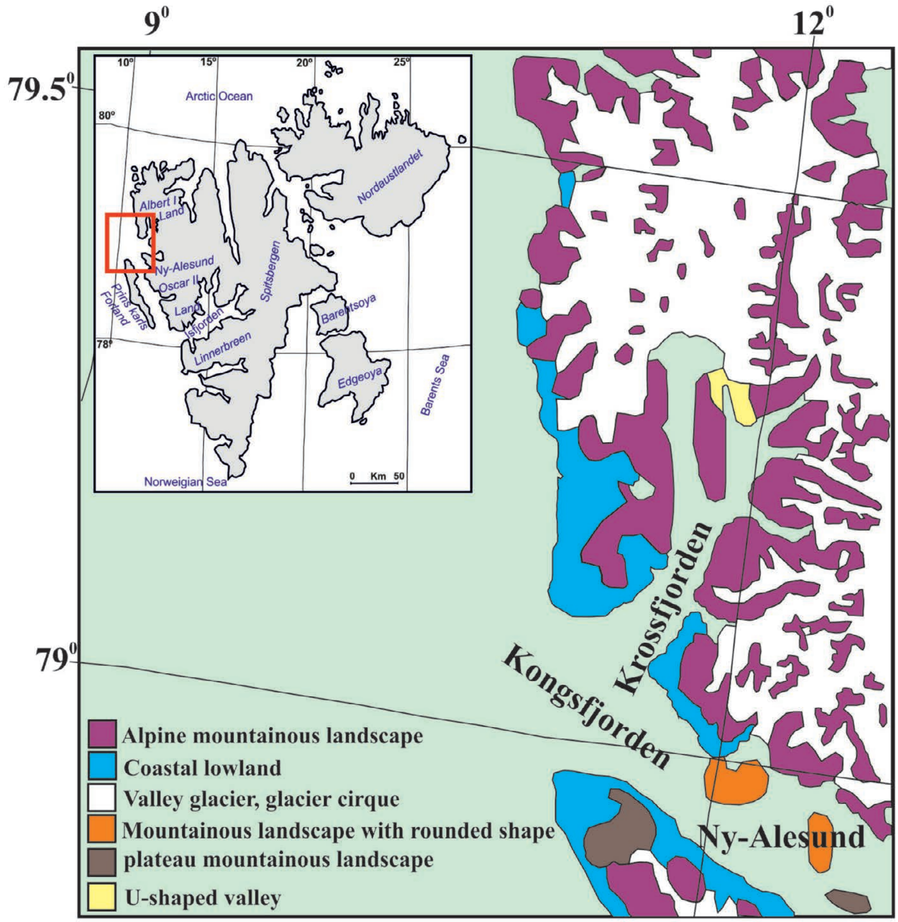

FIGURE 1.1 Map showing important landscape types and geomorphological features in and around Kongsfjorden-Krossfjorden system.

covered with Quaternary deposits of moraines, marine shore, and fluvial deposits (Ingvaldsen et al., 2001; Kumar et al., 2018).

The coastal geomorphology of Svalbard is dominated by Coastal cliffs, spit-barrier lagoons, deltas, flats and raised beaches. Wind, rain or/and wave action in coastal areas erode the soft rocks, resulting in the formation of cliffs that belongs to hard rock remnants of the shore lithology. Longshore drift in the coastal areas results in spit-barrier lagoons. These common features associated with the coast are formed in accordance with the variation in sediment supply, longshore drift and exposure to fetch (Brückner and Schellmann, 2003). River incisions of bed-rocks in the coastal area form steep scarps and channels perpendicular to the coast (Berthling et al., 2020).

Coastal lowlands with well-developed raised beaches are a characteristic feature of Svalbard. However, its distribution is not uniform, and they are on wide display along the western boundary. The genesis of raised beaches is related to post-glacial isostatic rebound (Berthling et al., 2020). The western coastline of Spitsbergen is characterized by a series of marine terraces. Strandflats are common in coastal areas, which are mostly bounded by mountains and low coastal cliffs with beaches towards the sea. Raised beaches are preserved on the strand flats (Streuff, 2013). Currently, the coast is covered with linear and pocket-sized rocky cliffs and gravel beaches, including Lagoons and deltas. The western rocky shoreline of Kongsfjorden-Krossfjorden fjord system exhibits vertical cliffs with caves and pocket beaches. Low-lying areas of Broggerhalvoya in the Kongsfjord-Krossfjord system have well developed Patterned ground and sorted circles (Svendsen et al., 2002). Lagoons and single bars are common along all the coasts (e.g. Brandallaguna).

Coastal Sandur deltas are another important coastal landform. These are formed during the glacial retreat which leads to the exposure of terrigenous sediments and further transport and deposition resulting in the Sandur delta (Bourriquen et al., 2018). The sandur deltas of the Brogger peninsula are some of the examples formed by this geological process (Austre Lovénbreen, Midtre Lovénbreen, and Vestre Lovénbreen glaciers). Stone circles and patterned grounds are observed on the coastal part of Kvadehuken and in the lowland areas of Broggerhalvoya (Kumar et al., 2018).

1.3.2 Slope Landforms

Talus slopes and cones, rock falls and pro talus remparts are the important slope landforms in Kongfjorden-Krosfjorden fjord system. Rock slopes exhibit characteristic fan-shaped landforms. These landforms indicate a transition zone between coastal features and mountain ranges where debris fall and deposition is high. Periglacial processes on the slope generate talus deposits, which may form pro-talus ramparts, and rock glaciers e.g., at the foot of Zeppelinfjellet (Zeppelin Mountain) and Stuphallet (Stup Cliff) on Broggerhalvoya, and in the northern part of Blomstrandhalvoya (Svendsen et al., 2002). Debris that gets piled up to a characteristic angle of repose is called talus slope. The deposits related to rock slopes are fan-shaped landforms. Certain climatic processes favor the development of slope processes, rockfalls, debris and solifluction covers. Steep mountain slopes cut by gullies, lower gradient slope with debris covers and slopes with solifluction lobes and sometimes flattened parts dominated by shales are some of the features formed by the runoff of melting snow or/and snow avalanches and gullies formed alluvial fans (Zwoliński et al., 2013).

1.3.3 Mountain Ranges and Wide Valleys

The overall distribution of mountain ranges and wide valleys follow geological structures and the meridian of the location (Zwoliński et al., 2013). Hecahoek rocks, formed of metamorphosed crystalline rocks, quartzite, marble and slate appear as mountain ranges (Zwoliński et al., 2013). Fjords of Spitsbergen might indicate the path of the old valley system, which was reformed in Quaternary glaciations (Zwoliński et al., 2013). The downslope flow of valley glaciers creates a trough, which is called a U-shaped valley (Fredin et al., 2013). Hence, this flat bottomed and steep-walled landform is a product of the erosive action of glaciers. This erosive action is called glacial plucking, which generally occurs at the bottom of the valleys. The mountain peaks on the southern side of inner Kongsfjorden, Nunataks surrounding the inner Kongsfjorden, the pyramidical peaks of Tre Kroner and high mountains surrounding Fjord Krossfjorden, North of Kongsfjorden are some of the examples of mountain ranges in the Krossfjorden-Kongsfjorden system. The mountain ranges in the Kaffioyra generally occur as narrow ridges with narrow crests and steep slopes (Svendsen et al., 2002).

Landforms associated with limestone terrain are also reported here. Dissolution of limestone bedrocks resulted in landscape with Karst topography. Most of these are small-scale surface features, however, some larger features like caves also occur, e.g. caves in Blomstrandhalvoya (Blümel, 1971).

1.4 SURFACE MATERIAL IN AND AROUND KONGSFJORD-KROSSFJORD REGION

The border area around Kongsfjorden-Krossfjorden fjord system is largely covered by marine deposits, slope deposits and weathering material (Kristiansen and Sollid, 1986). Glacio-fluvial, fluvial and recent moraine are also present. Patches of exposed bedrock can also be seen in the area.

Glaciers: More than 60% land area of Svalbard is covered with glaciers (Etzelmüller et al., 2000). In Svalbard, glaciers of every kind can be seen. In Spitsbergen, valley glaciers are predominate, and massive ice caps are frequent in Nordaustlandet, Edgerya, and Barentsrya. Glaciological research began in the late 19th century and became very popular in the 20th century. They include ice-core studies and research in meteorology, mass balance, glacier flow, glacial erosion, and radio-echo sounding (Liestøl, 1988). Since many of the glaciers in Svalbard are known to surge frequently (86 have surged till the beginning of 20th century), it is challenging to use fluctuations of glaciers as climatic indicators. Important morphological feature developed during the glacier advance and deglaciation is river valleys, through which the water drains from the glaciers (Svendsen et al., 2002). At the Kongfjorden fjord, the glaciers can be found directly calving into the sea. These glaciers are both subpolar and polythermal, indicating that they have both warm (above or near zero, where meltwater can exist), and cold (below zero) zones. Surging glaciers are common in the study area.

Von Postbreen, a large land-terminating glacier; Kongsvegen and Tunabreen, large tidewater glaciers; Midtre Lovénbreen, Tellbreen and Longyearbreen, small valley glaciers, Kongsvegen and Midtre Lovénbreen are examples of some of the important glaciers in the main island of Spitsbergen (Sevestre et al., 2015). Kongsfjorden and Krossfjorden are dominated by tidewater glaciers: Lilliehookbreen at the head of Krossfjorden (Lilliehookfjorden) and five other calving glaciers along its eastern coast. Kronebreen and Kongsvegan at the head, and Conwaybreen and Blomstrandbreen on northern coast of Kongsfjorden. Glacial, periglacial and hydroglacial processes influence the landscape.

The main glacierized area consists of a large glacier complex in the inner part of the fjords, which has many calving fronts at its head. These glaciers drain the large icefields of Isachsenfonna and Holtedalfonna. Blomstrandbreen on the northern side of Kongsfjorden also has a calving front. On the southern side, there are several valleys or cirque glaciers (Svendsen et al., 2002), and None of them reaches the fjord. Glaciers are associated with a different types of moraine deposits and their front portion is characterized by rivers and outwash plains (Berthling et al., 2020).

Moraines: Towards the end of glaciers, large amounts of rock debris get deposited beneath the active glacier. The size of accumulated debris ranges from meter-sized boulders to millimeter-sized dust particles. This random mixture of rock particles is called till and mounds, sheets or sinuous ridges of sediment deposits are called moraines (Elvevold et al., 2007). Austre Lovénbreen, Midtre Lovénbreen and Vestre Lovénbreen are some of the examples for terminal moraines (Bourriquen et al., 2018).

1.5 SUMMARY

Arctic regions are important in geomorphological studies as the region is characterized by the lowest sediment fluxes. However, this region has large sediment storage and a favorable topography for sediment transportation. The Svalbard archipelago in the Arctic has been widely studied in terms of its landscape, glacial dynamics, sediment transports, and paleoclimate. The Fjord system is a transition zone between the terrestrial and marine environment, acting as an important sediment archive that influenced by both the environments. These archives provide ample opportunity for high-resolution studies on paleo-environmental changes. Diverse geomorphological features developed in Svalbard are due to the interplay of active climate and surficial processes. Detailed study on these features will help to understand the sequence and mechanism of the surficial processes.

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Significance of Foraminiferal Studies from the Southern High Latitudes in Assessing Global Climate Change

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Isotope Hydrochemistry of Lakes and Transient Ponds of East Antarctica with Varying Degree of Environmental Condition

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Glacial Morpho-Sedimentology and Processes of Landscape Evolution in Gangotri Glacier Area, Garhwal Himalaya, India

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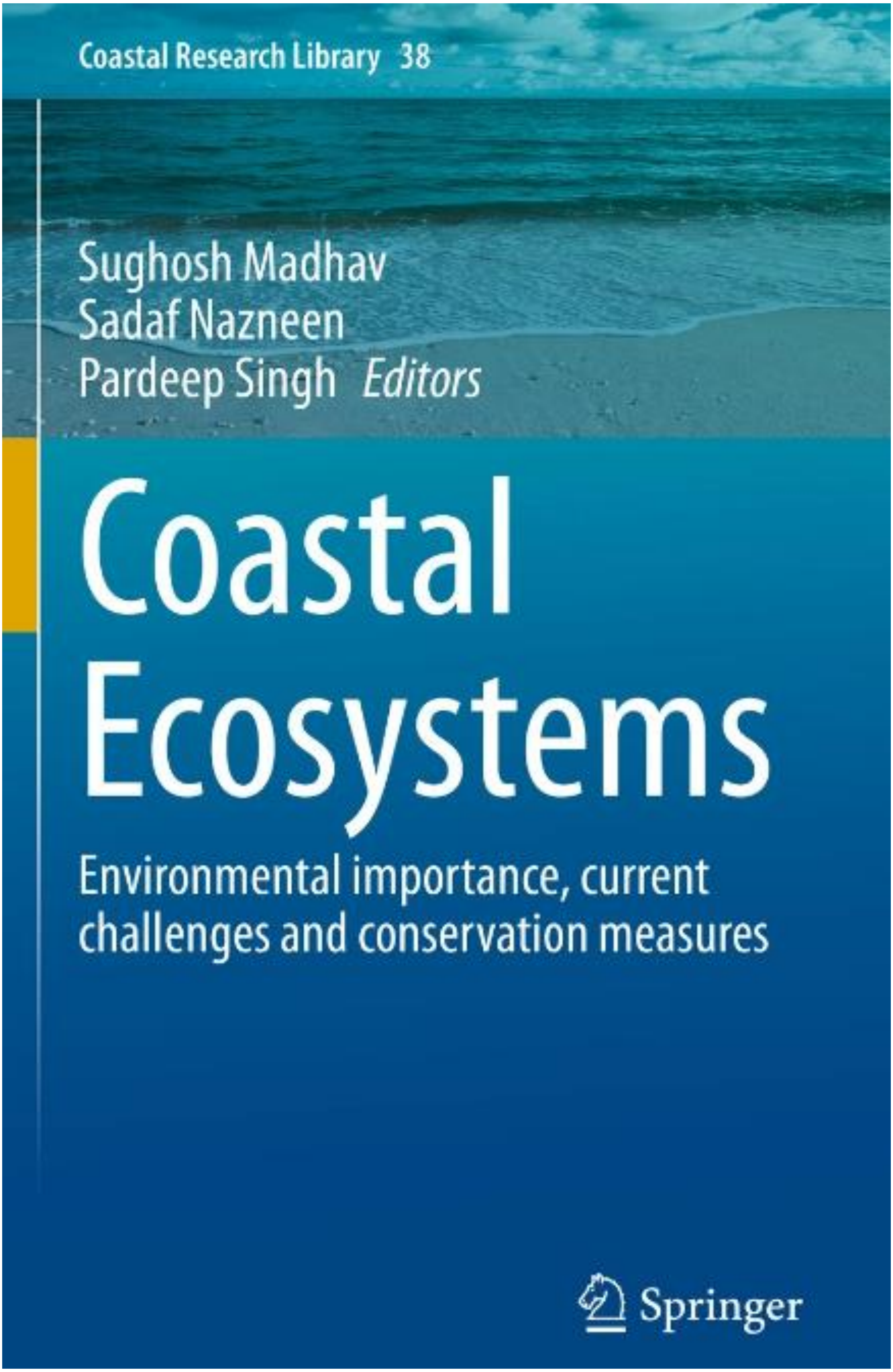
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Editors
Sanjay Kumar Gupta
School of Molecular Diagnostic Prophylactics and Nano-Biotechnology (SMDPN), ICAR-Indian Institute of Agricultural Biotechnology
Ranchi, Jharkhand, India

Sib Sankar Giri
Laboratory of Aquatic Biomedicine, College of Veterinary Medicine and Research Institute for Veterinary Science
Seoul National University
Seoul, South Korea

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Dedicated to
All
COVID-19 Warriors
and Frontline Workers

Foreword

Aquaculture is one of the cheapest animal protein farming practices that has shown tremendous growth over the past few decades. Currently it contributes about 52 percentage of the total fish for human consumption globally (FAO 2020). Asian countries are major drivers that produce about 80 percentage of the total global production and contribute directly and indirectly to economic and food security. To accelerate the production in an ecologically safe and environmentally sound manner, responsible use of resources and quality inputs deserve due care and importance considering the sustainability of aquaculture. However, with the growing demand of the cheap quality protein, unsustainable intensification of the industry has been proliferated and getting popular in several parts of the globe, resulting in growing incidences of disease outbreak. With the further expansion of aquaculture, incidence of outbreaks of infectious disease is also expected to increase multi-fold and even at serious epizootological level, thus causing serious threat and limiting the growth of the industry. Biotechnological applications play a key role in aquaculture health management as it facilitates the rapid and reliable detection and identification of virulent pathogens. In the era of omics evolution, modern state-of-the-art technologies such as transcriptomics, proteomics, metabolomics, microbiomics, RNA interference and cell culture techniques would offer excellent application to decode the molecular mechanism of disease progression and in developing their control and management strategies.

This book has been compiled with chapters that encompass the fundamental facets connected with the biotechnological advances of disease management in aquaculture. Recent advances on the role of various dietary supplements, viz. probiotics, prebiotics, synbiotics, immunostimulants, etc., in health management have also been extensively covered, which would offer enormous benefits to global readers of all categories and also provide insights into the underlying mechanism of health promotion in aquaculture.

I sincerely would like to place a record of appreciation to the book editors and specialist contributors for their sincere efforts in the comprehensive collation of brilliant chapters on biotechnological advances in aquaculture health management. I would like to urge the reader to gain insights from the valuable compilation and to join the editors in this enthralling, exciting and gratifying attempt.

Dilip Kumar

International Civil Service (FAO of UN), ICAR CIFE
Mumbai, India
28 May 2021

Dilip Kumar

Foreword

Aquaculture is a multi-billion-dollar industry that is expanding rapidly to cater to the demands of livelihood and nutritional security of humankind globally. The sector has been confronting serious challenges which are sophisticated and multidimensional. Among these challenges, prevalence of infectious diseases takes the lion's share leading to huge economic losses. The annual loss of revenues incurred due to disease upsurges is estimated to the tune of six billion US dollars. The figure is projected to surpass 40% of the global production with emergent diseases in the shrimp sector. This poses a major threat towards the collapse of the aquaculture industry in several developing nations of Asia. Additionally, there are also upcoming issues of climate change and antimicrobial resistance that have aggravated the risks associated with this sector and need to be addressed judiciously on a priority basis. Hence, it is imperative to upgrade the application of technological advances in this sector under the umbrella of environmental sustainability and health promotion of the cultured species.

Understanding the potential of biotechnological tools such as transcriptomics, metabolomics, microbiomics, genome editing and RNA interference would not only prove to be the cornerstone in tackling the incidence of disease outbreak but also pave the way for the development of diagnostics and curative measures. The importance of disease prevention by boosting the inherent immunity of fish via diet supplementation and vaccination, rather than disease management, would prove to be a paradigm shift in the enhancement of safety against infectious pathogens.

The biotechnological inventions can be applied towards refining the health strategies for qualitative and quantitative production from the aquaculture sector in a holistic manner. This book is a humble effort towards the compilation of the multifarious aspects of technological advances in aquaculture health management.

The book will be useful to readers who are exploring opportunities to make contributions in the field of aquaculture health management. The updated literature survey highlights the voids in the area that may be crucial to realize the potential of blue economy. I applaud the entire team of editors and contributors for putting their best efforts towards building a comprehensive compilation in the form of this book entitled *Biotechnological Advances in Aquaculture Health Management*. It should be helpful to both academicians (students, teachers, researchers) and aqua-preneurs for upgrading their skills and knowledge in the area of aquaculture health management driven by biotechnological advances.

Peter Bossier

Laboratory of Aquaculture and
Artemia Reference Center, Ghent University
Ghent, Belgium
28 May 2021

Preface

Globally, the aquaculture industry has witnessed phenomenal growth in the last two decades that has contributed to enhance the preference of protein-rich meat in the diet of the poorest of the poor. Aquaculture produce are recognized as one of the healthiest foods on the planet, as it holds great promise in transforming food systems, and eradication of hunger as well as malnutrition in numerous developing countries of the world. As per recent reports of FAO, the total fish production is expected to expand from 179 million tonnes in 2018 to 204 million tonnes in 2030. Out of which, aquaculture production is anticipated to touch 109 million tonnes in 2030, an escalation of 32% (26 million tonnes) over 2018 (FAO). With the increasing production, the global average annual fish consumption has also risen to the tune of 20.30 kg in 2017 (FAO). The global aquaculture market is projected to grow with a healthy growth rate of more than 7.1% during the estimated period of 2020–2027. Growing demand for quality fish products has promoted both horizontal and vertical expansion of aquaculture activities globally. However, the major obstacles in the sustainable growth of aquaculture are seriously challenged with the prevalence of disease outbreak caused by a diverse group of infectious pathogens and several non-infectious agents. Such detrimental circumstances often lead to deprived growth, compromised immune response and intense mortality and ultimately hamper the aquaculture production. Therefore, to rescue this sunrise sector, application of biotechnological interventions or tools could be a milestone step to ensure long-term economic and social benefits towards food security. The advent of high-throughput sequencing technology and omics approaches such as genomics, transcriptomics, microbiomics and metabolomics has enabled scientists/researchers not only to understand the complex biological processes and underlying molecular mechanism but also helped in precise and targeted invention of remedial measures to curb huge economic losses to farmers. The development of molecular diagnostics for the identification of diseases, prophylactic measures for control, management and analysis of biological resources are some of the prime concerns that have been detailed in this book. Prevention at the host's end is equally important in this aspect which paves the way to immunomodulation via dietary supplementation of prebiotic, probiotics, synbiotics and immunostimulants. The aquaculture sector needs innovative biotechnological approaches to overcome challenges such as water quality management, rapid disease diagnostic services, disease prevention and management of outbreaks, supply of disease-free or high health broodstock and seed. Of late, biotechnological science is growing rapidly and has endowed us with several new tools and technology to create new horizons in aquaculture, especially health management. Some of the advanced biotechnological approaches such as vaccination, antimicrobial peptides, gene editing, metagenomics, RNA interference and cell culture techniques have shown promising results in managing the health of cultured aquatic organisms over different agro-climatic condition across the globe. Nanotechnology has emerged as an alternative approach with innovative materials and protocols to solve persisting issues in fish health management. Biofloc technology is becoming increasingly popular as an emerging avenue in aquatic animal healthcare and directed to maximize aquaculture productivity by using microbial biotechnology.

Apart from economic potential for the fisheries sector, health management through biotechnology also holds promise for sustainable management of aquaculture practices, which is crucial for the prevention of environmental degradation due to intensive farming within the aquaculture industry.

The editors have tried their best to make comprehensive coverage of the biotechnological advances in aquaculture health management. This book updates the subject matter, illustrations and problems to incorporate new concepts and issues related to biotechnological aspects of health management. The publication of this book has been possible through the enthusiastic support, assistance and cooperation of dedicated scientists/researchers of different institutions working in the areas of aquaculture and fisheries across the globe. The processing and editing of various chapters has taken a long time, and we express our sincere gratitude to all the contributors for bearing with us.

I wish this book would be of immense benefit to researchers, scientists, students, entrepreneurs, and even industry players working in the field of aquaculture, biotechnology, fish health management and fisheries.

Ranchi, Jharkhand, India — Sanjay Kumar Gupta
Seoul, South Korea — Sib Sankar Giri

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This book is an outcome of continued professional collaboration of both editors. We would like to express our sincere appreciation to all contributors who have contributed to this book in the form of chapters. Critical remarks and suggestions of two anonymous reviewers were very much helpful in picking up several relevant and innovative topics. Indeed, it is our utmost pleasure to acknowledge all the persons who have directly or indirectly helped us in completing this book.

We are immensely grateful to Dr. Dilip Kumar, Ex Director/VC of ICAR CIFE Mumbai, India, and Prof. Dr. ir. Peter Bossier, Director, Laboratory of Aquaculture & Artemia Reference Center, Ghent University, Belgium, for their encouragement, suggestions and support to the young researchers for their contributions in this book.

Unflinching support of family members, students, colleagues, and friends in this pandemic situation is a great source of motivation for us to complete this book.

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Finally, we would like to bow our heads before Almighty God, whose great power and eternal wisdom has embraced us with strength and audacity to complete this book.

28 May 2021

Sanjay Kumar Gupta
Sib Sankar Giri

"Once you replace negative thoughts with positive ones, you'll start having positive results."
—Willie Nelson

Contents

Editors and Contributors

About the Editors

Sanjay Kumar Gupta, M.F.Sc., Ph.D. is a scientist at the Division of Molecular Diagnostics, Prophylactics and Nano-biotechnology, ICAR-Indian Institute of Agricultural Biotechnology (IIAB), Ranchi, Jharkhand, India. He graduated from the College of Fisheries, Panangad, Kochi, Kerala, and obtained his master's and doctoral degrees from Central Institute of Fisheries Education (CIFE), Mumbai. His major research area focuses on the application of omics technology for qualitative and quantitative enhancement of aquaculture production. He has published more than 60 peer-reviewed research papers in SCIE journals and has delivered numerous oral and posters presentations in diverse international meetings. Dr. Gupta has edited 04 books, authored 02 books, published 40 scientific popular articles 30 book chapters, 10 bulletins, 8 instruction manuals and 6 leaflets. He serves as editor and reviewer for various international scientific journals and has been honoured with several awards of national and international repute for his outstanding contribution to the field of aquaculture. He also has extensive experience working with various aquaculture systems and the application of control measures in aquaculture health management using advanced molecular tools. He was awarded as one of the top global researchers to avail prestigious Endeavour Post-doc Fellowship by Australian Government in 2018.

Sib Sankar Giri, M.Sc., M.Phil., Ph.D. is a senior Research Associate in the Lab of Aquatic Biomedicine, College of Veterinary Medicine and Research Institute for Veterinary Science, Seoul National University (SNU), Seoul, South Korea. He received his Master of Philosophy and Doctor of Philosophy degrees in Biotechnology from Periyar Maniammai Institute of Science & Technology (Erstwhile Periyar Maniammai University), India, in 2008 and 2014, respectively. He has extensive research experience in aquaculture probiotics, fish immunostimulants, and microbial biotechnology. He was the recipient of INSPIRE fellowship from the Department of Science and Technology, Govt of India, for doctoral research. He has published more than hundred research articles in SCIE journals and wrote three book chapters in knowledge-based editions published by renowned international publishers. He co-authored a book titled *Life Within Life-A book on biodiversity*. He is an editorial member of *Scientific Reports*—Nature group, *Frontiers in Microbiology* and *Frontiers in Physiology*. He has worked as Assistant Research Professor at the Lab of Aquatic Biomedicine of SNU (2019–2021). He was awarded prestigious "Brain Pool Fellowship" (2016–2021) by National Research Foundation, Ministry of Science, ICT, and Future Planning, Republic of Korea.

Contributors

Suja Aarattuthodi Thad Cochran National Warmwater Aquaculture Center, Mississippi State University, Stoneville, MS, USA

Thangapalam Jawahar Abraham Department of Aquatic Animal Health, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Kolkata, India

Kazi Rabeya Akther Department of Fish Biology and Genetics, Sylhet Agricultural University, Sylhet, Bangladesh

Bijay Kumar Behera Aquatic Environmental Biotechnology and Nanotechnology (AEBN) Division, ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, India

Irfan Ahmad Bhat Institute of Life and Environmental Sciences, School of Engineering and Natural Sciences, University of Iceland, Reykjavik, Iceland

Rayees Ahmad Bhat Department of Zoology, Kurukshetra University, Kurukshetra, Haryana, India

Pradyut Biswas College of Fisheries, Central Agricultural University (Imphal), Lembucherra, Tripura, India

Anirban Chakraborty Nitte (Deemed to be University), Nitte University Centre for Science Education and Research (NUCSER), Paneer Campus, Deralakatte, Mangalore, India

Saranya Chakrapani ICAR-Central Institute of Brackishwater Aquaculture, Chennai, India

Tanmoy Gon Choudhury Department of Aquatic Health and Environment, College of Fisheries, Central Agricultural University (Imphal), Lembucherra, Tripura, India

Md. Atick Chowdhury Department of Fish Biology and Genetics, Sylhet Agricultural University, Sylhet, Bangladesh

Basanta Kumar Das ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, India

Jyoti Prakash Dash Department of Biotechnology, Maharaja Sriram Chandra Bhanja Deo University, (Erstwhile North Orissa University), Baripada, Mayurbhanj, Odisha, India

Vandana Dharan Thad Cochran National Warmwater Aquaculture Center, Mississippi State University, Stoneville, MS, USA

Akhila Dharnappa Sannejal Nitte (Deemed to be University), Nitte University Centre for Science Education and Research, Mangaluru, Karnataka, India

Pranabkanti Dutta Department of Biotechnology, Maharaja Sriram Chandra Bhanja Deo University, (Erstwhile North Orissa University), Baripada, Mayurbhanj, Odisha, India

Md Javed Foysal Faculty of Science and Engineering, Curtin University, Bentley, WA, Australia

Sib Sankar Giri Laboratory of Aquatic Biomedicine, College of Veterinary Medicine and Research Institute for Veterinary Science, Seoul National University, Seoul, South Korea

Girisha S Kallappa College of Fisheries, KVAFSU, Mangalore, India

Amrutha Gopan Centurion University of Technology and Management, Sitapur, Odisha, India

Akruti Gupta Vinoba Bhave University, Hazaribag, Jharkhand, India
ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand, India

Rajan Gupta School of Molecular Diagnostic, Prophylactics and Nanobio-technology (SMDPN), ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand, India

Sanjay Kumar Gupta School of Molecular Diagnostic, Prophylactics and Nanobio-technology (SMDPN), ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand, India

Seyyed Morteza Hoseini Inland Waters Aquatics Resources Research Center, Iranian Fisheries Sciences Research Institute, Agricultural Research, Education and Extension Organization, Gorgan, Iran

Hussna Faculty of Fisheries, SKUAST K, Ganderbal, Jammu and Kashmir, India

Indrani Karunasagar University Enclave, Medical Sciences Complex, Nitte (Deemed to be University), Deralakatte, Mangalore, India

Md. Idrish Raja Khan Department of Aquatic Health and Environment, College of Fisheries, Central Agricultural University (Imphal), Lembucherra, Tripura, India

George Seghal Kiran Department of Food Science and Technology, Pondicherry University, Puducherry, India

Neeraj Kumar ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, India

Satendra Kumar Krishi Vigyan Kendra (JNKVV), Dindori, Madhya Pradesh, India

Saurav Kumar Aquatic Environment and Health Management Division, ICAR-Central Institute of Fisheries Education, Mumbai, India

Vikash Kumar Aquatic Environmental Biotechnology and Nanotechnology (AEBN) Division, ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, India

Pushpa Kumari Aquatic Environment and Health Management Division, ICAR-Central Institute of Fisheries Education, Mumbai, India

Rakhi Kumari Fish Nutrition and Physiology Division, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India

Biswajit Maiti Nitte (Deemed to be University), Nitte University Centre for Science Education and Research (NUCSER), Paneer Campus, Deralakatte, Mangalore, India

Sukham Munilkumar ICAR-Central Institute of Fisheries Education, Kolkata Centre, Kolkata, West Bengal, India

Marjana Jannat Munni Department of Fish Biology and Genetics, Sylhet Agricultural University, Sylhet, Bangladesh

Myung-Hwa Jung Hanseo University, Chung-Nam, South Korea

Sukanta Kumar Nayak Department of Biotechnology, Maharaja Sriram Chandra Bhanja Deo University, (Erstwhile North Orissa University), Takatpur, Baripada, Mayurbhanj, Odisha, India

T. Vijaya Nirmala Krishi Vigyan Kendra, Dr.YSR Horticultural University, West Godavari, Andhra Pradesh, India

Esakkiraj Palanichamy ICAR-Central Institute of Brackishwater Aquaculture, Chennai, India

Akshaya Panigrahi ICAR - Central Institute of Brackishwater Aquaculture, Chennai, India

Se Chang Park Laboratory of Aquatic Biomedicine, College of Veterinary Medicine and Research Institute for Veterinary Science, Seoul National University, Seoul, South Korea

Prasanna Kumar Patil ICAR - Central Institute of Brackishwater Aquaculture, Chennai, India

Anirban Paul Fish Health Management Division, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India

Nilesh A. Pawar ICAR-Central Marine Fisheries Research Institute, Mumbai Regional Station, Mumbai, Maharashtra, India

Sweta Pradhan Aquaculture Production and Environment Division, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India

Ramya Premanath Krishi Vigyan Kendra, Dr.YSR Horticultural University, West Godavari, Andhra Pradesh, India

Manisha Priyam School of Molecular Diagnostics, Prophylactics and Nanobiotechnology (SMDPN), ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand, India

Ashwath Priyanka Nitte (Deemed to be University), Nitte University Centre for Science Education and Research, Mangaluru, Karnataka, India

Riya Rajeev Department of Microbiology, Pondicherry University, Puducherry, India

Devivaraprasad Reddy Alla Krishi Vigyan Kendra, Dr.YSR Horticultural University, West Godavari, Andhra Pradesh, India

V. J. Rejish Kumar Kerala University of Fisheries and Ocean Studies, Kochi, India

Miriam Reverter Institute of Chemistry and Biology of the Marine Environment (ICBM), Carl von Ossietzky Universität Oldenburg, Wilhelmshaven, Germany

Nirmal Chandra Roy Department of Fish Biology and Genetics, Sylhet Agricultural University, Sylhet, Bangladesh

Suvra Roy Aquatic Environmental Biotechnology and Nanotechnology (AEBN) Division, ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, India

Biplab Sarkar School of Molecular Diagnostic, Prophylactics and Nanobiotechnology (SMDPN), ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand, India

Sudeshna Sarker Department of Aquatic Animal Health, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Kolkata, India

Shailesh Saurabh Aquaculture Production and Environment Division, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India

P. S. Seethalakshmi Department of Microbiology, Pondicherry University, Puducherry, India

Joseph Selvin Department of Microbiology, Pondicherry University, Puducherry, India

Siddaiah GM Fish Nutrition and Physiology Division, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India

Soibam Khogen Singh College of Fisheries, Central Agricultural University (Imphal), Lembucherra, Tripura, India

Tincy Varghese Fish Nutrition, Biochemistry and Physiology Division, ICAR-Central Institute of Fisheries Education, Mumbai, India

Vinay TN ICAR - Central Institute of Brackishwater Aquaculture, Chennai, India

Wenzhi Wei College of Animal Science and Technology, Yangzhou University, Yangzhou, China

Hui Yang College of Animal Science and Technology, Yangzhou University, Yangzhou, China

Yingying Zhang College of Animal Science and Technology, Yangzhou University, Yangzhou, China

Balamuralikrishnan Balasubramanian
Wen-Chao Liu
Govindharajan Sattanathan *Editors*

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Balamuralikrishnan Balasubramanian •
Wen-Chao Liu • Govindharajan Sattanathan
Editors

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Editors
Balamuralikrishnan Balasubramanian
Department of Food Science and Biotechnology
Sejong University
Seoul, Korea (Republic of)

Wen-Chao Liu
Department of Animal Science
Guangdong Ocean University
Zhanjiang, China

Govindharajan Sattanathan
Department of Zoology
St.Joseph University
Dimapur, Nagaland, India

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Preface

Aquaculture has the potential to contribute significantly to universal food sanctuary, but new venture is required to light expected request. In general, aquaculture's small-scale and organic growing has made it tough to normalize, contributing to an extreme level of risk for new investors. Aquaculture's major risk factors are primarily determined by water management, production intensity, and the proximity of fish farms to one another. Aquaculture now has a place of importance in fisheries administrations and private sector industries, despite decades of hesitation or outright skepticism. Though aquaculture has been a way of life for farmers in many Asian countries for centuries, its status in terms of global food production, aquatic resource management, and rural socioeconomic development has remained a point of contention until recently. With changes in global fisheries and the spectacular success of certain types of aquaculture ventures, the scenario has changed dramatically.

Aquaculture is a vital and rapidly expanding segment of global agriculture. Soon, new technological advancements and increased demand for fish as an animal protein source are expected to accelerate the industry's growth. As the industry grows, the cultivation methods have become more intensive to produce higher yields per unit area. In intensive culture operations, infectious disease is the leading cause of financial loss. Current disease treatment options in both developing and developed countries are partial to a small amount of government-approved antibiotics or chemotherapeutics that are only marginally effective. High cost, creation of antibiotic-resistant pathogens, required withdrawal period, and ecological contamination are some of the issues that arise from the use of the drugs, whether through medicated diets or water treatments. Aqua culturists are interested in developing cost-effective preventative measures to prevent outbreaks or reduce the severity of epizootics for these reasons. One such preventive measure is the development of various nutritional strategies that may reduce or eliminate diseases, which the aquaculture industry is currently investigating.

Over the past era, scientists have recognized the importance of nutrition in maintaining the health of humans and other animal species, including fish. Humans and other terrestrial animals were the focus of previous research on the links between nutrition, immune response, and disease resistance. However, attempts to conduct similar studies using fish have met with limited success in the last two decades due to a lack of understanding of the immune response in fish. Evidence from unintentional or intentional infection of fish in some of these nutritional studies suggests that most, if not all, dietary nutrients have an impact on immune role and disease resistance. A nutrient deficiency or excess could have a significant impact on fish infection and survival, owing to its effects on host defense mechanisms.

Other factors that affect fish health include nutrient bioavailability and interactions, the occurrence of immunostimulants and toxins, and feeding organization. This clearly demonstrates the potential role of nutrition in improving fish immune response and disease resistance. The book contains the chapters on nutrition, feed and feed additives, ecology, immunology, microbiology, toxicology, biochemistry, nanotechnology, pharmacology, and biotechnology, among other fields of basic and applied research. The chapters will serve as introductions to these fields and up-to-date reviews of recent research advances. This book is intended for a wide range of readers, including nutritionists, disease specialists, feed formulators, students, extension specialists, and farmers, as well as university teachers, graduates, and doctoral students in zoology, physiology, aquaculture, and biology in general.

Our sincere gratitude goes to the contributors for their insights on applications of various feed additives in aqua sector.

We sincerely thank Dr William Achauer, Director, Springer; Dr Anil Chandy, Managing Director, Springer; Ms. Emmy Lee, Associate Editor, Biomedicine & Life Science Books, for their generous assistance, constant support, and patience in finalizing this book.

Seoul, Korea (Republic of) Balamuralikrishnan Balasubramanian
Zhanjiang, China Wen-Chao Liu
Dimapur, Nagaland, India Govindharajan Sattanathan

Contents

Editors and Contributors

About the Editors

B. Balamuralikrishnan, Ph.D., is an assistant professor in the Department of Food Science and Biotechnology, Sejong University, Seoul, South Korea. His area of research focuses multidisciplinary of biological science in molecular genetics, food microbiology, animal science, nutrition science and food biotechnology, especially food resources and microbiological science. His interests include nutrition in aquaculture; synthesis of bioactive compounds from natural by-products and their applications in nutraceutical products; and isolation and characterization of probiotic for food/feed supplementation and biological field. To his credit, he has participated in various international symposia and conferences in the USA, Canada, Japan, Austria, Italy, Czech Republic, Thailand, and South Korea and has published more than 100 research papers in international journal of repute. He has been serving as academic editor in Journal of "PlosOne" and guest editor in Animals [MDPI] and act as potential reviewer in many high-reputed journals. He is a life member in various scientific societies such as The Korean Society of Food Science and Technology, Poultry Science Association, Korean Society of Animal Science and Technology, and Animal Nutrition Society of India (ANSI). Dr. B. Balamuralikrishnan worked as post-doctoral researcher in the Department of Animal Science, Dankook University, Cheonan, South Korea, and research assistant in the Department of Zoology, Bharathiar University, Coimbatore, India.

Wen-Chao Liu, Ph.D., is an associate professor in the Department of Animal Science, College of Coastal Agricultural Sciences, Guangdong Ocean University, China. His area of research focuses on animal nutrition and feed science, especially the nutritional regulation of immune response and redox status in stressed animals. His interests include extraction of bioactive compounds and synthesis of nanomaterials from natural by-products (especially the marine source) and their applications for animals and aquaculture. He has published more than 50 research papers in international peer-review journals, four of the papers were selected as Essential Science Indicators (ESI) Highly Cited Papers. He acted as potential reviewer in many high-reputed journals. He is a life member and director in various scientific societies such as Animal Ecology Branch of Chinese Society of Animal Husbandry and Veterinary Medicine, Animal Welfare and Healthy Production Branch of Chinese Society of Animal Husbandry and Veterinary Medicine.

Govindharajan Sattanathan, Ph.D., is an assistant professor at MASS College of Arts and Science and the Department of Life Science at Bharathidasan University, Trichy, Tamil Nadu, India, and is the author or co-author of seven peer-reviewed journal articles and eight conference papers and a newsletter. He is a reviewer and editorial board member of several peer-reviewed journals. He has been an active member of the organizing committees of several national and international seminars and conferences. He received a B.Sc. and M.Sc. (Zoology) from Government Arts College (Autonomous), Kumbakonam, Tamil Nadu, India. After graduating from Government Arts College (Autonomous), Kumbakonam, affiliated to Bharathidasan University, Trichy, he was selected UGC Project Fellow (Major Research Project) in Government College for Women (Autonomous), Kumbakonam, for the Ph.D. doctoral programme. He worked as an assistant professor in MASS College of

Arts and Science (Affiliated to Bharathidasan University, Trichy—24), Kumbakonam—612 501, Thanjavur, Tamil Nadu, India, from Nov 2017 to Feb 2021. Currently, he is working as an assistant professor and head, Department of Zoology, Sacred Heart Arts and Science College, Perani—605 651, Tindivanam, Villupuram, Tamil Nadu, India, from March 2021.

Contributors

M. Abinaya Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

S. Adhithya Sankar CHRIST (Deemed to be University), Bangalore, Karnataka, India

Juhee Ahn College of Biomedical Science, Department of Medical Biomaterials Engineering, Kangwon National University, Chuncheon, Republic of Korea

Isamma AkbarAli School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, Cochin, Kerala, India

Naif Abdullah Al-Dhabi Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia

G. Allwyn Vyas CHRIST (Deemed to be University), Bangalore, Karnataka, India

Vijaya Anand Arumugam Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Mariadhas Valan Arasu Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia

B. Balamuralikrishnan Department of Food Science and Biotechnology, Sejong University, Seoul, South Korea

Preethi Basavaraju Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Haripriya Kuchi Bhotla Bioknowl Insights Private Limited, Coimbatore, Tamil Nadu, India

Waleewan Changpasert Division of Food Science and Technology Management, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand

Aarranee Chotiko Division of Food Science and Technology Management, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand

Alexander Chouljenko Department of Food Bioprocessing and Nutrition Sciences, North Carolina State University, Center for Marine Sciences and Technology, Morehead City, NC, USA

Maheswaran Easwaran College of Veterinary Medicine and Research Institute of Veterinary Medicine, Chungnam National University, Daejeon, Republic of Korea

Murugesh Easwaran Bioknowl Insights Private Limited, Coimbatore, Tamil Nadu, India

Damaris Eveline Department of Biomedical Engineering, Sethu Institute of Technology, Tamil Nadu, India

Jannathul Firdous Cluster for Integrative Physiology and Molecular Medicine (CIPMM), Faculty of Medicine, Royal College of Medicine Perak, Ipoh, Perak, Malaysia

Utthapon Issara Division of Food Science and Technology Management, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand

Nayana Jagannath Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Saranya Jayaram Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

T. Karpagam Department of Biochemistry, Shrimati Indira Gandhi College, Tiruchirappalli, India

Hemalatha Karuppiah Department of Biomedical Engineering, Sethu Institute of Technology, Tamil Nadu, India

Bharathi Kathirvel Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Abhay Kumar Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Kruthi Ashok Kumar Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Shobana Kumar Sri Visalakshi College for Women, Tamil Nadu, India

Wen-Chao Liu Department of Animal Science, College of Coastal Agricultural Sciences, Guangdong Ocean University, Zhanjiang, P. R. China

Vignesh Marimuthu Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Swetha M. Menon Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Arun Meyyazhagan Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Kaviya Mohandass Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

K. Mohan PG Research Department of Zoology, Sri Vasavi College, Erode, Tamil Nadu, India

N. Monford Paul Abishek Department of Biological Sciences, College of Biological Sciences and Biotechnology, Chungnam National University, Daejeon, Republic of Korea

T. Muralisankar Aquatic Ecology Laboratory, Department of Zoology, School of Life Sciences, Bharathiar University, Coimbatore, Tamil Nadu, India

Arjunan Nareshkumar Department of Zoology, School of Life Sciences, Periyar University, Salem, India

Sampathkumar Palanisamy Department of Chemistry and Biosciences, SASTRA University—SRC, Tamil Nadu, India

Manikantan Pappuswamy Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Shyamsundar Paul Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Ponnirul Ponmanickam Department of Zoology, Ayya Nadar Janaki Ammal College, Sivakasi, Tamil Nadu, India

Karthika Pushparaj Department of Zoology, School of Biosciences, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India

Divya Kandathil Radhakrishnan School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, Cochin, Kerala, India

Nageshwari Raja Department of Biomedical Engineering, Sethu Institute of Technology, Tamil Nadu, India

Manoharan Rajesh Department of Biochemistry, Bharathiar University, Coimbatore, Tamil Nadu, India

Manikandan Ramasamy Department of Biochemistry, University, M.I.E.T. Arts and Science College, Tiruchirappalli, Tamil Nadu, India

Mythili Ravichandran Department of Microbiology, K. S. Rangasamy College of Arts and Science, Tiruchengode, Namakkal, Tamil Nadu, India

Rengasamy Lakshminarayanan Rengarajan Department of Zoology, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

Sumathi Chettipalayam Samiappan Department of Chemistry and Biosciences, SASTRA University – SRC, Tamil Nadu, India

Vetriselvi Sampath Department of Animal Resource & Science, Dankook University, Chungnam, South Korea

K. Sapthami CHRIST (Deemed to be University), Bangalore, Karnataka, India

V. Saradhasri Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Anurag Deendayal Sarawagi Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Suma Sarojini Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

A. Shanmugapriya Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Hyun-Jin Shin College of Veterinary Medicine and Research Institute of Veterinary Medicine, Chungnam National University, Daejeon, Republic of Korea

Bhadrapriya Sivakumar Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India
Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

R. Sridevi Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Liya Merin Stanly CHRIST (Deemed to be University), Bangalore, Karnataka, India

V. Suganya Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Shanmugam Sureshkumar Department of Animal Resource & Science, Dankook University, Chungnam, South Korea

Sreehari Suresh CHRIST (Deemed to be University), Bangalore, Karnataka, India

Sangeetha Thangavelu Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Basheer Thazeem Integrated Rural Technology Centre (IRTC), Palakkad, Kerala, India

V. Udhayakumar PG Research Department of Zoology, Sri Vasavi College, Erode, Tamil Nadu, India

Mridul Umesh Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

B. Varalakshmi Department of Biochemistry, Shrimati Indira Gandhi College, Tiruchirappalli, India

S. Velayuthaprabhu Department of Biotechnology, Bharathiar University, Coimbatore, India

Kannan Vijayarani Department of Education, Bharathiar University, Coimbatore, Tamil Nadu, India

Yue Zhao Department of Animal Science, College of Coastal Agricultural Sciences, Guangdong Ocean University, Zhanjiang, P. R. China

Aquatic Lectins

Preetham Elumalai • Baskaralingam Vaseeharan • Sreeja Lakshmi
Editors

Aquatic Lectins

Immune Defense, Biological Recognition and Molecular Advancements

Springer

Editors
Preetham Elumalai
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology
Cochin, Kerala, India

Sreeja Lakshmi
School of Ocean Science and Technology
Kerala University of Fisheries and Ocean Studies
Cochin, Kerala, India

Baskaralingam Vaseeharan
Department of Animal Health and Management
Alagappa University
Karaikudi, Tamil Nadu, India

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I dedicate this book to my parents who taught me to face life with enthusiasm and perseverance and whose encouraging words instigated me to pursue my dreams and succeed in life.

Preetham Elumalai

Foreword

It is a great pleasure to write a foreword for the book *Aquatic Lectins: Immune Defense, Biological Recognition and Molecular Advancements*" edited by Dr. Preetham Elumalai, Dr. Baskaralingam Vaseeharan, and Dr. Sreeja Lakshmi. I am sure that this book will prove to be good reading material for upcoming academicians, researchers, and students.

The curiosity and questions put into a chain of series end up in novel findings that open up new fields of science. The traditional aspect is extended nowadays by contemporary knowledge on methodologies renovating the applicability of advanced and novel ideas of young scientific minds. The success of a study is when it reaches towards the betterment of society. Lectins, indeed a new category, are found to be a highly debated scientific component pertaining to their ability to defend the invading pathogens and conferring immunity.

Preserving healthy environments and practices to improve disease management by enhancing the innate immune response is a highly debated current topic. Lectins hold a pivotal role in disease resistance, having been identified as proteins that possess a specific carbohydrate-binding site. Apart from the widespread natural existence, lectins can also be synthesized by the recombinant technology.

I found the vision of the book very innovative in applied science pertaining to modern knowledge that guides young researchers to take up research activities in the related area in order to extend the basic knowledge on advanced immunological parameters contributed by lectins for researchers/academicians working in the current area.

I am sure this book will captivate a wide readership, and I appreciate the sincere efforts by the authors and editors for bringing this compendium.

Shri. Parshottam Rupala
The Hon'ble Minister for Fisheries,
Animal Husbandry & Dairying
Government of India, Krishi Bhawan
New Delhi, India

Foreword

I consider it a great privilege to have an opportunity to pen this foreword for the book entitled *Aquatic Lectins: Immune Defense, Biological Recognition and Molecular Advancements*. I sincerely believe this important volume must be the output of the long years of research experience in the subject and concerted efforts of Dr. E.-P. Preetham and co-editors Dr. B. Vaseeharan and Dr. Sreeja Lakshmi. The book provides an overview of lectins with special reference to their therapeutic applications and emphasizes their sweeping development in immune defense properties. Each chapter of this book is intended to provide specific aspects of lectins, and I am sure readers will be able to explore the basics of the elaborative biological functions of aquatic lectins. I truly complement the authors and editors for their efforts to gather and integrate all related information for the successful outcome of this book.

Ever since the term Lectin was coined by Prof. Boyd during the 1960s, the research on lectin, particularly its function in the immune system, witnessed phenomenal growth. Lectin is widely distributed in bacteria, fungi, viruses, plants, and animals. Even the skin of several animal species, including fish, is identified to be a rich source of novel and new unreported lectins. In addition to this, skin mucus, stomach, liver, intestine, gills, eggs, and plasma of fish are reported to have lectins.

Different types of lectins such as ficolins, galectins, calnexin, pentraxin, F-type lectins, intelectins, and mannose-binding protein (MBP) are known to play important roles in innate immunity and disease resistance. Other main functions of fish lectins are agglutination of bacteria, fungi, parasites, and viruses, immobilization with complement-mediated neutralization and death of pathogens.

Lectins not only have roles in cellular recognition but also interact with carbohydrates. The complement system plays a vital role in protecting against invading microorganisms and acts through three activation pathways: the classic, alternative, and lectin pathways. In the lectin pathway, upon binding of the Mannan-binding lectin serine protease (MASPs) complexes to carbohydrates on the surface of pathogens, MASPs are activated and cleave the complement components C4 and C2. This results in the elimination of pathogens after a chain reaction of proteolysis of complement components and protein assembly. However, this defense mechanism is poorly understood in fish. Therefore, identification of immune-related genes and studying their expression patterns during these pathways are imperative. The book comprehensively provides up-to-date information on lectin-immune system pathways and immune gene expression analysis.

I truly appreciate the authors for their scholarly contributions to cover a wide range of aspects of lectins including their classifications, functions, and characterizations. I am sure the book will excite, educate, and encourage the next generation of researchers in exploring the ever-expanding field of lectin research.

Dr. J. K. Jena
Indian Council of Agricultural Research
Krishi Anusandhan Bhavan-II
Pusa, New Delhi, India

Foreword

The discovery and characterization of the first lectin (named “agglutinin” at the time) from the edible snail *Helix pomatia* by Camus in 1899 promoted a series of follow-up studies, initially in aquatic invertebrates and later in vertebrates, that eventually led to the realization that carbohydrate-binding proteins are ubiquitous in animal taxa. Although the initial studies were focused on the carbohydrate specificity of the newly discovered proteins, the lack of true immunoglobulin antibodies in invertebrate species suggested that they may represent their functional analogues as recognition proteins involved in defense against microbial pathogens. Since then, this book *Aquatic Lectins: Immune Defense, Biological Recognition and Molecular Advancements* edited by Drs. P. Elumalai, V. Baskaralingam, and S. Lakshmi is the first collection of review articles focused on lectins from aquatic organisms encompassing taxa from algae to invertebrates and fish, and their roles in innate immunity.

Lectins are carbohydrate-binding proteins that among multiple biological functions play key roles in innate immunity. For example, multivalent lectins can recognize a wide range of microbial pathogens, immobilize them by cross-linking, and promote their uptake and killing by phagocytic cells. Lectins are characterized by a carbohydrate recognition domain (CRD), and based on their structural fold and unique sequence motifs in their CRDs, these proteins are classified into several families, such as C-, P-, F-, R-, and I-types, galectins, ficolins, and pentraxins, all known to play important roles in a variety of functions. The binding properties towards microbial surface structures have led to the inclusion of some lectins as pattern-recognition receptors (PRRs), a heterogeneous group of molecules that recognize microbial-associated molecular patterns (MAMPs) shared by broad classes of microorganisms. As cell surface components are essential for the microbe's survival, MAMPs are highly conserved among different microbial pathogens, and their structural features are widely recognized by innate immune receptors in their potential hosts.

Aquatic animals rely on a variety of recognition and effector factors for defense against potential infectious agents. Invertebrates lack the typical adaptive immunity of vertebrates characterized by immunoglobulins, B and T cells, and mostly rely on diverse repertoires of lectins, antimicrobial peptides, and other innate immune factors for defense against viral, bacterial, parasitic, and fungal infection. Further, although both cartilaginous and bony fish display most components of the adaptive immunity of mammals, they also depend on lectins for the rapid and effective responses targeting invading microorganisms. In both invertebrates and vertebrates, the recognition properties of lectins are amply complemented by their effector and regulatory functions that enable not only the rapid destruction of the potential pathogen, for example by the complement pathway, but also the activation and regulation of adaptive immune mechanisms.

The chapters of this book systematically and comprehensively address the recognition, effector, and regulatory functions of lectins from aquatic animals and algae, as well as their impact on biomedical sciences, including applications in diagnosis and novel therapeutic approaches. The chapters have been selected based on examples of different lectin families from a variety of animal species, in an attempt to provide an integrated view of the biological functions of these proteins that have been characterized by the implementation of interdisciplinary experimental approaches to relevant examples from different aquatic taxa.

It is clear that the future discovery of novel lectins from aquatic organisms will continue to increase the current repertory of defense molecules that are active in these organisms, and contribute to our knowledge about their structural, functional, and evolutionary relationships, as well as their potential translational value for biomedicine and aquaculture. In this regard, the editors and authors of the first edition of this book have engaged in the commendable task of organizing and integrating a substantial body of information in this field, and the resulting volume will be a very useful resource for a wide readership.

Prof. Gerardo R. Vasta
Microbiology and Immunology
Institute of Marine and
Environmental Technology
Baltimore, MD, USA

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Aquaculture Science and Engineering

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Editors
Balamuralikrishnan Balasubramanian
Department of Food Science and Biotechnology
Sejong University
Seoul, Korea (Republic of)

Wen-Chao Liu
Department of Animal Science
Guangdong Ocean University
Zhanjiang, China

Govindharajan Sattanathan
Department of Zoology
St.Joseph University
Dimapur, Nagaland, India

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Preface

Aquaculture has the potential to contribute significantly to universal food sanctuary, but new venture is required to light expected request. In general, aquaculture's small-scale and organic growing has made it tough to normalize, contributing to an extreme level of risk for new investors. Aquaculture's major risk factors are primarily determined by water management, production intensity, and the proximity of fish farms to one another. Aquaculture now has a place of importance in fisheries administrations and private sector industries, despite decades of hesitation or outright skepticism. Though aquaculture has been a way of life for farmers in many Asian countries for centuries, its status in terms of global food production, aquatic resource management, and rural socioeconomic development has remained a point of contention until recently. With changes in global fisheries and the spectacular success of certain types of aquaculture ventures, the scenario has changed dramatically.

Aquaculture is a vital and rapidly expanding segment of global agriculture. Soon, new technological advancements and increased demand for fish as an animal protein source are expected to accelerate the industry's growth. As the industry grows, the cultivation methods have become more intensive to produce higher yields per unit area. In intensive culture operations, infectious disease is the leading cause of financial loss. Current disease treatment options in both developing and developed countries are partial to a small amount of government-approved antibiotics or chemotherapeutics that are only marginally effective. High cost, creation of antibiotic-resistant pathogens, required withdrawal period, and ecological contamination are some of the issues that arise from the use of the drugs, whether through medicated diets or water treatments. Aqua culturists are interested in developing cost-effective preventative measures to prevent outbreaks or reduce the severity of epizootics for these reasons. One such preventive measure is the development of various nutritional strategies that may reduce or eliminate diseases, which the aquaculture industry is currently investigating.

Over the past era, scientists have recognized the importance of nutrition in maintaining the health of humans and other animal species, including fish. Humans and other terrestrial animals were the focus of previous research on the links between nutrition, immune response, and disease resistance. However, attempts to conduct similar studies using fish have met with limited success in the last two decades due to a lack of understanding of the immune response in fish. Evidence from unintentional or intentional infection of fish in some of these nutritional studies suggests that most, if not all, dietary nutrients have an impact on immune role and disease resistance. A nutrient deficiency or excess could have a significant impact on fish infection and survival, owing to its effects on host defense mechanisms.

Other factors that affect fish health include nutrient bioavailability and interactions, the occurrence of immunostimulants and toxins, and feeding organization. This clearly demonstrates the potential role of nutrition in improving fish immune response and disease resistance. The book contains the chapters on nutrition, feed and feed additives, ecology, immunology, microbiology, toxicology, biochemistry, nanotechnology, pharmacology, and biotechnology, among other fields of basic and applied research. The chapters will serve as introductions to these fields and up-to-date reviews of recent research advances. This book is intended for a wide range of readers, including nutritionists, disease specialists, feed formulators, students, extension specialists, and farmers, as well as university teachers, graduates, and doctoral students in zoology, physiology, aquaculture, and biology in general.

Our sincere gratitude goes to the contributors for their insights on applications of various feed additives in aqua sector.

We sincerely thank Dr William Achauer, Director, Springer; Dr Anil Chandy, Managing Director, Springer; Ms. Emmy Lee, Associate Editor, Biomedicine & Life Science Books, for their generous assistance, constant support, and patience in finalizing this book.

Seoul, Korea (Republic of) — Balamuralikrishnan Balasubramanian
Zhanjiang, China — Wen-Chao Liu
Dimapur, Nagaland, India — Govindharajan Sattanathan

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Editors and Contributors

About the Editors

B. Balamuralikrishnan, Ph.D., is an assistant professor in the Department of Food Science and Biotechnology, Sejong University, Seoul, South Korea. His area of research focuses multidisciplinary of biological science in molecular genetics, food microbiology, animal science, nutrition science and food biotechnology, especially food resources and microbiological science. His interests include nutrition in aquaculture; synthesis of bioactive compounds from natural by-products and their applications in nutraceutical products; and isolation and characterization of probiotic for food/feed supplementation and biological field. To his credit, he has participated in various international symposia and conferences in the USA, Canada, Japan, Austria, Italy, Czech Republic, Thailand, and South Korea and has published more than 100 research papers in international journal of repute. He has been serving as academic editor in Journal of "PlosOne" and guest editor in Animals [MDPI] and act as potential reviewer in many high-reputed journals. He is a life member in various scientific societies such as The Korean Society of Food Science and Technology, Poultry Science Association, Korean Society of Animal Science and Technology, and Animal Nutrition Society of India (ANSI). Dr. B. Balamuralikrishnan worked as post-doctoral researcher in the Department of Animal Science, Dankook University, Cheonan, South Korea, and research assistant in the Department of Zoology, Bharathiar University, Coimbatore, India.

Wen-Chao Liu, Ph.D., is an associate professor in the Department of Animal Science, College of Coastal Agricultural Sciences, Guangdong Ocean University, China. His area of research focuses on animal nutrition and feed science, especially the nutritional regulation of immune response and redox status in stressed animals. His interests include extraction of bioactive compounds and synthesis of nanomaterials from natural by-products (especially the marine source) and their applications for animals and aquaculture. He has published more than 50 research papers in international peer-review journals, four of the papers were selected as Essential Science Indicators (ESI) Highly Cited Papers. He acted as potential reviewer in many high-reputed journals. He is a life member and director in various scientific societies such as Animal Ecology Branch of Chinese Society of Animal Husbandry and Veterinary Medicine, Animal Welfare and Healthy Production Branch of Chinese Society of Animal Husbandry and Veterinary Medicine.

Govindharajan Sattanathan, Ph.D., is an assistant professor at MASS College of Arts and Science and the Department of Life Science at Bharathidasan University, Trichy, Tamil Nadu, India, and is the author or co-author of seven peer-reviewed journal articles and eight conference papers and a newsletter. He is a reviewer and editorial board member of several peer-reviewed journals. He has been an active member of the organizing committees of several national and international seminars and conferences. He received a B.Sc. and M.Sc. (Zoology) from Government Arts College (Autonomous), Kumbakonam, Tamil Nadu, India. After graduating from Government Arts College (Autonomous), Kumbakonam, affiliated to Bharathidasan University, Trichy, he was selected UGC Project Fellow (Major Research Project) in Government College for Women (Autonomous), Kumbakonam, for the Ph.D. doctoral programme. He worked as an assistant professor in MASS College of

Arts and Science (Affiliated to Bharathidasan University, Trichy—24), Kumbakonam—612 501, Thanjavur, Tamil Nadu, India, from Nov 2017 to Feb 2021. Currently, he is working as an assistant professor and head, Department of Zoology, Sacred Heart Arts and Science College, Perani—605 651, Tindivanam, Villupuram, Tamil Nadu, India, from March 2021.

Contributors

M. Abinaya Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

S. Adhithya Sankar CHRIST (Deemed to be University), Bangalore, Karnataka, India

Juhee Ahn College of Biomedical Science, Department of Medical Biomaterials Engineering, Kangwon National University, Chuncheon, Republic of Korea

Isamma AkbarAli School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, Cochin, Kerala, India

Naif Abdullah Al-Dhabi Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia

G. Allwyn Vyas CHRIST (Deemed to be University), Bangalore, Karnataka, India

Vijaya Anand Arumugam Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Mariadhas Valan Arasu Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia

B. Balamuralikrishnan Department of Food Science and Biotechnology, Sejong University, Seoul, South Korea

Preethi Basavaraju Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Haripriya Kuchi Bhotla Bioknowl Insights Private Limited, Coimbatore, Tamil Nadu, India

Waleewan Changpasert Division of Food Science and Technology Management, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand

Aarranee Chotiko Division of Food Science and Technology Management, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand

Alexander Chouljenko Department of Food Bioprocessing and Nutrition Sciences, North Carolina State University, Center for Marine Sciences and Technology, Morehead City, NC, USA

Maheswaran Easwaran College of Veterinary Medicine and Research Institute of Veterinary Medicine, Chungnam National University, Daejeon, Republic of Korea

Murugesh Easwaran Bioknowl Insights Private Limited, Coimbatore, Tamil Nadu, India

Damaris Eveline Department of Biomedical Engineering, Sethu Institute of Technology, Tamil Nadu, India

Jannathul Firdous Cluster for Integrative Physiology and Molecular Medicine (CIPMM), Faculty of Medicine, Royal College of Medicine Perak, Ipoh, Perak, Malaysia

Utthapon Issara Division of Food Science and Technology Management, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand

Nayana Jagannath Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Saranya Jayaram Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

T. Karpagam Department of Biochemistry, Shrimati Indira Gandhi College, Tiruchirappalli, India

Hemalatha Karuppiah Department of Biomedical Engineering, Sethu Institute of Technology, Tamil Nadu, India

Bharathi Kathirvel Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Abhay Kumar Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Kruthi Ashok Kumar Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Shobana Kumar Sri Visalakshi College for Women, Tamil Nadu, India

Wen-Chao Liu Department of Animal Science, College of Coastal Agricultural Sciences, Guangdong Ocean University, Zhanjiang, P. R. China

Vignesh Marimuthu Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Swetha M. Menon Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

Arun Meyyazhagan Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Kaviya Mohandass Department of Human Genetics and Molecular Genetics, Bharathiar University, Coimbatore, Tamil Nadu, India

K. Mohan PG Research Department of Zoology, Sri Vasavi College, Erode, Tamil Nadu, India

N. Monford Paul Abishek Department of Biological Sciences, College of Biological Sciences and Biotechnology, Chungnam National University, Daejeon, Republic of Korea

T. Muralisankar Aquatic Ecology Laboratory, Department of Zoology, School of Life Sciences, Bharathiar University, Coimbatore, Tamil Nadu, India

Arjunan Nareshkumar Department of Zoology, School of Life Sciences, Periyar University, Salem, India

Sampathkumar Palanisamy Department of Chemistry and Biosciences, SASTRA University—SRC, Tamil Nadu, India

Manikantan Pappuswamy Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Shyamsundar Paul Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Ponnirul Ponmanickam Department of Zoology, Ayya Nadar Janaki Ammal College, Sivakasi, Tamil Nadu, India

Karthika Pushparaj Department of Zoology, School of Biosciences, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India

Divya Kandathil Radhakrishnan School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, Cochin, Kerala, India

Nageshwari Raja Department of Biomedical Engineering, Sethu Institute of Technology, Tamil Nadu, India

Manoharan Rajesh Department of Biochemistry, Bharathiar University, Coimbatore, Tamil Nadu, India

Manikandan Ramasamy Department of Biochemistry, University, M.I.E.T. Arts and Science College, Tiruchirappalli, Tamil Nadu, India

Mythili Ravichandran Department of Microbiology, K. S. Rangasamy College of Arts and Science, Tiruchengode, Namakkal, Tamil Nadu, India

Rengasamy Lakshminarayanan Rengarajan Department of Zoology, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

Sumathi Chettipalayam Samiappan Department of Chemistry and Biosciences, SASTRA University – SRC, Tamil Nadu, India

Vetriselvi Sampath Department of Animal Resource & Science, Dankook University, Chungnam, South Korea

K. Sapthami CHRIST (Deemed to be University), Bangalore, Karnataka, India

V. Saradhasri Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Anurag Deendayal Sarawagi Prajakt Life Science Pvt Ltd, Surat, Gujarat, India

Suma Sarojini Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

A. Shanmugapriya Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Hyun-Jin Shin College of Veterinary Medicine and Research Institute of Veterinary Medicine, Chungnam National University, Daejeon, Republic of Korea

Bhadrapriya Sivakumar Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India
Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

R. Sridevi Department of Biochemistry, Shrimati Indira Gandhi College, Trichy, Tamil Nadu, India

Liya Merin Stanly CHRIST (Deemed to be University), Bangalore, Karnataka, India

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Sreehari Suresh CHRIST (Deemed to be University), Bangalore, Karnataka, India

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Basheer Thazeem Integrated Rural Technology Centre (IRTC), Palakkad, Kerala, India

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Mridul Umesh Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, Karnataka, India

B. Varalakshmi Department of Biochemistry, Shrimati Indira Gandhi College, Tiruchirappalli, India

S. Velayuthaprabhu Department of Biotechnology, Bharathiar University, Coimbatore, India

Kannan Vijayarani Department of Education, Bharathiar University, Coimbatore, Tamil Nadu, India

Yue Zhao Department of Animal Science, College of Coastal Agricultural Sciences, Guangdong Ocean University, Zhanjiang, P. R. China

Preetham Elumalai
Sreeja Lakshmi *Editors*

Functional Foods and Therapeutic Strategies for Neurodegenerative Disorders

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Editors

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Editors
Dr. Preetham Elumalai
Department of Marine Biology, Microbiology and Biochemistry
School of Marine Sciences, Cochin University of Science and Technology
Cochin, Kerala, India

Dr. Sreeja Lakshmi
School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies
Cochin, Kerala, India

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I dedicate this book to my loving late mother without whom I would never be able to succeed in my life, to my late father who instigated me to stay independent and determined, and to all my diligent students whose feedback has always helped me to be a better teacher.

–Preetham Elumalai

Foreword

It is a great pleasure to write the foreword to the book *Functional Foods and Therapeutic Strategies for Neurodegenerative disorders* edited by Dr. Preetham Elumalai and Dr. Sreeja Lakshmi. The book carries importance in the current context where people practice healthy ageing encompassing natural treatment strategies.

Diseases are never ending as far as human life is concerned. Disorders of brain destroy us both physically and mentally. Ageing remains as the major risk factor for many diseases. The highly debated neurodegenerative disorders procure enormous fruitful investigations over the past years, towards a plethora of treatment strategies as these diseases make one's life really challenging owing to their disastrous approach and leaving a high healthcare cost. As age progresses, people suffering from neurodegenerative disorders like Alzheimer's, Parkinson's and Huntington's diseases are unable to bear the side effects as well as the cost of the medications prescribed for the same. As science inclines to natural treatment practices, scientific researches are successfully ahead with exploring natural resources for bioactive compounds that can be applied as efficient tools for treating diseases.

The book is a comprehensive collection of contemporary treatment strategies employing natural bioactive compounds as well as modern diagnostic applications with nanoparticles, biomarkers and in silico techniques towards neurodegenerative disorders. I take this opportunity to appreciate the editors and authors for their sincere effort to bring this book to enlighten and uplift the knowledge on the management and treatment of neurodegenerative disorders.

K. K. Shailaja Teacher
Former Kerala Health Minister,
Member, Kerala Legislative Assembly,
Mattannur, Kannur, Kerala, India

Foreword

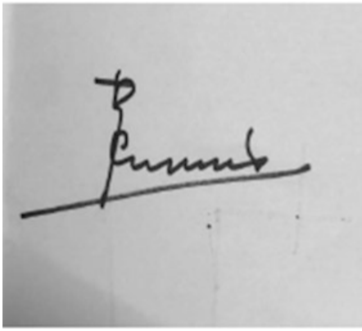
I am so pleased to have an opportunity to write the foreword for the book *Functional Foods and Therapeutic Strategies for Neurodegenerative Disorders* edited by Dr. Preetham Elumalai and Dr. Sreeja Lakshmi.

"Old age is the supreme evil, because it deprives us of all pleasures, leaving us only the appetite and it brings with it all sufferings. Nevertheless, we fear death, and we desire old age."- Giacomo Leopardi.

Aging and related health disorders have become an unavoidable phase in the life cycle of every human being. The mechanisms underlying aging, age-linked susceptibility to diseases and the consequential medical treatments for age-related health disorders are emerging as excellent researchable issues among researchers across the world. Neurodegenerative disorders have always been an invaluable research topic, and the most common type of diseases such as Alzheimer's, Parkinson's and Huntington's disease has seen long fruitful years of productive research during the past four decades. Neurodegenerative disorders are most frequently viewed as one of the life-threatening ailments and therefore highly challenging as they bring about heavy burden not only to the patients but to their families and societies at large which attract exorbitant healthcare costs.

We all need healthy brain. Nowadays people understand the importance of healthy aging and scientific practices to contain diseases through diet, lifestyle factors, exercises, etc. Owing to the high risk of side effects of medicines for neurodegenerative disorders, science is more inclined nowadays to naturopathy which is easily accessible, cost-effective and relatively free from side effects.

In the present book, the authors comprehensively illustrate contemporary treatment protocols in respect of diverse neurodegenerative disorders incorporating bioactive compounds from natural resources as well as advanced interdisciplinary diagnostic practices including nanoparticles, biomarkers and in silico techniques. I sincerely appreciate the painstaking efforts made by the authors in articulating this book which will definitely provide an enchanting reference material for validating the progress attained in the therapy and management of neurodegenerative disorders besides serving as a valuable addition to the existing body of knowledge.



Prof. Dr. B. Madhusoodana Kurup
Founder Vice Chancellor,
Kerala University of Fisheries and Ocean Studies,
Former Advisor to Minister for Fisheries,
Govt. of Kerala,
Chairman, Scientific Advisory Committee,
RGCA, MPEDA, Govt. of India

Chairman, Research Advisory Committee,
ICAR-CIBA, CIFRI,
Cochin, Kerala, India

Preface

Aging is an inevitable phenomenon creating entropy in one's life by deteriorating one's physiological systems and anatomical structures. Senescence is associated with increased risk for a plethora of diseases and some of them end up with loss of homeostasis and finally death. As age progresses many of the biological processes as well as environmental factors conjointly lead to progressive neurodegeneration. Neurodegeneration is an inherent condition characterised by structural and functional impairment of neurons. The most prevalent neurodegenerative disorders—Alzheimer's disease (AD), Parkinson's disease (PD), Huntington's disease (HD), and Amyotrophic lateral sclerosis (ALS)—are often hired as life threatening as well as a social and economic burden to the healthcare system. Despite the conventional beliefs and strategies, science along with the healthcare system has taken initiatives to step forward with healthy aging for better living of aged people. Past few year's scientific research has explored novel remedies, incorporating diet, lifestyle factors, and bioactive compounds/immunostimulants from natural resources to treat neurodegenerative disorders in the context where therapeutic drugs were found ineffective in reverting or pausing neurodegenerative disorders. Moreover, these natural antidotes are depicted as highlighters that boons the sustainability of healthy brain rendering protection against neurodegeneration.

Our book is anticipated to provide an overview of the current status of research and future perspectives in the field of treating neurodegenerative disorders. The book will integrate different aspects such as advancements in current treatment scenario incorporating prebiotics, phytochemicals, polyphenols and potential marine bioactive compounds towards the treatment strategies along with leading contemporary methods for prophylactic and diagnostic practices, comprising nanoparticles, in silico techniques and biomarkers. We expect that the contents of the book provide potential knowledge regarding future perspectives in the management of neurodegenerative disorders.

Cochin, Kerala, India

Preetham Elumalai
Sreeja Lakshmi

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About the Editors

Preetham Elumalai is an Associate Professor (Biochemistry) in the Department of Marine Biology, Microbiology and Biochemistry at Cochin University of Science and Technology (CUSAT), Cochin, Kerala, and completed his Master's from the University of Madras, Tamil Nadu. He has qualified the National Eligibility Test for Lecturership conducted by ASRB/ICAR/UGC. He received his PhD in Biochemistry and Molecular Immunology from the Institute for Immunology, University of Regensburg, Germany. He did his postdoctoral research in the same University and worked on lectin glycomics.

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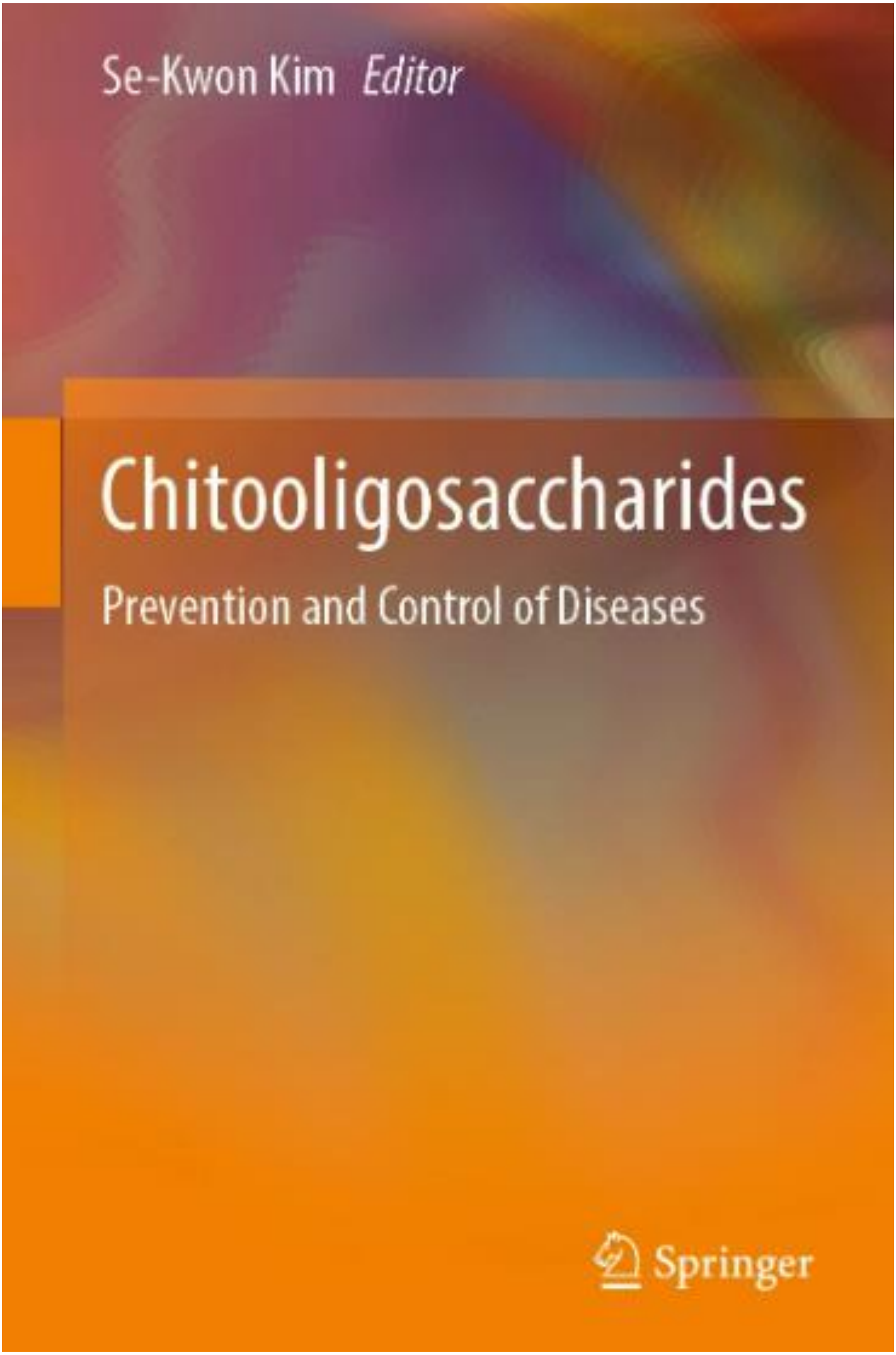
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Editor
Se-Kwon Kim
Department of Marine Science
and Convergence Engineering
College of Science and Technology
Hanyang University ERICA
Seoul, Korea (Republic of)

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Preface

Natural biomaterials have gained considerable attention in recent years for the development of medical products. For example, chitooligosaccharide (COS) is a natural biopolymer and is extensively studied in medical applications. COS is a chitosan derivative and can be produced using chemical and enzyme hydrolysis techniques. The essential advantages of COSs are their solubility in the neutral condition. This solubility property of COS opens up a way to research various applications, including cosmeceutical and pharmaceutical applications.

This book aims to provide COS synthesis and its biological and biomedical applications. This book is mainly focused on medical product development using COS and its derivatives. In the initial part of the book, the chapters are focused on the chemical and enzymatic preparation of COS from marine crustacean shell wastes. In some of the book chapters, systematic and step-by-step approaches were included for the production of COS. Different enzymes involved in the development of COS production were discussed. In addition, the isolation of chitinolytic enzymes and the development of COS were also discussed. Furthermore, the influence of isolation conditions on the physicochemical COS from crustacean shell wastes was presented. Finally, some of the chapters are focused on the synthesis of COS derivatives for biological applications.

In the middle of the book, chapters are covered on the biological application of COS. These biological applications are antimicrobial, antioxidant, anti-inflammatory, anti-allergy, and anticancer activities. Chapters reveal the current status, and future trends in disease-preventing bioactivities of COS are discussed. In addition to this biological activity, the mechanistic pathways for the various biological applications, including effects of matrix metalloproteinases, inhibitory effects for cancer studies, and immunomodulatory effects of COS and their derivatives, were included in the book. The development of single COS and their roles in various bioactivities are also reviewed.

The final part of the book includes the biomedical applications of COS. Nanoparticles, hydrogels, and biocomposites made up of COS are also discussed for medical applications. In addition, wound healing materials, tissue engineering, drug delivery, and food, and nutraceutical applications of COS are included in the book. The book provides a basic understanding of COS for medical product development.

Seoul, South Korea Prof. Se-Kwon Kim

Acknowledgements

Dr. **Jae-Chul Kim** is the chairman, president, and founder of the Dongwon group. The company was established in 1969 to explore and utilize the oceans and marine resources. Chairman Kim is the pioneer in the deep-sea fishing boats in South Korea. He started tuna fishing in 1958 as the first mate of Korea's first deep-sea fishing vessel.

After graduating from National Fisheries University of Busan, he jumped into tuna fishing, and the university was renamed as Pukyong National University. Further, he became the captain of a fleet of deep-sea fishing boats and a new tuna fishing method. He developed and succeeded in catching large amounts of tuna in the South Pacific and Indian Oceans.

He founded Dongwon Industries in 1969 at the age of 35 and started tuna fishing as the first president. After that, he built a tuna processing plant and started to produce canned food. He immersed himself in business management in earnest based on the experience he learned in the sea from his youth.

Dongwon Group has successfully expanded its business from the fishery industry as the primary industry to the manufacturing industry as the secondary industry and financial services as the tertiary industry. Currently, Mr. Kim runs 30 affiliated companies.

To contribute to social welfare, he also established the Dongwon Educational Foundation. He devoted himself, his heart, and his soul to nurturing competent people who are the backbone of our society. He has provided scholarships to numerous college students and grants R&D funds for researchers. He recognized the great value and potential of underutilized marine resources from his youth. He dedicated himself to publishing technical books emphasizing the scientific importance of marine life and related research.

With his help, this book has been published, providing readers with how the scientific values of marine life can enhance human health and wellbeing.

I want to thank him sincerely for his support in publishing this book.

Seoul, South Korea

Prof. Se-Kwon Kim
Distinguished Professor

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About the Editor

Prof. Se-Kwon Kim Ph.D., is presently working as a Distinguished Professor in Hanyang University and Kolmar Korea Company. He worked as a Distinguished Professor at the Department of Marine Bio Convergence Science and Technology and Director of Marine Bioprocess Research Center (MBPRC) at Pukyong National University, Busan, South Korea.

He received his M.Sc. and Ph.D. degrees from Pukyong National University and conducted his postdoctoral studies at the Laboratory of Biochemical Engineering, University of Illinois, Urbana-Champaign, Illinois, USA. Later, he became a visiting scientist at the Memorial University of Newfoundland and the University of British Colombia in Canada.

Dr. Kim served as president of the 'Korean Society of Chitin and Chitosan' in 1986–1990, and the 'Korean Society of Marine Biotechnology' in 2006–2007. To the credit for his research, he won the best paper award from the American Oil Chemists' Society in 2002. Dr. Kim was also the chairman for '7th Asia-pacific Chitin and Chitosan Symposium', which was held in South Korea in 2006. He was the chief editor in the 'Korean Society of Fisheries and Aquatic Science' during 2008-2009. In addition, he is the board member of International Society of Marine Biotechnology Associations (IMBA) and International Society of Nutraceuticals and Functional Food (ISNFF).

His major research interests are investigation and development of bioactive substances from marine resources. His immense experience of marine bioprocessing and mass-production technologies for marine bio-industry is the key asset of holding majorly funded Marine Bio projects in Korea. Furthermore, he expanded his research fields up to the development of bioactive materials from marine organisms for their applications in oriental medicine, cosmeceuticals, and nutraceuticals. To this date, he has authored around 750 research papers, 70 books, and 120 patents.

Preetham Elumalai
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Lectins

Innate Immune Defense and Therapeutics

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Editors
Dr. Preetham Elumalai
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology
Cochin, Kerala, India

Dr. Sreeja Lakshmi
School of Ocean Science and Technology
Kerala University of Fisheries and Ocean Studies
Cochin, Kerala, India

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This book is lovingly dedicated to my late parents whose sacrifice, care and unconditional love brought me to this stage and to all my diligent students for being a huge factor in helping me to be a better teacher.

—Preetham Elumalai

Foreword by Dr. Devaraj & Dr. Niranjali Devaraj

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The immune system of vertebrates involves both innate and acquired immune responses. Innate immunity is more generalized with a robust response whereas the latter has a highly specific response to pathogens. The innate immunity components which identify sugars are called as lectins. The innate immune recognition process depends largely on the pattern-based recognition of microbial targets as "non-self" by host lectins and related proteins and their subsequent destruction by complement and phagocytic cells.

All lectins possess one carbohydrate recognition domain (CRD) which specifically and reversibly binds to a specific carbohydrate. Lectins are widely distributed in bacteria, fungi, viruses, plants and animals. Lectins are found in serum, plasma, mucosal surfaces and egg surface. The skin of several animal species, including fish, is assumed to be a rich source of novel and new unreported lectins. Different types of lectins such as ficolins, galectins, calnexin, pentraxin, F-type lectins, intelectins, and mannose-binding protein (MBP) are known to play important roles in innate immunity and disease resistance.

The complement system plays an essential role in protecting against invading microorganisms and acts through three activation pathways, namely, the classic, alternative and lectin pathways. In the lectin pathway, binding of the lectin-Mannose Binding Serine Proteases (MASPs) complexes to carbohydrates on the surface of pathogens activates MASPs to acquire proteolytic activity against complement components C4 and C2, resulting in the elimination of pathogens after a chain reaction of proteolysis of complement components and protein assembly. However, this defense mechanism is poorly understood. Therefore, identification of immune-related genes and their expression studies are imperative.

The collective efforts of the authors and editors of this book are greatly appreciated. It is our hope that the book will be both engrossing and inspiring to the scientists so that they can gain more knowledge in this specific field.

Best wishes

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Former Vice Chairman, UGC
UGC-BSR Faculty Fellow
Department of Zoology
University of Madras, Guindy Campus
Chennai, India

Dr. S. Niranjali Devaraj
Former Professor and Head
Emeritus Scientist, ICMR
Department of Biochemistry
University of Madras, Guindy Campus
Chennai, India

Foreword by Prof. Sadasivam J. Kaushik

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As proteins which bind to specific carbohydrate structures, mono- or oligosaccharides, hundreds of “lectins” have been identified in almost all phyla, plants, animals or microbials. Knowledge on the identification, classification and their role as hemo-agglutinating agents has been increasing ever since the first discovery in the late nineteenth century.

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Former European Research Area (ERA) Chair, Ecoaqua
Past Director of Research, INRA, France

Ecoaqua University Institute
University of Las Palmas de Gran Canaria (ULPGC)
Las Palmas, Spain

ECOAQUA

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Department of Marine Biology,
Microbiology and Biochemistry,
School of Marine Sciences
Cochin University of Science
and Technology
Cochin, Kerala, India

Dr. Sreeja Lakshmi
School of Ocean Science and Technology
Kerala University of Fisheries and Ocean
Studies
Cochin, Kerala, India

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Application of Remote Sensing and GIS in Natural Resources and Built Infrastructure Management

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Water Science and Technology Library

Volume 105

The aim of the *Water Science and Technology Library* is to provide a forum for dissemination of the state-of-the-art of topics of current interest in the area of water science and technology. This is accomplished through publication of reference books and monographs, authored or edited. Occasionally also proceedings volumes are accepted for publication in the series. *Water Science and Technology Library* encompasses a wide range of topics dealing with science as well as socio-economic aspects of water, environment, and ecology. Both the water quantity and quality issues are relevant and are embraced by *Water Science and Technology Library*. The emphasis may be on either the scientific content, or techniques of solution, or both. There is increasing emphasis these days on processes and *Water Science and Technology Library* is committed to promoting this emphasis by publishing books emphasizing scientific discussions of physical, chemical, and/or biological aspects of water resources. Likewise, current or emerging solution techniques receive high priority. Interdisciplinary coverage is encouraged. Case studies contributing to our knowledge of water science and technology are also embraced by the series. Innovative ideas and novel techniques are of particular interest.

Comments or suggestions for future volumes are welcomed.

Vijay P. Singh, Department of Biological and Agricultural Engineering & Zachry Department of Civil and Environment Engineering, Texas A&M University, USA Email: vsingh@tamu.edu

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Editors

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Editors
Vijay P. Singh
Department of Biological and Agricultural Engineering, Zachry Department of Civil and Environment Engineering
Texas A&M University
College Station, TX, USA

Krishna Kumar Yadav
Faculty of Science
Madhyanchal Professional University
Bhopal, India

Francisco Muñoz-Arriola
The School of Natural Resources and Department of Biological Systems Engineering
University of Nebraska-Lincoln
Lincoln, Nebraska, USA

Shalini Yadav
Department of Civil Engineering
Rabindranath Tagore University
Bhopal, Madhya Pradesh, India

Gerald Augusto Corzo Perez
IHE Delft Institute for Water Education
Delft, The Netherlands

Ram Narayan Yadava
Madhyanchal Professional University
Bhopal, India

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Contents

About the Editors

Professor Vijay P. Singh Ph.D., D.Sc., D. Eng. (Hon.), Ph.D. (Hon.), P.E., P.H., Hon.D.WRE, Dist.M. ASCE, Dist.Hon. M. IWRA, Dist.F. AGGS, Hon. Member AWRA,NAE, holds the Caroline & William N. Lehrer Distinguished Chair in Water Engineering and is a Distinguished Professor and a Regents Professor, Department of Biological, and Agricultural Engineering, and Zachry Department of Civil & Environmental Engineering at Texas A&M University, USA. Professor Singh has been recognized for four decades of leadership in research, teaching and service to the hydrologic and water resources engineering profession. Singh's contribution to the state of the art has been significant in many different specialty areas, including hydrologic science and engineering, hydraulic engineering, water resources engineering, environmental engineering, irrigation science, soil and water conservation engineering, entropy-based modeling, copula-based modeling, and mathematical modeling. His extensive publications in these areas include 32 textbooks, 1432 refereed journal articles, 80 edited books, 115 book chapters, 330 conference proceedings papers, and 72 technical reports.

For his seminal contributions, Dr. Singh has been honored with more than 105national/international awards from professional organizations. As a sample, he is a recipient of the Arid Land Hydraulic Engineering Award, Ven Te Chow Award, Torrens Award, Norma Medal, Royce C. Tipton Award, Lifetime Achievement Award, Distinguished Membership, and OPAL Award, all given by ASCE. He was awarded the Ray K. Linsley Award for outstanding contributions to surface water hydrology and the Founders Award of AIH. He has been awarded three honorary doctorates. He is a fellow of ASCE, AWRA, IE, ISAE, IWRS, IASWC, and IAH; a member of AGU, IAHR, IAHS and WASER. He is member/fellow of 12 engineering/science academies, including National Academy of Engineering (NAE). Prof. Singh is licensed as a Professional Engineer (PE), a Professional Hydrologist (PH), and Honorary Diplomate, AAWRE.

Prof. Shalini Yadav is a Professor in the Dept. of Civil Engineering and Head of theCentre of Excellence in Advanced Water and Environmental Research, Rabindranath Tagore University, Bhopal, India. Her research interests include solid and hazardous waste management, construction management, environmental quality, and water resources. She has executed a variety of research/consultancy projects in the area of environment and water science, and has got rich experience in planning, formulating, organizing, executing, and management of R&D programs. She has got to her credit guiding of 35 M.Tech. and 10 Ph.D. students.

She has published more than 90 journal articles and technical reports. She is a member of the organizing and scientific committee of several conferences and reviewer in several of international journals. Also she has published a number of edited books, namely Climate Change Impacts, Water Resources Management, Groundwater, Energy and Environment, Environmental Pollution, Hydrologic Modeling, Water Quality Management, Environmental Degradation: Challenges and Strategies for Mitigation in the Water Science and Technology Library; and Environmental Management in India: Waste to Wealth, Wastewater Assessment, Treatment, Reuse and Development in India in the Earth and Environmental Sciences Library of Springer Nature.

Dr. Krishna Kumar Yadav is working on a position of Assistant Professor in the Faculty of Science and Information Technology of the Madhyanchal Professional University, Madhya Pradesh, India. His research interest is in Defluoridation of Groundwater, Waste Management, and Bioremediation/ Phytoremediation of Heavy Metals, and Energy Recovery from the Waste. He has executed a Varity of research and consultancy projects in the area Environmental Sciences, Sustainability, Water Quality and Water and Waste Water Treatment, and Material Science. Also Dr. Krishna Kumar has got rich experience in executing, and management of R&D programs, He has earned his Master of Science in Environmental Science from V. B. S. Purvanchal University, Jaunpur, India; Master of Philosophy and Doctor of Philosophy in Environmental Science from the Bundelkhand University, Jhansi, India. Also he is recipient of Young Environmental Scientist Award in an International Conference on Agriculture, Allied and Applied Sciences held at JNU New Delhi, India in 2018.

Dr. Krishna Kumar has published more than 70 journal articles and technical reports. He is a member of the organizing and scientific committee of several conferences and reviewer of Journal of cleaner production, Journal of Hazardous Materials, Energy; and Section Editor of International Journal of Environmental Chemistry. Also he has published a number of edited books.

Dr. Gerald Augusto Corzo Perez is Associate Professor at IHE Delft institute for water education. His research work covers a full range of water resources areas applying spatiotemporal statistics, pattern recognition and machine learning techniques. Since the last four year he has been working on the analysis of global hydrological extremes, exploring responses to drought and floods. In 2012 he won the Tison award as young scientist from the IAHS association. He has worked on different international institution like Wageningen University in the Netherlands and the Technologic of Monterrey in Mexico. He has coordinated the statistics of the Climate change inventory of adaptation and mitigation actions for Latin-America, presented at the WWF in 2012. Civil engineer by training with a strong background on computational science and an specialization on Telecommunications. He has developed methods for integrating computational intelligent algorithms and hydrological conceptual models for hydrological forecasting. During his Ph.D. he also worked in Flood Early Warning System models integrating Machine Learning models (Delft-FEWS). He developed scripts for areas of computational intelligence, optimization of water resources, online modeling and in fluid dynamics simulation in MATLAB. One of his recent projects focuses on exploring the use spatiotemporal rainfall objects as inputs for pattern recognition and tracking models. He is innovating in new paradigms in the areas of Natural Language processing and AI Chatbots for new concepts in decision support.

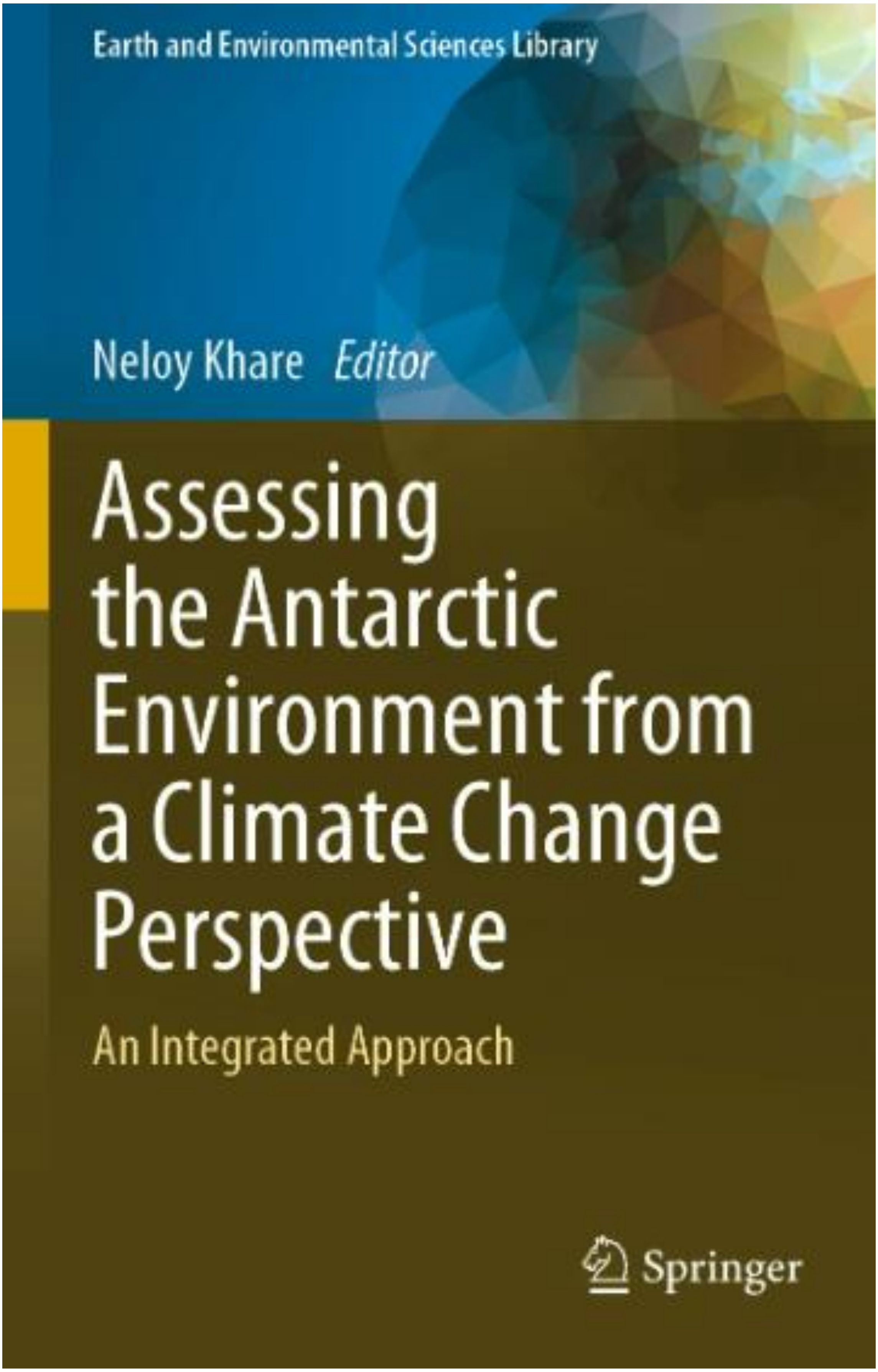
He have participated on research projects in different countries like China with the North China University for Water Conservancy and Electric Power in China, Colombia (CINARA), Mexico (Technologico of Monterrey), England (CEH), Norway (University of Oslo) and others. The last two years he served as chair of the session on geo-statistics at the European Geoscience Union. From 2011 to 2012 he created and leaded the LatinAqua network for water research scientist in Latin-America.

Dr. Francisco Muñoz-Arriola is an Associate Professor in "Climate Analytics, Analysis, and Synthesis" in the School of Natural Resources and the Department of Biological Systems Engineering at the University of Nebraska-Lincoln, and an Adjunct Faculty in the Department of Biosystems Engineering at Universidade do Sao Paulo. He is also a fellow of the Robert B. Daugherty Water for Food Global Institute, the University of Nebraska's Public Policy Center, and the Nebraska Governance and Technology Center. Francisco is a member of the American Meteorological Society (AMS) Water Resources Committee and co-chair of the presidential sessions on Food Security and Water Security at the 2022 AMS annual meeting. Francisco studies the predictability of hydrometeorological and climate extremes and their impacts on natural systems and infrastructure. He is member of the Climate-Resilient and Environmentally Adequate Infrastructure (CREA-I) research collective. CREA-I pursues to connect engineering with other disciplines creating adaptive planning and management strategies, information technologies, models, and theories. Some of Francisco's fundamental and applied research includes the study of the resilience of complex systems to changes in weather and climate, the predictability of regime shifts in water, agriculture, and public health, the integrated management of water quality and quantity, and the (re)design of climate-resilient infrastructure and actions. His collaborative network includes researchers from more than twenty countries in Asia, Europe, and the Americas, working on multiple disciplinary and transdisciplinary challenges. Francisco is an enthusiast mentor and advocate for a diverse, equal, inclusive, ethical, and accessible education. Francisco's Ph.D. is in Civil and Environmental Engineering from Duke University, and he has postdoctoral experiences at the University of Washington and the University of California, San Diego. His bachelor's degree is in Oceanography from the Facultad de Ciencias Marinas at the Universidad Autónoma de Baja California, México.

Prof. Ram Narayan Yadava holds position of Director of Research and International Affairs in Madhyanchal Professional University, Bhopal, (M.P.) India; and Director of Patel Group of Institutions, India. He has worked as a advisor of AISECT Group of Universities and a founding Vice Chancellor of the AISECT University, Hazaribag (Jharkhand), India. Prof. Yadava is also a founding member of Advanced Materials and Processes Research Institute (AMPRI) under the umbrella of Council of Scientific and Industrial Research (CSIR), India. His research interests include Solid Mechanics, Environmental Quality and Water Resources, Hydrologic Modeling, Environmental Sciences, and R&D Planning and Management. Dr. Yadava has executed a variety of research/consultancy projects in the area of Water Resources Planning and Management, Environment, Remote Sensing, Mathematical Modeling, Technology Forecasting, etc.

He has adequate experience in establishing institutes/organizations from scratch. In addition, he has adequate experience in planning, formulating, executing and managing of R&D programs including organizing seminars/symposia/conferences at national and international levels. He has got to his credit guiding a number of M. Tech. and Ph.D. students in the area of Mathematical Sciences and Earth Sciences. Dr. Yadava has visited and delivered invited lectures at different institutes/universities in India as well as in abroad in the various countries such as USA, Canada, UK, France, Thailand, Germany, South Korea, Malaysia, Singapore, South Africa, Costa Rica, The Netherlands, France, China, and Australia. He is Recipient of Raman Research Fellowship and other awards.

Dr. Yadava has been recognized for four decades of leadership in research and service to the hydrologic, environment and water resources profession. Dr. Yadava's contribution to the state of the art has been significant in many different specialty areas, including water resources management, environmental sciences, irrigation science, soil and water conservation engineering, and mathematical modeling. He has published more than 100 journal articles; four text books; sixteen edited reference books. He is reviewer of scientific journals and member of the scientific committee of international conferences. He also holds position of Vice President of International Association of Water, Environment, Energy and Society.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Assessing the Antarctic Environment from a Climate Change Perspective
An Integrated Approach
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Neloy Khare
Editor

Assessing the Antarctic Environment from a Climate Change Perspective

An Integrated Approach

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Editor
Neloy Khare
Government of India
Ministry of Earth Sciences
New Delhi, India

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Foreword

Antarctica is the last great untouched wilderness. Antarctica's frozen continent is an incredible continent of stunning and alien beauty with a rich history of adventure, exploration, and discovery. It is known for diversified uniqueness and is a key to understanding how anthropogenic activities adversely impact the world's climate and carry an associated impact on it. Indubitably, Antarctica is also essential for science because of its profound effect on the Earth's climate and ocean systems which has also revealed much about the impact of human activity on the natural world.

The looming danger of global warming on Antarctica is not confined but spreading fast across the continent, long thought to be untouched by warming. But now, the glaciers and ice shelves in this frigid region are showing signs of melting. Such unprecedented development portends dramatic rises in sea levels in this century and beyond. The collapse of the Larsen C ice shelf warns us against the Antarctic's fragile environment. The subtle climatic changes may primarily pose dire global consequences because collapsing ice shelves prompt the glaciers behind them to retreat more quickly, causing further sea-level rise, thus increasing peril, especially for island countries.

Some of the changes Antarctica is facing are already irreversible, and the situation may turn out to be devastating if the issues are not timely managed through appropriate strategies. To tackle the potential impact of climate, it becomes imperative to prepare futuristic climate change trends to prepare humankind in a larger perspective. It necessitates an in-depth assessment of the Antarctic Environment through an integrated approach.

Over four decades, India has been actively pursuing Antarctic research commensurate with its scientific strength and global visibility. A particular focus has been paid towards climate change. The present book, *Assessing the Antarctic Environment from Climate Change perspective: An Integrated Approach,* provides a comprehensive overview of Antarctic Environmental changes in space and time and assesses climate change scenarios in the present context global warming. It is aptly brought out with eighteen dedicated chapters, where each chapter has its specific significance.

The book begins with *Dhanasree Jayaram's* detailed account on current geopolitical issues arising out of ongoing environmental shift due to unfavourable activities elsewhere, causing damage to the icy continent's pristine nature requiring a firm committed and transparent Antarctic Governance. *Dastidar and Khare* used the data obtained from the web of science and analysed various trends and patterns from the scientific literature on Antarctic Climate Change science. Such analyses significantly impact the direction of the present research to help understand climate change and variability. Subsequently, a detailed assessment is made by *Choudhary and Khare* on how climate change over the Antarctic and the Southern Ocean impacts the global climate system. Gleaning clues drawn from the marine sedimentary records. *Singh et al.* illustriously elaborated Cenozoic Evolution of Antarctic Ice sheet, Circum Antarctic Circulation and Antarctic climate.

To understand the Antarctic region's climate scenarios, a firm understanding of the past climatic evolution is exciting and a key factor. *Baba et al.* studied the variations in the cosmogenic radionuclides. They reconstructed the climatic conditions and glacial history over the DronningMaudland region. Whereas' *Shrivastava et al.* utilised yet another proxy (Terrestrial Diamicts and Lacustrine Sediments) to illuminate Late Quaternary Climate Change in Schirmacher Region, East Antarctica. It is well corroborated with *Govil and Mazumder's* focused review on lacustrine signatures of the palaeoclimatic conditions. Glacial-interglacial paleoenvironmental records have been retrieved from lake sediments of Schirmacher Oasis, East Antarctica, by *Warier et al.*

On the contrary, Nutrient cycling and productivity in Antarctic lakes have been detailed by *Choudhary et al.* In contrast, the Chemical and isotopic characterisation of lakes in the Larsemann Hills, East Antarctica, has been addressed by *Reshmi et al.*

Gwal et al. studied the effect of Ionospheric scintillation and observed the loss of lock-in GPS signals. Further the effect of Ionospheric Scintillation on the positional error and loss of lock of GPS Signal have also been investied in details by *Gwal et al.* Towards understanding biological response to ongoing climate changes over the Antarctic region, *Pande* and *Kuppusamy* highlighted that the rapid changes in the physical environment of the Antarctic and the Southern Ocean affect marine life at all trophic levels, from the primary prey species (zooplankton including Antarctic Krill) to mesopredators (like squids) to top predators such as marine mammals and seabirds. They also postulated that the Seabird populations across the globe are threatened with human-induced changes. Long-term monitoring programs have highlighted exciting trends, including foreseen threats and the declining status of seabirds worldwide.

Similarly, *Nayaka and Rai* have examined the response of Antarctic lichen to climate change. Their evaluation was primarily based on the evidence from natural gradients and temperature enchantment. Simultaneously, *Singh et al.* found a higher Pigment Synthesis rate in Antarctic Plants as an adaptive survival strategy under U.V. radiation.

Catherine et al. have provided an overview of Antarctica's Geoscience studies. In contrast, the Antarctic region's seismogenesis and seismic potential have been assessed for the future comprehensive study by *Mishra.* On the contrary, *Sunil et al.* demonstrated the Antarctic plate's new kinematics using GPS and GRACE data.

Understanding is a continuous process, so the Scientific advancements in Antarctic Science may pose a more significant database to attend to challenging scientific questions. It requires enhanced monitoring, long-ranged time series climate data, efficient models and strong international collaborations to help understand Antarctic climates' evolution.

This book aptly consolidates recent scientific findings and insights related to the ongoing climate change in and around the Antarctic region through an integrated approach. This book will act as a ready reference to all avid researchers and students.

This book will be a good source of information about the Antarctic climate and act as a reference for students, professionals and researchers.

April 2021

A. E. Muthunayagam
Former Secretary, Department
of Ocean Development
Government of India
Thiruvananthapuram, India

Preface

Over 100 million years ago, Antarctica was part of the supercontinent Gondwana. Gondwana gradually broke apart with passing time, and Antarctica in its present situation was formed around 25 million years ago, owing to the opening of the Drake Passage between it and South America. The vast frozen landmass at the southernmost part of the planet is more than just spectacular icing worldwide. The Antarctic ice deflects some of the sun's rays away from the Earth, keeping temperatures liveable. It could be vital for our survival too.

Historically, the first confirmed sighting of mainland Antarctica was recorded on January 27, 1820. Antarctica's discovery is attributed to the Russian expedition led by Fabian Gottlieb von Bellingshausen and Mikhail Lazarev. They discovered an ice shelf at Princess Martha Coast, subsequently known as the Fimbul Ice Shelf. This continent carries many superlatives like it holds most of the world's freshwater but remains a desert. Antarctica used to be as warm as any other tropical place. The Antarctic, which has active volcanoes and several subglacial lakes, has no time zone.

Owing to ongoing global warming, the Antarctic Peninsula has become one of Earth's most rapidly warming areas. The high ice sheet and the polar location make Antarctica a powerful heat sink that strongly affects the climate of the whole Earth. The Antarctic ice sheet contains sufficient ice to raise worldwide sea level by more than 60 meters if melted completely. Through Antarctica, we can understand the Earth's past, present, and future. It also exhibits a platform to understand and value our planet. The ice sheets over the Antarctic region also holds over half-million-years old climatic change signatures. The major threats to this pristine region are climate change which is the greatest long-term threat to the area, increased fishing pressure and illegal fishing, marine pollution, persistent organic pollutants (POPs), and invasive species. It is now a fact that Antarctica and its surrounding waters are under pressure from a variety of forces that are already transforming the area. The most immediate threats are regional warming, ocean acidification, and sea ice loss, all linked to global levels of carbon dioxide. Environmental impacts in Antarctica occur at a range of scales. Global warming, ozone depletion, and global contamination have planet-wide consequences. These affect Antarctica at the most significant scale. Fishing and hunting have more localized impacts but still, have the potential to cause region-wide effects. Indubitably, if all the ice covering Antarctica, Greenland, and mountain glaciers worldwide were to melt, the sea level would rise about 70 meters. The ocean would cover all the coastal cities, and the land area would shrink significantly. However, all the ice is not going to melt. Altogether, Greenland and Antarctica have lost 6.4 trillion tons of ice since the 1990s. The resulting meltwater boosted global sea levels by 0.7 inches. Therefore, it is essential but vital to understand the environmental conditions vis-a-vis the impact of global climate change on this icy continent.

The present book *Assessing the Antarctic Environment from Climate Change perspective: An Integrated Approach* attempts to address various facets of the climate change being witnessed over the Antarctic region. The book begins with the Geopolitics, Environmental Change and Antarctic Governance ably highlighted by *Dhanasree Jayaram.* Although the Antarctic Treaty (AT) is considered a successful example of science diplomacy, as countries have set aside their territorial claims and the continent is a nuclear-free zone by shifting focus to scientific cooperation, its future remains uncertain with these developments. Science diplomacy always goes hand in hand with geopolitics. The AT that reflects Cold War geopolitics needs to be modified to represent present-day geopolitical realities for it to be enduring. A transformative approach to Antarctic governance (including the Southern Ocean), especially in terms of its resources, needs to be adopted. This chapter is followed by detailed data analyses obtained from the web of science dealing with the climate change-related research over Antarctica by world's researchers by *Dastidar and Khare.* Their efforts observe peculiar trends and patterns in the climate change research suggesting priority for climate change research since the 1970s. *Choudhary and Khare* have addressed the climate change over the Antarctic and the Southern Ocean and its impact and bearing on the global climate system. They advocated for a thorough understanding and knowledge of the causes and impacts of climate change and the duration and rates of change, requiring the integration of observational and modelling knowledge from all Earth system-based scientific disciplines.

In a significant manner, *Singh et al.* put forth the evolution of the Antarctic Ice sheet, Circum Antarctic Circulation, and Antarctic climate during Cenozoic by gleaning clues from marine sedimentary records. This chapter ably covers the geological evidence for the origin and evolution of the Antarctic Ice sheet, which primarily includes marine sediments deposited from southern to lower latitudes and summarizes crucial research regarding the origin and development of the Antarctic Ice Sheet (AIS) and offers some future directions for research.

While *Baba et al.* utilized cosmogenic radionuclides to reconstruct the glacial history of the Dronning Maudland region of East Antarctica, this chapter deliberates on the comprehensive outline of DML, basics of cosmogenic radionuclide and its application, and major glacial events from DML. Further, meltwater pulse due to deglaciation of EAIS and evidence related to the marine isotope stages are discussed to understand the impact of deglaciation on the global ocean. This region shows sparse or no evidence of ice thickening during the last glacial maximum (LGM). Field observations and ice core models show that the ice sheet's interior parts, the ice dome, were possibly 100 m lower during LGM than the present. On the other hand, *Shrivastava et al.* discussed the Late Quaternary climate change in the Schirmacher region, based on the terrestrial diamicts and lacustrine sediments. The multi-proxy data, generated from the moraines and sediment cores of a variety of lakes from the Schirmacher region, cDML, has provided better insight into the Late Pleistocene to Holocene paleoclimatic evolution of the region during the Late Quaternary. This chapter highlights the glacial signatures, which are very well preserved in all kinds of sediments of this region. The clay minerals indicate a gradual shift in the weathering regime and that in climate from strongly glacial to fluvio-glacial during Late Quaternary. The results of surface textures of quartz grains have been discussed depth wise and in the same samples. In general, it shows dominant glacial and glaciofluvial actions. The OSL chronology on moraines has provided information on different events of deglaciation in Schirmacher region, East Antarctica. An overview of the paleoclimate changes archived in the lacustrine sediments has been provided by *Govil and Mazumder*. Major palaeoclimatic/palaeoenvironmental studies from this region reveal the presence of several episodes of alternating warm–cold events during Holocene and even beyond, based on a large number of proxies, mainly biological, geochemical, and sedimentological parameters. On the basis of these data, the morphological evolution of the lakes and palaeoclimatic reconstruction of the Schirmacher Oasis have been deciphered. The lacustrine signatures have further been explored to synthesize a glacial–interglacial paleoenvironmental conditions of Schirmacher Oasis, East Antarctica. Paleoclimatic studies using lake sediments drew scientific attention due to its efficiency to record long, high-resolution climate records. Recent studies have employed multiple proxies like environmental magnetism, isotope geochemistry, petrography, sedimentology, and geochronology on lake sediments of Schirmacher Oasis to decipher the past climate and the prevailing environmental conditions. The existing studies poorly record climatic events such as the Mid-Holocene Warm period, Hypsithermal and neoglacial cooling. Despite better chronometric control in these studies, coarse temporal resolution and sparsely documented finer scale climatic variations place the need for future high-resolution works in the East Antarctic region. To fill up this gap, *Warier et al.* have synthesized glacial–interglacial paleoenvironmental records from lake sediments of Schirmacher Oasis, East Antarctica. The nutrient cycling and productivity in Antarctic lakes have been addressed by *Choudhary et al.,* who used sedimentary organic matter from the Antarctic lakes as the source of various proxies to study productivity changes. A total of three sediment cores have been analyzed for TOC, total nitrogen (TN), total phosphorus (TP), biogenic silica (BSi), and their ratios were computed to understand the nutrient cycling and productivity in Antarctic lakes. On the contrary, *Reshmi et al.* studied chemical and isotopic characterization of lakes in the Larsemann Hills, East Antarctica. The ionic and isotopic ratios of some lakes kinetic controlled ice-water fractionation and evaporation processes are found to affect the isotopic evolution of lake water.

In the field of Antarctic ionospheric research, the effect of ionosphere scintillations on the loss of lock in GPS signals has been detailed by *Gwal et al.* during the five most disturbed days of the December 2006. During all the disturbed days weak, moderate or intense geomagnetic storms were observed. The amplitude and phase scintillation become frequently, the visible PRNSs does not remain stable for longer periods. The loss of lock occurs frequently whenever the GPS signals scintillate. Similarly, *Gwal et al.* also attempted to understand the effect of Ionospheric Scintillation on the Positional Error and Loss of Lock of GPS Signal in Antarctic Region. They reported that during all the five geomagnetically disturbed days, the positional error increases significantly.

In Antarctic Biology, *Pande and Kuppusamy* provided an insight into the impacts of ongoing climate changes on Antarctic birds. They have assessed the population status, distribution, and genetic structure of key seabird species (Adelie penguin, snow petrel, south polar skua, Wilson's storm petrel) breeding around Indian research stations, whereas *Nayaka and Rai* have detailed the response of lichens to temperature rise. The extreme climatic conditions such as temperature, precipitation, and smaller ice-free regions allow only cryptogams like bryophytes and lichens to grow dominantly. Lichens are well-known biomonitors and bioindicators of climate change, environmental pollution, and anthropogenic perturbations, they have explored their potential. The study points out that climate warming will cause the extinction of sensitive species. Simultaneously, some will increase their geographical extension due to the increased water availability and nutrients in changed ecosystems. On the contrary, *Singh et al.* assessed the Strategy of Antarctic plants for survival under UV radiations. Antarctic cryptogams are growing in the photosynthetically active radiation (PAR), and ultraviolet radiations (UV-R), closely associated with the synthesis of photosynthetic and photo protective pigments. Antarctic cryptogams cope with high UV radiation stress by synthesizing UV-absorbing compounds; UV-B absorbs pigments and other compounds; the pigment synthesis provides protection to cryptogamic flora.

An exhaustive collation of significant geoscientific studies in Antarctica has been made by *Catherine et al.,* with special mention of CSIR-NGRI which has been participating in these expeditions and has established seismological and GPS observatories for monitoring seismicity and to understand the tectonics of the Antarctica plate and has carried out some geological and geophysical studies too. They summarize some of the important contributions of CSIR-NGRI. While seismogenesis and seismic potential of Antarctic region has not yet been well understood because of unique and complex tectonic settings of the region, besides several causative factors associated with natural and anthropogenic, which are still enigmatic in sense to unravel the fact what and how the genesis of earthquakes is related to the glacial dynamics. *Mishra* have ably provided a comprehensive overview on these aspects to suggest future course of action to undertake detailed study on the glacial mass change induced earthquakes (GMCIE) for the Antarctic regions. The book ends with a dedicated chapter dealing with the Gravity Recovery and Climate Experiment (GRACE) satellites data by *Sunil et al.* which indicates global sea level rise by 0.35 millimetres per year. Antarctic GPS and GRACE data were reanalyzed and discussed to understand in this chapter to understand and estimate the kinematics of Antarctic plate.

The present book shall act as a ready reference to all researchers/academicians who have curiosity to know about various dimensions of the Antarctic climate. The latest insight and data shall be of immense use to climate scientists and policy makers.

New Delhi, India
April 2021

Neloy Khare

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Professor Anil Kumar Gupta, Indian Institute of Technology, Kharagpur (India) and Dr. Rajiv Nigam, former Adviser at the National Institute of Oceanography, Goa (India), are deeply acknowledged for providing many valuable suggestions to this book. This book has received significant support from Akshat Khare and Ashmit Khare, who helped me during the book preparation. Dr. Rajni Khare has unconditionally supported enormously during various stages of this book. Dr. Shabnam Choudhary, Shri Hemant Kumar, and Shri Hari Dass Sharma from the Ministry of Earth Sciences, New Delhi (India), have helped immensely formatting the text and figures of this book and bring the book to its present form. Publishers (Springer Nature) have done a commendable job and are sincerely acknowledged.

New Delhi, India
April 2021

Neloy Khare

Dedication

Late Professor Surendra Kumar
(14.8.1942 – 20.4.2021)

Professor Surendra Kumar was born in Lucknow. His schooling and college education are from Jubilee Inter College, Lucknow, and thereafter shifted to Lucknow University for graduation, postgraduation, and Ph. D. He worked on Almora Crystallines, Lesser Himalaya. He joined the Department of Geology as a faculty in September 1967.

He was a noted sedimentologist, however, also contributed significantly on Precambrian stromatolites and microbiota. He has worked on Lesser Himalaya, Tethys Himalaya, Vindhyan Supergroup, Marwar Supergroup, and Ganga River basin. His contributions on Vindhyan stromatolites are noteworthy in Indian geology as established and reported many new forms including *Maiharia maiharensis*. Similarly, reassessment and refinement of the Marwar Supergroup stratigraphy, based on organo-sedimentary structures, is again quite significant. Closely associated people are well aware of his systematic approach, planning, and skill of minute observations during the field work. Either as a leader or member of expedition, he visited the high-altitude, hostile, and glacial terrain of Malla Johar area, Tethys Himalaya for 3–4 timed and scaled more than 20,000 ft for sample and data collections. He was also concerned with the recent problems of river pollution and environmental hazards, therefore, concentrated on various aspects of the Ganga basin, helpful in planning and management for both State and Centre governments.

He is also the recipient of prestigious Alaxender von Humboldt Fellowship at Heidelberg. He has also been awarded the National Mineral Award by the Government of India in the year 1999. Served as an active member of Palaeontological Society of India in various capacities including the responsibility of the Editor of the Journal for many years. He has more than 100 research articles of national and international reputes in his credit besides three books/field guides on Lameta, Vindhyan Basin, and Marwar Supergroup. Superannuated in the year 2005, but committed to research activity for more than a decade. His sudden demise on April 20, 2021, has created a void in the field of Geology As his student, I pay my sincere tribute to his noble soul and humbly dedicate this book to him.

Neloy Khare

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Editors and Contributors

About the Editor

Dr. Neloy Khare presently Adviser/Scientist G to the Government of India at MoES. has a very distinctive acumen not only of administration but also of quality science and research in his areas of expertise covering a large spectrum of geographically distinct locations like Antarctic, Arctic, Southern Ocean, Bay of Bengal, Arabian Sea, Indian Ocean, etc. He has almost 30 years of experience in the field of paleoclimate research using paleobiology Paleontology)/teaching/science management/administration/coordination for scientific programmes (including Indian Polar Programme), etc. Having completed his doctorate (Ph.D.) on tropical marine region and Doctor of Science (D.Sc.) on Southern High latitude marine regions towards environmental/climatic implications using various proxies including foraminifera (micro-fossil), have made significant contributions in the field of palaeoclimatology of Southern high latitude regions (Antarctic and Southern Ocean) using Micropaleontology as a tool. These studies coupled with his palaeoclimatic reconstructions from tropical regions helped understand causal linkages and teleconnections between the processes taking place in Southern high latitudes with that of climate variability occurring in tropical regions. He has been conferred Honorary Professor and Adjunct Professor by many Indian universities. He has a very impressive list of publications to his credit (125 research articles in National and International Scientific journals; 3 special Issues of National Scientific Journals as Guest Editor; Edited Special Issue of Polar Science (Elsevier) as its Managing Editor, Quaternary International and Journal of Asian Earth Sciences as Guest Editor Authored/edited many books, 130 abstracts have been contributed to various seminars; 23 popular Science Articles; 5 technicalreports). Government of India and many professional bodies have bestowed him with many prestigious awards for his humble scientific contributions to Past climate changes/Oceanography/Polar Science and Southern Oceanography The most coveted award is Rajiv Gandhi National Award—2013 conferred by Honourable President of India. Other include ISCA Young Scientist Award, Boyscast Fellowship, CIES French Fellowship, Krishnan Gold Medal, Best Scientist Award, Eminent Scientist

Award, ISCA Platinum Jubilee Lecture, IGU Fellowship, besides many. He has made tremendous efforts to popularize ocean science and polar science across the country by the way of delivering many invited lectures, radio talks, and publishing popular science articles.

He has sailed in the Arctic Ocean as a part of "Science PUB" in 2008 during the International Polar Year campaign for scientific and became the first Indian to sail in the Arctic Ocean.

Contributors

Waseem Ahmad Baba Department of Geology, Central University of Punjab, Punjab, India

S. Amirtharaj Indian Institute of Geomagnetism, Mumbai, India

P. Arjun Centre for Water Resources Development and Management, Kozhikode, Kerala, India

Rajesh Asthana Geological Survey of India, Kolkata, India

Joshi K. Catherine CSIR-National Geophysical Research Institute, Uppal Raod, Hyderabad, India

Shabnam Choudhary National Centre for Polar and Ocean Research, Vasco da Gama, Goa-403802, India

Suryanshu Choudhary Department of Physics, Rabindranath Tagore University, Raisen, India;
Department of Physics, Dr A P J Abdul Kalam University, Indore, India

Prabir G. Dastidar Ministry of Earth Sciences, Prithvi BhawanNew Delhi, India

Ajay Dhar Indian Institute of Geomagnetism, Mumbai, India

Vineet K. Gahalaut CSIR-National Geophysical Research Institute, Uppal Raod, Hyderabad, India

Girish Gopinath Centre for Water Resources Development and Management, Kozhikode, Kerala, India;
Kerala University of Fisheries and Ocean Studies, Kochi, Kerala, India

Pawan Govil Birbal Sahni Institute of Palaeosciences, Lucknow, UP, India

A. K. Gwal Department of Physics, Rabindranath Tagore University, Raisen, India;
Department of Physics, Dr A P J Abdul Kalam University, Indore, India

Dhanasree Jayaram Department of Geopolitics and International Relations, Old TAPMI Building, Manipal Academy of Higher Education, Manipal, Karnataka, India

Tushar Kaushik Biodiversity and Palaeobiology, Agharkar Research Institute, Pune, India

Neloy Khare Ministry of Earth Sciences, Prithvi Bhawan, New Delhi, India

Rajni Khare Delhi Public School, Sector Gama-2, Greater Noida, Gautam Buddh Nagar, Uttar Pradesh, India

Jitendra Kumar Pattanaik Department of Geology, Central University of Punjab, Punjab, India

Prakash Kumar Shrivastava Geological Survey of India, Kolkata, India

Amit Kumar CSIR-National Geophysical Research Institute, Uppal Raod, Hyderabad, India

K. Vijay Kumar Indian Institute of Geomagnetism, Mumbai, India

Pankaj Kumar AMS Division & Geochronology Group, Inter-University Accelerator Centre, New Delhi, India

Sivakumar Kuppusamy Department of Endangered Species Management, Wildlife Institute of India, Dehradun, Uttarakhand, India

B. S. Mahesh National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Vasco-da-Gama, Goa, India

Kirtiranjan Mallick Department of Geology, Utkal University, Bhubaneswar, Odisha, India

Abhijit Mazumder Birbal Sahni Institute of Palaeosciences, Lucknow, UP, India

O. P. Mishra National Centre for Seismology, Ministry of Earth Sciences, New Delhi, India

Rahul Mohan National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Vasco-da-Gama, Goa, India

Ch Mohana Lakshmi CSIR-National Geophysical Research Institute, Uppal Raod, Hyderabad, India

Saroj K. Mondal CSIR-National Geophysical Research Institute, Uppal Raod, Hyderabad, India

G. N. Nayak Marine Sciences, School of Earth, Ocean and Atmospheric Sciences, Goa University, Taleigao, Goa, India

Sanjeeva Nayaka Lichenology Laboratory, Plant Diversity, Systematics and Herbarium Division, CSIR-National Botanical Research Institute, Lucknow, Uttar Pradesh, India

Anant Pande Department of Endangered Species Management, Wildlife Institute of India, Dehradun, Uttarakhand, India

M. Ponraj Indian Institute of Geomagnetism, Mumbai, India

M. Praveenbabu Centre for Water Resources Development and Management, Kozhikode, Kerala, India

Vikram Pratap Singh Department of Geology, Indira Gandhi National Tribal University, Amarkantak, India

Himanshu Rai Lichenology Laboratory, Plant Diversity, Systematics and Herbarium Division, CSIR-National Botanical Research Institute, Lucknow, Uttar Pradesh, India

V Rajesheswar Rao CSIR-National Geophysical Research Institute, Uppal Raod, Hyderabad, India

Rahul Rawat Indian Institute of Geomagnetism, Mumbai, Maharashtra, India

T. R. Resmi Centre for Water Resources Development and Management, Kozhikode, Kerala, India

Sandip Roy Geological Survey of India, Kolkata, India

Ajish P. Saji Indian Institute of Geomagnetism, Mumbai, India

A. S. Yamuna Sali Centre for Climate Studies / Department of Civil Engineering (Manipal Institute of Technology), Manipal Academy of Higher Education, Manipal, Karnataka, India

Joju George Sebastian Centre for Climate Studies / Department of Civil Engineering (Manipal Institute of Technology), Manipal Academy of Higher Education, Manipal, Karnataka, India

Ankush Shrivastava Department of Geology, Mohanlal Sukhadia University, Udaipur, Rajasthan, India

Jaswant Singh Department of Environmental Sciences, Dr R M. L. Avadh University, Ayodhya, Uttar Pradesh, India

Ashutosh K. Singh Department of Geology, Centre of Advanced Studies, University of Delhi, Delhi, India

Rudra P. Singh Department of Environmental Sciences, Dr R M. L. Avadh University, Ayodhya, Uttar Pradesh, India

Devesh K. Sinha Department of Geology, Centre of Advanced Studies, University of Delhi, Delhi, India

P. S. Sunil Department of Marine Geology and Geophysics, CUSAT-NCPOR Centre for Polar Sciences, School of Marine Sciences, Cochin University of Science and Technology, Kochi, Kerala, India

Ritesh Yadav Department of Physics, Rabindranath Tagore University, Raisen, India;
Department of Physics, Dr A P J Abdul Kalam University, Indore, India

Anish Kumar Warrier Centre for Climate Studies / Department of Civil Engineering (Manipal Institute of Technology), Manipal Academy of Higher Education, Manipal, Karnataka, India

Shalini Dhyani
Mrittika Basu
Harini Santhanam
Rajarshi Dasgupta *Editors*

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Editors
Shalini Dhyani
National Environmental Engineering Research Institute, NM
Council Scientific and Industrial Research
Nagpur, Maharashtra, India

Mrittika Basu
Laboratory of Sustainable Rural Development
Kyoto University
Kyoto, Japan

Harini Santhanam
National Institute of Advanced Studies
Bangalore, India

Rajarshi Dasgupta
Institute for Global Environmental Strategies
Kanagawa, Japan

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Foreword

Cities are expanding and so are the number of people inhabiting these cities. Following the current trend, the global urban population is expected to be 70% or 6.3 billion by 2050, nearly doubling up from the urban population in 2010, i.e. 3.5 billion. This increase will not only be concentrated in megacities, but also across small- and medium-sized cities across the world. Pressure on the urban resources is anticipated to increase manifold including, but not limited to, depleting green and blue spaces, water scarcity, air pollution, urban heat islands, increasing disaster risks, noise pollution, waste dumping, etc. Maintaining a healthy and habitable urban life is one of the major challenges facing the *Anthropocene*.

There have been quite a few studies on urban infrastructural facilities like transportation systems, wastewater treatment, solid waste disposal, water supply, electricity supply and urban settlements. On the other hand, urban ecological infrastructures like open spaces, parks, waterbodies, urban wetlands, etc., collectively referred to as 'Blue-Green Infrastructure' (BGI), are the first prey to urban expansion and, yet they fail to get ample attention. Though much has been written about the benefits provided by urban ecosystems, development of new blue-green infrastructures and their mainstreaming in urban policy planning is yet to be realized, especially in the Global South. This book *Blue-Green Infrastructure Across Asian Countries—Improving Urban Resilience and Sustainability* fills up this gap impeccably. The book clearly exemplifies the importance of the Blue-Green Infrastructures through various case studies across different Asian countries and suggests convincing ways to mainstream this infrastructure in urban policy planning.

This book not only explores the benefits and challenges of Blue-Green Infrastructures, but also explores the different advances that can be adopted like citizen science initiatives, spatial planning and socio-ecological technological approaches to monitor and implement them. Different environmental designs are proposed for the inclusion of Blue-Green Infrastructures in urban settings. For example, home gardens of Sri Lanka delineate the multifunctional role of ecological infrastructures and present a unique design where both blue- and green-infrastructures can be designed together at a relatively smaller space. The different environmental designs presented in this book provide an opportunity to replicate them to include in other urban areas with some modifications, if needed.

Blue infrastructures in urban areas find a special place in this book. Very little information on urbanization impacts on blue infrastructures is available except for spatial maps that show the shrinkage in urban waterbodies. Starting from the ancient waterbodies in India to nature-based solutions for marine and coastal ecosystems to alleviating the impacts of disasters like flood, the role of blue infrastructures is explored in detail and their implementation discussed. The book opens up new avenues of research on the roles of blue infrastructure that will ameliorate the quality of life of urban dwellers. Likewise, case studies on the importance of EcoDRR demonstrate the role of Blue-Green Infrastructure in urban resilience building and disaster risk mitigation.

Considering the urban complexities and uncertainties, it is timely and important to explore alternative interventions for a sustainable urban future, as detailed in this book. The book not only quantifies and explores the importance of Blue-Green Infrastructure, but also suggests on mainstreaming it in the urban policy planning process which will eventually help in implementing the ecological infrastructures. Academicians, policy planners, city planners, local communities and both local government and non-governmental agencies will find this book helpful as the book delivers an integrated knowledge on Blue-Green Infrastructure and makes a valuable contribution towards building a sustainable and resilient urban future.

I congratulate the authors for presenting diverse concepts, cases and novel approaches on the subject that are relevant for diverse stakeholders including urban planners and policy makers. I also warmly congratulate the editors: Shalini Dhyani, Mrittika Basu, Harini Santhanam and Rajarshi Dasgupta—for their timely efforts to produce this insightful volume of concepts, innovations and case studies. This book is an important and timely contribution to the knowledge pool of urban ecosystems, nature-based solutions, disaster risk reduction and climate change adaptations. Readers will be highly benefited from the insightful chapter content and analysis presented in this book. I wish the editors and authors all success in their endeavour.

Resilience to Disasters and Conflicts Support Branch, UNEP
Geneva, Switzerland
Muralee Thummarukudy

Acknowledgements

Putting together a book on a relatively futuristic topic of *Blue-Green Infrastructure Across Asian Countries: Improving Urban Resilience and Sustainability* would not have been possible without the constant support, contributions, perseverance and dedication of expert authors. We are enormously grateful to many subject experts, scientists and researchers who volunteered their precious and busy time out of their heavily engaged academic involvements and helped to critically review the book chapters. We truly appreciate their cooperation and good understanding in meeting our rather strict paper submissions and review deadlines. Many of our supporters deserve special appreciation. We sincerely thank the Director CSIR-NEERI, Nagpur, for the valuable support during the preparation of this book. We are grateful to many of our very hard working and supportive research scholars without whose critical support our efforts alone would not have been enough to bring out this book in time. We specially thank Ms. Sunidhi Singh for her keeping record of all the email communications and attachments and Ms. Kavita Bramhanwade for her help in overseeing formatting and language correction to avoid major mistakes. Finally, the production team members of Springer deserve special appreciation for guiding us through the process of publishing this work. Despite our best efforts to avoid any mistake, it is, however, possible that a very few errors, may be grammatical in nature, remain owing to the fast pace of production and strict timelines we had to adhere to. Each individual chapter included in this book was finalized with the primary responsibility of author and co-authors. The editors have gone through all the chapters included and reviewed them personally as well, with careful scrutiny following international standards including ethics of publication. We shall be immensely grateful to receive constructive comments and suggestions from readers of this book for further improvement of our publications in future. Any errors found in this book are the collective responsibility of the chapter authors and of the editors. Last but not least, we thank our family members, especially our parents, spouses and children, for their understanding, adjustments, patience and encouragement to continue and complete this mammoth task well in time.

In closing, we express our gratitude to Dr. Muralee Thummarukudy, Chief, UNEP, for writing the foreword for this book.

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About the Editors

Shalini Dhyani is a Senior Scientist in the Critical Zone Research Group of the Water Technology and Management Division at CSIR-NEERI, India. She is South Asia regional chair for IUCN-CEM (Commission on Ecosystems Management) and also serves as the lead author for IPBES Sustainable Use of Wild Species Assessment (2018–2021). She is a skilled ecologist with more than 17 years of strong experience in environmental impact assessment, ecosystem health assessment, climate change impact on natural ecosystems and species, nature-based solutions, climate-sensitive restoration and sustainability projects. She has extensively worked on the interlinkages between ecological, human and social systems through sustainability science approaches. Her research interest focuses on science-policy integration for better biodiversity and ecosystem-inclusive decision-making for impact assessment, sustainable development and disaster risk reduction. In the last few years, she has also contributed to assess the importance, threats and opportunities in fast expanding urban areas and mainstreaming blue-green infrastructure for ensuring urban resilience and sustainability. She has been involved in the gender task force of IUCN and has also helped to develop governance pathways for intergenerational partnerships in conservation. She was awarded first "IUCN-CEM Chair Young Professional Award" at the IUCN World Parks Congress 2014 in Sydney, Australia, for her excellent research and publications on forests of the Himalayan region. She is recipient of various national as well as international financial grants, viz. Indo-Italian joint bilateral research grant, Indo-Japan multilateral grant from APN, UNEP, GIZ, FAO, IUCN, UNU, European Union-LEANES, Rufford SGP and DST. She has more than 60 peer-reviewed national and international publications with many popular articles to her credit.

Mrittika Basu is an Assistant Professor in the Laboratory of Sustainable Rural Development, Graduate School of Global Environmental Studies (GSGES), Kyoto University, Japan. Prior to this position, she was a UNU-JSPS postdoctoral fellow in the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS), Tokyo. Her research mainly focused on understanding the change in ecosystem services, relational values and well-being among peri-urban communities affected by rapid urbanization and industrial development. She has also been a contributing author (CA) in the IPBES Global Assessment Report (2015–2018).

Currently, she is leading a project on migration decision-making in salinity-affected areas of Bangladesh and India (2020–2022), funded by Asia Pacific Network (APN) for Global Change Research. Apart from this, she is working on assessing nature connectedness and biophilia assessment among school children in India and Japan. Her research interests include, but not limited to, water ecosystem services, water resources management, ecosystem values and services and human–nature relations. She has published several peer-reviewed scientific papers in international journals.

Harini Santhanam is an Assistant Professor with the National Institute of Advanced Studies, Bangalore, India, studying multiple aspects of natural lake systems such as biogeochemistry, hydro-geological processes and land-water-human nexus from an ecosystem perspective. She has been a long-term researcher with IISc Bangalore, working in multidisciplinary teams with a focus on analytical and modelling techniques, with implications towards influencing management measures for the resource base. Recently, she led an investigation of the hydrochemistry of Pulicat Lake in detail, as the principal investigator of a DST-funded Women Scientists project (2015–2018) at IISc. She was awarded the National Doctoral Fellowship from AICTE, India (2004–2008). Her research interests are largely multidisciplinary, bringing together the insights from aquatic biogeochemistry (especially on themes like trophic status and ecosystem indices), geomatics-based integrative modelling, paleo-ecological reconstructions and investigating the anthropogenic influence on the recycling of nutrients through the aquatic food web, among others. Her work also encompasses the development and application of novel environmental proxies and indices. Further, she investigates the challenges towards sustainable development of urban lake environments and models the lake–land interactions from the perspective of urban blue-green infrastructure development and adopting nature-based solutions for enhancing urban resilience. She has more than 20 publications in national and international journals and conferences.

Rajarshi Dasgupta is a Senior Researcher in the domain of natural resource and ecosystem services at the Institute for Global Environmental Strategies (IGES), Kanagawa, Japan. He holds diverse research interests in the field of landscape ecology and planning, which include Ecosystem-based Disaster Risk Reduction (Eco-DRR), spatial quantification of ecosystem services, land change simulation, development of socio-ecological scenarios, participatory conservation and social forestry. Earlier, he has worked extensively with mangrove communities in India, Bangladesh and Myanmar. Prior to joining IGES, he was working with the University of Tokyo as the Japan Society for the Promotion of Science (JSPS) postdoctoral fellow in the Graduate School of Agriculture and Life Sciences. Previously, he has worked in multiple technical and administrative capacities, including government, NGO and academia, and also served as a lead author (LA) for IPBES Asia-Pacific Regional Assessment Report. He is currently serving as the lead author for IPBES Sustainable Use of Wild Species Assessment (2018–2021), as chapter scientist/ contributing author of IPCC AR-6 (WG-II) and as a visiting associate professor in the Institute for Future Initiatives, University of Tokyo.

Abbreviations

ABC	Active, Beautiful, Clean Waters
ACB	ASEAN Centre for Biodiversity
ACCCRN	Asian Cities Climate Change Resilience Network
ADB	Asian Development Bank
AIIMS	All India Institute of Medical Sciences
ALI	Advanced Land Imager
ALOS- PALSAR	Advanced Land Observing Satellite- Phased Array type L-band Synthetic Aperture Radar
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AMS	Accelerator Mass Spectrometry
ANOVA	Analysis of Variance
AQI	Air Quality Index
AQMS	Air Quality Management System
ASDMA	Assam State Disaster Management Authority
ASTER	Advanced Spaceborne Thermal Emission and Reflector Radiometer
ATLAS	Advanced Topographic Laser Altimeter System
AZN	Currency of Azerbaijan: Azerbaijani Manat
B	Balancing loop
BAU	Business As Usual
BBA	Blue to Built-up Area
BDA	Bengaluru Development Authority
BGI	Blue-Green Infrastructure
BMCs	Biodiversity Management Committees
BMPs	Best Management Practices
BOD	Biological Oxygen Demand
C	Carbon
CALABARZON	Cavite, Laguna, Batangas, Rizal, Quezon
CAS	Climate Adaptation Summit
CBA	Community-Based Adaptation
CBD	Convention on Biodiversity
CBI	City Biodiversity Index
CCA	Climate Change Adaptation

CCBA	Climate Community and Biodiversity Alliance
CCC	Chittagong City Corporation
CDA	Chittagong Development Authority
CDD	Cooling Degree Days
CER-GI-CON	Ceramic-Galvanized Iron-Concrete
CER-GI-WD	Ceramic-Galvanized Iron-Wood
CER-LS-MXD	Ceramic-Long Span-Mixed Materials
CER-TEG-CON	Ceramic-Tegula-Concrete
CFD	Computational Fluid Dynamics
C-HED	Centre for Heritage, Environment and Development
CICES	Common International Classification of Ecosystem Services
CIS	Coupled Infrastructure System
Cl	Chlorine
CLD	Causal Loop Diagrams
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CON-GI-CON	Concrete-Galvanized Iron-Concrete
CON-GI-WD	Concrete-Galvanized Iron-Wood
CON-TEG-BR	Concrete-Tegula-Brick
CON-TEG-CON	Concrete-Tegula-Concrete
COP	Conference of the Parties
CPCB	Central Pollution Control Board
CSO	Combined Sewer Overflow
CSO	Civil Society Organisation
CV	Contingent Valuation
CWs	Constructed Wetlands
DADP	Detailed Area Development Planning
DAP	Detailed Area Plan
DEM	Digital Elevation Model
DMDP	Dhaka Metropolitan Development Plan
DN	Digital Numbers
DO	Dissolved Oxygen
DPSIR	Driver Pressure State Impact Response Framework
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DSM	Digital Surface Models
DSP	Dolphin Space Programme
EAF	Ecosystem Approach to Fisheries
EbDRR	Ecosystem-based Disaster Risk Reduction approaches
EBM	Ecosystem-Based Management
EMR	Electro Magnetic Radiation
EnMAP	Environmental Mapping and Analysis Program
ENPHO	Environmental Public Health Organization
ERI	Ecological Risk Index
ESS	Ecosystem Services

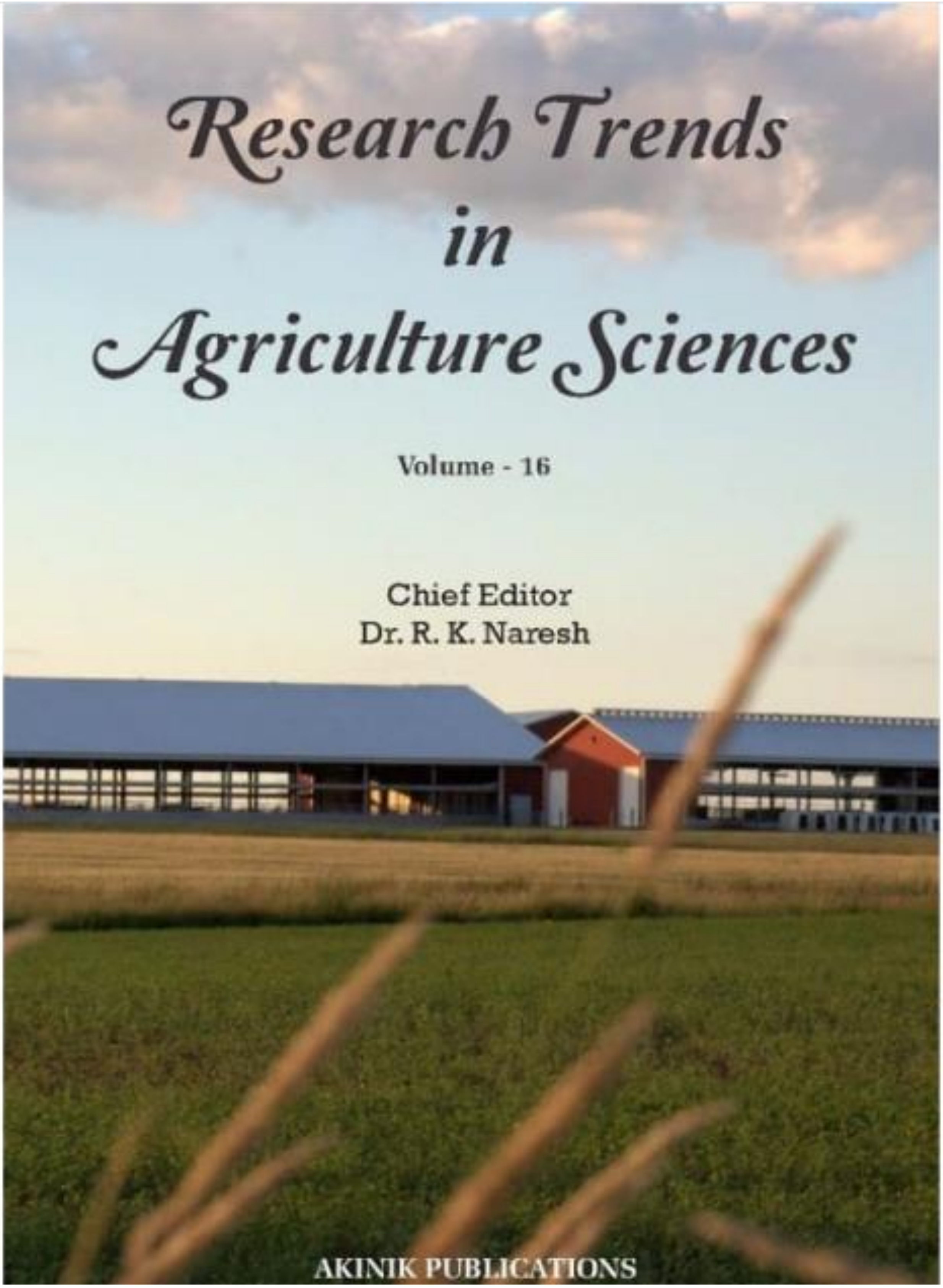
ESZ	Eco-Sensitive Zone
ETM	Enhanced Thematic Mapper
EV	Egyptian Vultures
EWS	Early Warning System
FAO	Food and Agricultural Organization
FD	Forest Department
FDPP	Full Depth Permeable Pavement
FEMA	Federal Emergency Management Agency
FGD	Focus Group Discussions
FPI	Fabry-Pérot Interferometer
GBA	Greater Baku Area
GBR	Green-to-Blue Ratio
GCDA	Greater Cochin Development Authority
GCF	Green Climate Fund
GDP	Gross Domestic Product
GE	Google Earth
GEDI	Global Ecosystem Dynamics Investigation
GEE	Google Earth Engine
GGF	Green Growth Framework
GHGs	Greenhouse Gases
GI	Green Infrastructure
GIM	National Mission for Green India
GIS	Geographical Information Systems
GLAS	Geoscience Laser Altimeter System
GMC	Guwahati Municipal Corporation
GMDA	Guwahati Metropolitan Development Authority
GPS	Global Positioning Systems
GR-GI-BAM	Ground-Galvanized Iron-Bamboo
GR-GI-MXD	Ground-Galvanized Iron-Mixed Materials
GR-GI-WD	Ground-Galvanized Iron-Wood
GR-NIP-MXD	Ground-Nipa-Mixed Materials
GR-NP-BAM	Ground-Nipa-Bamboo
GR-NP-WD	Ground-Nipa-Wood
GS	Guwahati-Shillong
HAC	Hoi An City
HDD	Heating Degree Days
HHMI	Hard Human-Made Infrastructure
HI	Human Infrastructure
HRIDAY	Heritage City Development and Augmentation Yojana
HySIS	Hyper Spectral Imaging Satellite
ICAP	India Cooling Action Plan
ICCC	Integrated Command and Control Center
ICELI KCC	ICLEI Kaohsiung Capacity Center
ICZM	Integrated Coastal Zone Management
IFM	Integrated Flood Management

IISD	International Institute for Sustainable Development
IMFFS	Integrated Mangroves Fisheries Farming System
INCOIS	Indian National Centre for Ocean Information Services
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPZ	Island Protection Zone
IRS LISS	Indian Remote Sensing Satellite Linear Imaging Self Scanning Sensor
ISA	Percentage Impervious Surface Area
ISRO	Indian Space Research Organisation
IUCN	International Union for Conservation of Nature
IUWM	Integrated Urban Water Management
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KDA	Khulna Development Authority
KHGs	Kandyan Homegardens
KSDMA	Kerala State Disaster Management Authority
KUIDFC	Karnataka Urban Infrastructure Development Finance Corporation
LAI	Leaf Area Index
LaP	Local Area Planning Authority
LBSAP	Local Biodiversity Strategy Action Plan
LBV	Long-Billed Vultures
LCS	Low-Carbon Society
LID	Low-Impact Development
LiDAR	Light Detection and Ranging
LLDA	Laguna Lake Development Authority
LPG	Liberalisation-Privatisation-Globalisation
LST	Land Surface Temperature
LULC	Land Use Land Cover
MFAs	Marine Fishery Advisories
MFF	Mangroves for the Future
MIMAROPA	Mindoro, Marinduque, Romblon, Palawan
MIMES	Multiscale Integrated Model of Ecosystem Services
MLC	Maximum Likelihood Classifier
MLIT	Ministry of Land, Infrastructure, Transport and Tourism, Japan
MNDWI	Modified Normalized Difference Water Index
MODIS	Moderate Resolution Imaging Spectroradiometer
MoE	Ministry of the Environment, Japan
MoEFCC	Ministry of Environment, Forest and Climate Change
MoES	Ministry of Earth Sciences
MONRE	Ministry of Natural Resources and Environment
MoUD	Ministry of Urban Development
MS	Multi Spectral
MSS	Multispectral Scanner System

MSWM	Municipal Solid Waste Management
MXD-GI-MXD	Mixed Materials-Galvanized Iron-Mixed Materials
MXD-TEG-BR	Mixed Materials-Tegula-Brick
N	Nitrogen
NAPCA	National Association for the Promotion of Community Universities, Taiwan
NAPCC	National Action Plan on Climate Change
NASA	National Aeronautics and Space Administration
NAT	NbS Assisting Technologies
NBA	National Biodiversity Act
NBS	Nature-Based Solutions
NCAER	National Council of Applied Economic Research
NCR	National Capital Region
NDC	Nationally Determined Contributions
NDMA	National Disaster Management Agency
NDRRMC	National Disaster Risk Reduction and Management Council
NDRRMP	National Disaster Risk Reduction and Management Plan
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NE	North East
NFCP	Natural Forest Conservation Program
NFPP	Natural Forest Protection Program
NGOs	Non-Governmental Organisations
NI	Natural Infrastructure
NIR	Near Infrared
NMEEE	National Mission of Enhanced Energy efficiency
NO_3	Nitrate
NRC	National Research Council
NRM	Natural Resources Management
NSCB	National Statistics Coordination Board
NSSL	National Severe Storms Laboratory
NTFP	Non-Timber Forest Products
OLI	Operational Land Imager
OP	Oriented-plan
OSF	Ocean State Forecast
OTH-GI-WD	Others-Galvanized Iron-Wood
OTH-TEG-BAM	Others-Tegula-Bamboo
PA	Protected Areas
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAN	Panchromatic
PBL	Planetary Boundary Layer
PFZ	Potential Fishing Zone
PHI-2	Push broom Hyperspectral Imaging II
PI	Public Infrastructure

PIP	Public Infrastructure Provider
PM	Particulate Matter
PMCG	Pembrokeshire Marine Code Group
PPP	Public–Private Partnership
PPS	Permeable Pavement Systems
PSA	Philippine Statistics Authority
PUB	Public Utilities Board
PV	Proportion of Vegetation cover
QGIS	Quantum GIS
R	Reinforcing Loop
RADAR	Radio Detection and Ranging
RBP	Reference Behaviour Pattern
RBTS	Reed Bed Treatment System
RCM	RADARSAT Constellation Mission
RDA	Rajshahi Development Authority
RF	Reserve Forest
RMDP	Rajshahi Metropolitan Development Plan
RMP	Revised Master Plan
RPI	River Pollution Index
RS	Remote Sensing
RS	Resource System
RU	Resource User
RVS	Ramadevarabetta Vulture Sanctuary
S	Scenario
S&T	Science and Technology
SAR	Synthetic Aperture Radar
SAVi	Sustainable Asset Valuation
SCC	Sponge City Concept
SCP-Asia	Sustainable Cities Programme-Asia
SDGs	Sustainable Development Goals
SDWF	Shannon Dolphin and Wildlife Foundation
SESs	Social-Ecological Systems
SET	Social-Ecological Technological
SHMI	Soft Human-Made Infrastructure
SIDS	Small Islands Developing States
SMCE	Spatial Multi-Criteria Evaluation
SNC	Second National Communication
SOI	Survey of India
SPC	Sponge City Program
SS	Suspended Solids
SSNN	Self-Adapting Selection of Multiple Artificial Neural Networks
SuDS	Sustainable Urban Drainage Systems
SUNRM	Sustainable Urban Natural Resources Management
SW	Southwest Monsoon
SWIR	Short-Wave Infrared

SWM	Solid Waste Management
TCPO	Town and Country Planning Organisation
TIR	Thermal Infrared
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TSS	Total Suspended Solids
UAV	Unmanned Aerial Vehicle
UBGI	Urban Blue-Green Infrastructure
UCCR	Urban Climate Change Resilience
UCI	Urban Cooling Islands
UDA	Urban Development Authority
UESs	Urban Ecosystem Services
UGI	Urban Green Infrastructure
UGS	Urban Green Spaces
UHI	Urban Heat Islands
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Fund for Population Activities
UNHABITAT	United Nations Human Settlements Programme
UNICEF	United Nations International Children's Emergency Fund
URR	Urban Risk Resiliency
UT	Union Territories
UV	Ultraviolet
VC	Ventilation Coefficient
VI	Vegetation Index
VNIR	Visible and Near-Infrared
WD-TEG-BAM	Wood-Tegula-Bamboo
WHO	World Health Organization
WI	Water Index
WRF	Weather Research and Forecasting
WSUD	Water Sensitive Urban Design
WTP	Willingness to Pay
WWT	Wastewater Treatment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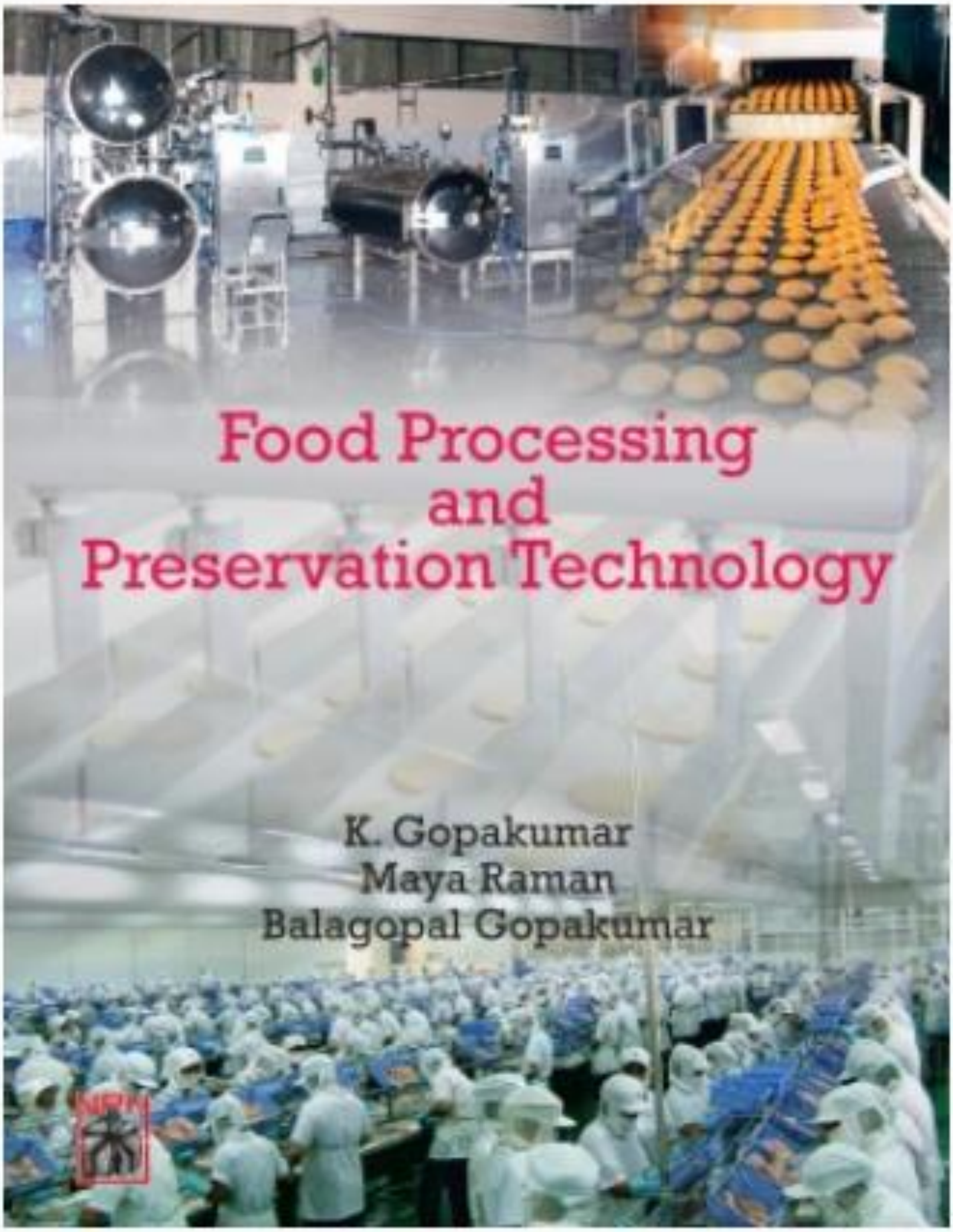
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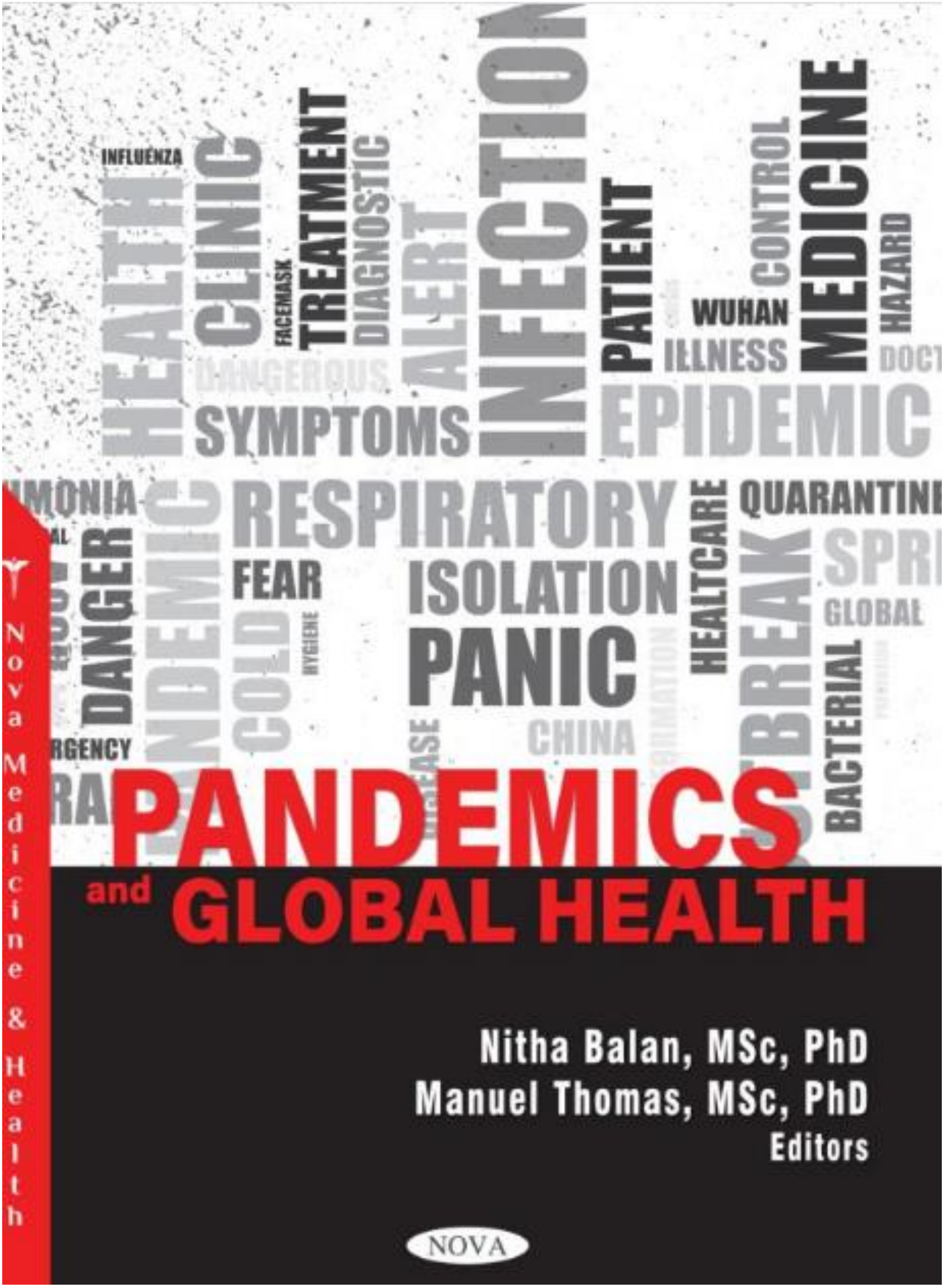
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Sourav Das
Tuhin Ghosh *Editors*

Estuarine Biogeochemical Dynamics of the East Coast of India

Springer

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Editors
Sourav Das
School of Oceanographic Studies
Jadavpur University
Kolkata, West Bengal, India

Tuhin Ghosh
School of Oceanographic Studies
Jadavpur University
Kolkata, West Bengal, India

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In the loving memory of

Late Prof. Ananda Deb Mukhopadhyay
(3 May 1938 – 8 October 2020)

Prof. Ananda Deb Mukhopadhyay was an eminent academician and a renowned researcher in multifarious fields of geology, oceanography, and environmental studies. He was a well-loved teacher with father-like character and guided a number of students in academia and their personal lives. His love and affection towards the student community is still cherished by many who came in touch with him. Being a professor in the Department of Geological Sciences at Jadavpur University, West Bengal, India, he founded the School of Oceanographic Studies. He has also served as the Vice Chancellor of Vidyasagar University, West Bengal, India. Till his last day, he was actively involved with the National Council of Education, India.

Preface

Estuaries, located at the interface between land and coastal oceans, are dynamic, highly productive systems that, in many cases, have been historically associated with the development of many of the great centers of early human civilization. Biogeochemistry of estuaries offers a comprehensive and interdisciplinary approach to understanding biogeochemical cycling in estuaries. Estuary and river systems play a critical role in the natural self-regulation of Earth's surface conditions by serving as a significant sink for anthropogenic CO_2. Approximately 90% of global carbon burial occurs in ocean margins, and the majority of this carbon remains buried in large delta-front estuaries. Many of the existing books in estuarine science comprise a suite of edited volumes, typically focused on specific topics in estuaries all over the world. However, the present book entitled *Estuarine Biogeochemical Dynamics of the East Coast of India* provides a unique foundation for the first time on the east coast of India. This book utilizes numerous illustrations and an extensive literature base to impart the current state-of-the-art knowledge in this field on the east coast of India adjacent to the Bay of Bengal. We collated chapters on geomorphology, carbon dynamics, bacterial population, estuarine pollution, and nutrient cycling of this region. The book also comprised the role of microbial diversity, microzooplankton variability in estuaries, CDOM dynamics of the east coast of India, and anthropogenic impacts of Indian Sundarbans (the largest mangrove forest in the world) with linkages to physical and biological processes in estuarine sciences. Consequentially, these systems have and continued to be severely impacted by anthropogenic inputs. This timely book can act as the foundational basis of elemental cycling in estuaries of the east coast of India and estuarine management issues. Estuarine and marine scientists, ecologists, biogeochemists, and environmentalists around India and other parts of the world would find interest in the present title. Intermediate to advanced level students can benefit by going through this book. This book presents both review and original study findings involving estuaries on the east coast of India. The future state of all of these estuaries may be a sensitive indicator of shifts in global weather patterns.

The book opens with an introductory chapter by the editors (Dr. Sourav Das and Prof. Tuhin Ghosh). Then, Mr. B. K. Saha (Former Senior Deputy Director-General, Geological Survey of India) presents a brief account of the geology of the east coast of India. Studies about the estuarine carbon dynamics along the east coast of India have seen tremendous growth over the past decade. Dr. Kunal Chakraborty (Scientist-E, INCOIS, Govt. of India) has reviewed these works in one of the chapters. A synthesis of previous research works on the biogeochemistry of the Mahanadi estuarine ecosystem is presented in one of the chapters by Dr. Tamoghna Acharyya (focusing on increased anthropogenic interferences). Dr. Abhra Chanda (Assistant Professor, School of Oceanographic Studies, Jadavpur University) has reviewed different pollution parameters along the east coast of India in three of the chapters (focusing on persistent organic pollutants, heavy metals, eutrophication, algal bloom, fecal coliform, organic matter, and petroleum hydrocarbon). Dr. Anirban Mukhopadhyay illustrated the variability of suspended particulate matter with the help of geo-statistical analysis. Dr. Rajdeep Roy (Scientist-E, National Remote Sensing Centre, India) has described the nutrient cycling, phytoplankton community structure, and seasonal dynamics of primary production of the estuarine waters of the east coast of India. Mercury-resistant marine bacterial population has been synthesized by Dr. Surajit Das. Dr. Biraja Kumar Sahu covered the microzooplankton studies carried out in estuaries, mangroves, and lagoons of the east coast of India. The book continues with a chapter by Dr. Sudarsanarao Pandi covering all the information and gap on CDOM-related researches carried out in estuaries and rivers draining into the Bay of Bengal. The book closes with an overview of the current understanding of biogeochemical dynamics and anthropogenic impacts on the Indian Sundarbans ecosystems by A. C. G. Henderson (Faculty, School of Geography, Politics & Sociology, Newcastle University, UK), Dr. S. Das, Prof. T. Ghosh, Dr. V. N. Panizzo, Dr. H. L. Moorhouse, Dr. L. R. Roberts, Dr. R. E. Walton, Dr. Y. Zheng, Dr. A. M. Bass, and Dr. S. McGowan.

Kolkata, India

Sourav Das
Tuhin Ghosh

Acknowledgments

We thank Dr. Rajdeep Roy, Dr. Sanjibakumar Baliar Singh, Dr. Tamoghna Acharyya, Dr. Anirban Akhand, and Dr. Abhra Chanda for their help in reviewing several chapters. We also thank Mr. Aaron Schiller, editor at Springer Nature, for his kind help and encouragement. We specially thank Dr. Andrew C. G. Henderson (School of Geography, Politics & Sociology, Newcastle University, UK) for his kind support and encouragement throughout this book project.

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Groundwater Resources Development and Planning in the Semi-Arid Region

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Editors
Chaitanya B. Pande
Sant Gadge Baba Amravati University
Amravati, Maharashtra, India

All India Coordinated Research Project
for Dryland Agriculture
Akola, Maharashtra, India

Kanak N. Moharir
Sant Gadge Baba Amravati University
Amravati, Maharashtra, India

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Dedicated to my parents and all my teachers

Preface

Semi-arid regions of the earth are today suffering from lack of sustainable water and groundwater. There is a growing demand throughout the world for sustainable watershed development, management, and planning. The demand is more significant in the rain-fed and drought-prone areas of earth surface, where watershed management is poorer and groundwater is limited. The primary focus of the book is the improvement of groundwater, aquifer mapping, soil and water conservation planning, suitable zones of groundwater development, flood mapping with surface runoff, trends of rainfall, land use impact on the groundwater, watershed development and planning, and water resource and environmental management. Conservation measures involve the preparation and implementation of various projects to improve the management of watershed functions that affect the plants, animals, and human communities within the watershed boundary. Rapid, accurate, and cost-effective latest technologies, Modflow software, machine learning, artificial intelligence, and geospatial technologies can be used for planning for groundwater development in the semi-arid region.

The book discusses on the groundwater related issues such as groundwater flow, watershed development, land use, rainfall, delineation of groundwater potential zones, soil and water conservation planning, and development of water and soil resources in the semi-arid region. The book highlights the recent application areas of groundwater flow modelling software, wavelets techniques, remote sensing, GIS, methods in rainfall trends, water conservation techniques in the field of watershed development, groundwater planning, changes of land use, monitoring and modelling of groundwater and aquifer mapping, hydrological modelling, and sustainable land management. This book has 26 chapters contributed by various researchers, scientists, and professors from various countries.

The book includes the research work of professors, planners, scientists, and research scholars from various universities, international organisation, and institutions from India as well as from other countries of the world, such as National

Institute of Hydrology, University of Bergen, Geophysical Institute, CIMA Research Foundation—International Centre on Environmental Monitoring, Helmholtz-Zentrum für Umweltforschung, Fiji National University, James Cook University, Australia, Bahir Dar University, University of Mumbai, Maulana Azad National Urdu University, Indian Institute Technology Roorkee, Indian Institute of Technology (BHU), Varanasi, École des mines d'Alès, avenue de Clavières, National Institute of Technology Raipur, Sathyabama Institute of Science and Technology, Bharathidasan University, All India Coordinated Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, M. Kumarasamy College of Engineering, Chemiqua Water & Wastewater Company Kraków, University of Naples Federico II, RWTH Aachen University, National Centre for Earth Science Studies, University of Kerala, The Gandhigram Rural Institute-Deemed to be University, University of Lucknow, Indian Institute of Remote Sensing, ISRO, and Asian Institute of Technology, Bangkok.

Amravati, Maharashtra, India Chaitanya Baliram Pande
Akola, Maharashtra, India Kanak N. Moharir

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About the Editors

Chaitanya B. Pande (Dr. PDKV, Akola) received his Ph.D. from Sant Gadge Baba Amravati University, Amravati. He has more than a decade of university, research, and industrial experience. Dr. Pande is a reviewer of *Earth Science Research Journal*, *American Journal of Geophysics, Geochemistry, and Geosystems*, *Sustainable Water Resources Management* (Springer journal), *Modeling Earth Systems and Environment* (Springer journal), *Applied Geomatics* (Springer journal), *Journal of Agriculture Sciences* (Bioinfo Publication), *Applied Water Science* (Springer), *Journal of the Institution of Engineers (India): series A* (Springer), *Groundwater Sustainable Development* (Elsevier journal), and *Environmental Sustainable Development* (Springer journal). He has published 40 research papers in international journals with Springer, Taylor and Francis, and Elsevier with citations more than 355. He has published one book with Springer. He has presented more than 20 research papers in national and international conferences. His research interests include remote sensing, GIS, watershed management, hydrogeology, hydrological modelling, land use and land cover analysis, groundwater quality, urban planning, hydro-geochemistry, groundwater modelling, geology, hyperspectral remote sensing, remote sensing and GIS application in natural resources management, watershed management, and environmental monitoring and assessment subjects.

Kanak N. Moharir works in the Department of Geology, Sant Gadge Baba Amravati University, Amravati, and is a Researcher in the Department of Geology at Amravati University, Amravati. With more than 6 years of teaching and research experience, she has published more than 37 research papers in various national and international journals and has presented 15 research papers in national and international conferences with citations more than 280. Her research interests include remote sensing, watershed management hydrology, land use and land cover, aquifer mapping, groundwater modelling, hydrogeology, geomorphology, and geology. She is a reviewer of eight springer journals and other journals.

ICT Tools for Knowledge Management and Control of Emerging Zoonoses and Animal Health Threats

Edited by
Dr. M K Narayanan
Dr. Shahaji Phand
Dr. Prejit
Dr. Jess Vergis
Dr. Asha K
Dr. Vidya P

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Kerala Veterinary and Animal Sciences University
Centre for One Health Education, Advocacy, Research and Training, (COHEART), Wayanad, Kerala
&
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COHEART, KVASU, Wayanand & MANAGE, Hyderabad

ICT Tools for Knowledge Management and Control of Emerging Zoonoses and Animal Health Threats

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MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

New and reemerging zoonoses have evolved throughout the last three decades partly as a consequence of the increasing interdependence of humans on animals and their products and our close association with companion animals. Zoonosis is the single most critical risk factor to human health and well-being, with regard to infectious diseases. The first, and the most significant step towards the management of outbreak of zoonotic diseases is forecasting the occurrence of outbreaks. There have been unprecedented advancements in use of technology during the pandemic. ICT tools gives significant credence to the importance of examining health effects across species, in order to fully understand the public health and economic impact of such diseases and to help implement treatment and preventive programs by veterinarians.

It is a pleasure to note that, SAU-Kerala Veterinary and Animal Sciences University, Centre for One Health Education, Advocacy, Research and Training, (COHEART), Wayanad, Kerala and MANAGE, Hyderabad, Telangana is organizing a collaborative training program on ICT Tools for Knowledge Management and Control of Emerging Zoonoses and Animal Health Threats from 20-23 September, 2021 and coming up with this joint publication as e-book as immediate outcome of the training program.

I wish the program be very purposeful and meaningful to the participants and also the e-book will be useful for stakeholders across the country. I extend my best wishes for success of the program and also I wish SAU-Kerala Veterinary and Animal Sciences University, Centre for One Health Education, Advocacy, Research and Training, (COHEART), Wayanad, Kerala many more glorious years in service of Indian livestock sector ultimately benefitting the farmers. I would like to compliment the efforts of Dr. Shahaji Phand, Center Head-EAAS, MANAGE and Dr. M. K. Narayanan, Director of Entrepreneurship, KVASU for this valuable publication.

Dr. P. Chandra Shekara
Director General, MANAGE

MESSAGE

Livestock sector contributes nearly one-fourth to the national GDP; still the animal health and productivity remains a major concern in the country. The existing lacunae in the animal husbandry sector such as inappropriate managemental practices, infectious as well as metabolic diseases, inadequate marketing infrastructure, and unorganised marketing could only be transformed into full productive potential meeting quality livestock support services by exploiting the use of ICT or web based tools and also by improving the knowledge provided to the Veterinarians as well as para-veterinarians. Zoonoses are yet another significant public health concern that cause considerable socioeconomic problems globally. A wealth of new technologies is becoming increasingly available for more accurate monitoring of zoonotic disease activity.

In changing times, ICT tools could provide effective media for spreading awareness about the latest scientific managemental practices among Veterinarians as well as para-vets with an intention to improve the production performance and health status of animals of the country. With the recent resurgence of COVID pandemic, the significance of ICT tools in various sectors including, animal husbandry has increased manifold. Hence, it is pertinent to note that the Directorate of Entrepreneurship and Centre for One Health Education Advocacy Research and Training (COHEART) of our university in collaboration with MANAGE, Hyderabad is organising a four-day training programme in online mode (Sept. 20-23). It gives me pleasure to note that the topic of training 'ICT Tools for Knowledge Management and Control of Emerging Zoonoses and Animal Health Threats' is relevant. As we grapple with the gigantic task to manage the COVID-19 pandemic, ICT tools will broaden the horizon for its control.

I understand that this training has been designed in such a way to provide ample exposure to the participants in assimilating the thematic concept of ICT tools in knowledge dissemination for the control of public health threats and applying this doctrine in their respective domains of expertise. It is of utmost importance to note that this deliberation envisages the participants to learn and discuss across disciplines beyond boundaries and in close association with the stake holders in capacity building and evolve suitable models for regional, national as well as global leadership.

Let me congratulate the dynamic team behind conceptualization of this training into reality. Without their commitment and contributions, this e- book would not been possible and successfully delivered at this time.

Once again, I wish the faculty and participants all the best.

With warm regards,

Prof. (Dr.) M.R. Saseendranath
Vice Chancellor, KVASU

MESSAGE

Animal welfare is human welfare too. It is all the most revealed in the current scenario of pandemic. In most of the infectious disease, we can observe an involvement of animals in its course of spread which mark the relevance of “One Health” approach. The health and veterinary sectors in the country has undergone considerable transformation during this pandemic. The major breakthrough is the introduction of Information technology and Artificial Intelligence based approaches to control Emerging Zoonoses and Animal Health Threats. Such tools can reduce the risk of Zoonoses becoming epidemics and pandemics, by understanding disease origins, their drivers and dynamics. An early warning or forecasting system communicates information about impending risk to vulnerable population before a hazard event occurs. Thus, ICT initiatives will be the futuristic requirements of the society, immensely helping in conceptualizing and strategizing control measures of zoonotic diseases.

It is of immense pleasure to organize the training on "ICT Tools for Knowledge Management and Control of Emerging Zoonoses and Animal Health Threats" in collaboration with National Institute of Agricultural Extension Management (MANAGE), Hyderabad. I would like to underline and reiterate the fact that a healthy nation could only be built by the healthy individuals and the animals and the surrounding environment. As we are in the era of global health crisis due to COVID-19 pandemic, the animal husbandry and allied sectors should take all the care and measures for controlling the emerging zoonoses and health threat in animals at large for which we will have to make best use of ICT tools. Also, technologies evolve rapidly as new tools become available, allowing for the development of more sophisticated surveillance methods and more accurate predictive models. To make it a reality One Health collaboration between institutions, scientists and public health networks involved in diseases surveillance is important in order to timely detect and respond to novel threats and pandemics.

I am pleased to note the joint publication of e-book as the outcome of the training program. I also hope, the deliberations held during the training would bring out the vital understanding on the use of ICT Tools for Control of Emerging Zoonoses and Animal Health Threats. I wish the training a grand success.

Prof. (Dr.) M. K. Narayanan
Director of Entrepreneurship, KVASU

PREFACE

This e-book is an outcome of collaborative online training program on "ICT Tools for Knowledge Management and Control of Emerging Zoonoses and Animal Health Threats". This is intended to sensitize the veterinarians and related health workers to learn about various ICT tools for Knowledge management and control of emerging zoonoses as well as other animal health threats, and also to practice and implement One Health approach, as back-up to the Global Health Security Agenda using technology driven approach. Furthermore, this e-book will update their knowledge regarding recent advances in technologies and innovations in the domain of zoonoses and animal health threats

Veterinary and Human health systems must continuously adapt and evolve to their contexts giving significance to latest technologies. ICT tools are such technologies that provide access to information through telecommunications, and includes networks, the Internet, wireless, mobile devices and other communications-related technology. The content of training programme was designed to provide updated information towards capacity building in proposed area. Attempt has been made to cover topics on Emerging Zoonoses and Animal health threats, Epidemiological Surveillance and Disease Modeling, tools such as National Animal Disease Referral Expert System and Integrated Health Information Platform. Focus was also on Artificial Intelligence driven approach for control of vector borne diseases, existing early warning system for the spread of emerging diseases and Application of Artificial Intelligence for animal health threats. The topics shall also cover GIS and Web based tools for Disaster risk mapping and innovative Participatory Disease Surveillance model that is successfully used in various countries. The applied aspects of the use of ICT tools for knowledge management of wild animal health as well as for Animal Husbandry are also covered.

Taken together, these experiences are enriched with technical insights and operational know-how. They provide practical evidence of actions that have proven imperative for improving services delivery.ICTs tools have the potential to transform the way in which the veterinary and health services are accessed and delivered. ICTs can provide information systems for reporting and research, and deliver healthcare services and advice to even the most remote locations.

The valuable suggestions for future improvements are always welcome.

September, 2021 **Editors**

CONTENTS

OVERVIEW OF EMERGING ZOONOSES AND EARLY WARNING SYSTEMS

Prejit, Officer-in-Charge,
Centre for One Health Education, Advocacy Research and Training
Kerala Veterinary and Animal Sciences University, Pookode, Wayanad- 673576

Introduction

Emerging and re-emerging zoonoses are a significant public health concern and cause considerable socio-economic problems globally. The COVID-19 pandemic has made us to realize that man do not have complete dominion over animals, nature or even minute organisms like virus. There are about 60 per cent of human infectious diseases that are zoonotic (Taylor *et. al*., 2001) and among the latest one (Emergng) 75% are zoonotic in nature. Emerging zoonoses are those which are newly identified and previously unknown, that cause public health problems either locally or internationally (eg: Avian Influenza, Ebola, Nipah, Zika, MERS COVID etc). Re-emerging zoonoses are those that have been known for some time, had fallen to such low levels that they were no longer considered public health problem and are now showing upward trends in incidence or prevalence worldwide (eg: Chikungunya, Japanese Encephalitis etc). The factors that make India a hotspot of zoonoses include its large area (32,87,263 sq. km, 2.4% of worlds surface area), coastal area of 7516.6km, border sharing with 7 countries , diversity of climate and physical conditions, great variety of fauna (over 92,037 species), whopping population of 135.26 crores (17.7% of world's population) and having agriculture in more than 58% of the population.

India has initiated One Health action strategies for control of emerging zoonoses such as Avian Influenza. Multi-sectoral approaches under a One Health (OH) umbrella are more expedient and effective, and lead to efficient utilization of limited resources (Heymann *et al*., 2014). Kerala has demonstrated One Health success stories for control of emerging zoonoses such as Kyasannur Forest Disease. As it is recognized that emerging infectious diseases occur at the interface of human, animal, and ecosystem health, the world now promotes a trans-sectoral approach to address infectious disease risk management. Emerging infectious diseases will continue to challenge health infrastructure, test credibility of health services, and threaten to devastate health and economic development unless a strategic vision and an effective plan of action are developed to combat these.

Emerging Zoonoses

Zoonoses are not something that is rare but it still remains one of the world's greatest threats to human and animal life, the environment, local communities and economies. A vast majority of the emerging and remerging infectious diseases have their origins in animals. Emerging zoonosescould be as a result of the globalization of trade, breakdown of public health measures, expanding human population, intensification of wildlife farming, change in land use (Japanese encephalitis, Lyme disease), agricultural industry, medical industry, food industry, International travel and commerce (SARS, MERS, COVID 19), disasters (plague, leptospirosis), climate and weather (West nile fever), human demography & behavior (KFD), bush meat consumption (Ebola). Early detection helps keep infection to its area of origin, which in our increasingly mobile world is vital in stopping life threatening diseases such as Zika, Ebola and Yellow Fever.

From age old Rabies to the recent COVID-19, the list of zoonoses keeps growing day by day. But the major hurdle in combating the zoonoses is the presence of animal reservoirs. In global scenario, there is a significant increase in the emergence of zoonotic diseases causing about 1 billion cases of illness and millions of deaths every year (Karesh *et al.*, 2012). In the last two decades, emerging diseases had direct costs of more than US$100 billion; if these outbreaks had become human pandemics, the losses would have amounted to several trillion dollars (World Bank, 2012). The greatest burden on human health and livelihoods is caused by endemic zoonoses that are persistent regional health problems around the world (ILRI, 2012). Given the high economic and societal cost of recent outbreaks (World Bank, 2012), policy decisions and investments can be oriented to create incentives for advancing a One Health approach aimed at preventing (and not just responding to) disease outbreaks.Globally, the top 13 zoonoses deemed most impactful to poor livestock keepers in developing countries are responsible for an estimated 2.7 million deaths and 2.4 billion cases of human illness each year (Grace *et al.*, 2012). The Livestock Revolution paradigm is leading to rapid increases in livestock populations in developing countries, which increases the likelihood of disease transmission (Pica-Ciamarra and Otte, 2011) with repeated outbreaks from meat, eggs, milk, and cheese, or meat by-products (Karesh*et al.*, 2012).

After the emergence of SARS in 2002 and MERS in 2012, COVID 19 was the third coronavirus resulting in a major global public health crisis. At the end of the SARS epidemic, there were more than 8,000 cases of the disease and 774 deaths, with a case-fatality rate of 7% (Anderson *et al.*, 2004). Following, MERS epidemic there were a total 2494 cases of disease and 858 deaths with 34.4% case-fatality rate (Al-Omari *et al.*, 2019). Currently

COVID 19 has become a serious global public health concern. In the current scenario, the SARS-CoV-2 has spread rapidly to various parts of the world (Yoo and Yoo, 2020). As COVID-19 spreads, there is a significant role for veterinarians under One Health framework to reduce the economic impacts on the livestock industry and food supply (Yoo and Yoo, 2020). Thus, the global impact of emerging and endemic zoonoses on both human and animal populations make their control and prevention a natural starting point for collaboration between human and animal health sectors (Rist*et al.*, 2014).

Early warning systems

The use of technology has been under constant expansion following pandemic. Early detection of diseases and infections at animal source will help us to understand the etiology, epidemiology and pathogenesis of them and will pave a way to prevent transmission of them into humans. The first, and the most significant step towards the management of outbreak of zoonotic diseases is forecasting the occurrence of outbreaks. Forecasting refers to the monitoring of specific risk factors that could lead to the occurrence, and subsequent spread of the disease. The early warning or forecasts can be considered as "alert signals" intended to increase epidemic preparedness of the public. It will save the time as well as resources during an emergency. Prevention and control of zoonoses is the best strategy one could adopt in a crisis situation. Apart from emerging viral zoonoses, there are several emerging food borne zoonoses such as enterohaemorrhagic *Escherichia coli* (*E coli* O157:H7) and silent pandemics like anti microbial resistance that are becoming a major concern now. The major components of early warning system involves; routine surveillance of the targeted disease and identification of its risk indicators, examination of feasibility of their monitoring using existing data sources or modeling the risk of disease based on historical surveillance and contemporary environmental data, forecasting future risk through the use of predictive models and continued epidemiological and environmental surveillance.

Epidemiologists use ‘predictive models’ as to analyse when and where the next occurrence may occur. The use of Geographical Information System (GIS) to study associations between environmental variables like temperature, humidity, vector density etc. using satellite mapping has been gaining acceptance as a disease forecasting tool. Initiatives, such as GLEWS (Global Early Warning and response System), a joint system developed by WHO, OIE and FAO, assists in prediction, prevention and control of zoonotic disease outbreak through field work, epidemiological analysis, and sharing of the acquired information. Disease-specific collaborations such as the network for animal influenza (OFFLU), are active between the three Organizations. These collaborations range beyond surveillance to incorporate joint response mechanisms as events demand. The Joint FAO/OIE Crisis Management Centre for Animal Health supports rapid response capacities to assist countries for animal diseases events (domestic, wildlife, terrestrial or aquatic), and has collaborated in outbreak responses with WHO and the Global Outbreak Alert and Response Network (GOARN). Similarly, a cross-sectoral 'One Health' approach is increasingly being adopted within and amongst countries to address these problems.

OIE-WAHIS (OIE World Animal Health Information System) is a unique comprehensive database through which information on the animal health situation worldwide is reported and disseminated throughout the world. OIE-WAHIS data reflects the information gathered by the Veterinary Services from OIE Members and non-Members Countries and Territories on OIE-listed diseases in domestic animals and wildlife, as well as on emerging diseases and zoonoses.

Existing Surveillance systems in India include, integrated Disease Surveillance Project (IDSP, Medical Sector), National Animal Disease Reporting System(NADRS) and National Animal Disease Referral Expert System (NADRES, Veterinary Sector), ICAR - NIVEDI (Epidemic diseases), ICAR – NIHSAD (Exotic diseases), Inter-sectorial collaboration on avian influenza: Joint Task Force & Joint Monitoring Group and also on zoonoses (National Standing Committee on Zoonoses).Decreasing interactions with wild animals lowers our exposure to diseases such as Kysannur Forest Disease which is endemic in karnataka and now in Kerala, Tamil nadu and Goa. Studies of the incidence and prevalence of such diseases are necessary in the endemic areas. If a disease is preventable by vaccination, it is better to vaccinate the susceptible populations. For diseases such as rabies, apart from vaccinating the pet animals, stray dog population control is a much needed strategy.

Conclusion

Prevention is a broad and continuous effort that requires people's participation and expert knowledge. The prerequisites for controlling emerging infectious disease includes availability of diagnostic assays for mass-scale testing of samples, generating baseline data about the disease, new and better vaccines, intensify border checking at entry points at borders, enforce strict quarantine measures. Furthermore, the use of ICT based system has great advantages such as Geographic Imaging Systems, IT tools monitoring disease dynamics, dashboards for surveillance and forecasting, risk mapping tools for knowing wild life sources for diseases.

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PARTICIPATORY ONE HEALTH DISEASE DETECTION (PODD) TOOL TO DETECT EMERGING ANIMAL AND ENVIRONMENTAL HEALTH THREATS: A THAILAND EXAMPLE MODEL

Terdsak Yano

Department of Food Animal Clinics, Faculty of Veterinary Medicine, Chiang Mai University

Introduction

The COVID-19 is the great example of pandemic which effect the global in several aspects, especially in economic. In tourism industry, COVID-19 causes a loss of more than $4 trillion to the global GDP during 2020 and 2021 (UNCTAD,2021). It has high potential of emerging disease occur and affect human, mostly possibly originating from animal. Animal-health surveillance provides an essential component of the evidence required to protect animal-health, facilitate trade, and ultimately protect public health, especially from zoonosis. Through early detection and informed response, surveillance reduces the impact of animal disease on animal production and welfare and on public health. Effective surveillance also ensures that confidence in the health status of animal moving between countries is maintained and ensures that trade barriers are justified. When trade is maintained, the impact of disease outbreaks on the economy is reduced, including: Severe Acute Respiratory Syndrome (SARS); Bovine Spongiform Encephalopathy (BSE); Foot-and-Mouth Disease (FMD); and Highly Pathogenic Avian Influenza (HPAI). The frequent movement of animals and their products around the world means that there is an increasing risk that infection will spread. Therefore, there is a need for exchange of comparable information about disease incidence and lead to protect population's health.

One Health approach is an effective concept that allow people monitor disease in animal and environment before spilling over to human (Stärk *et al.*, 2015). One health indicated the strong relationship of health among animal, human and environment. It plays an important role in global disease prevention with engaging multidiscipline to achieve better health. The people in community can be a part ofOne Health by participate the disease or abnormal health event reporting. The community also can responses those reports in advance before the authority takes any action.

Since the digital technology has been exploded, people increase the usage of mobile phone and internet. It has been introduced disease surveillance system and allow people to participate by reporting via their mobile or computer. The US Flu Near You system having previously demonstrated how participatory reporting using digital tools can help detect influenza outbreaks in human populations faster than traditional surveillance (*Smolinski et al.*, 2015)

PODD system

PODD system or "Participatory One-health Digital Disease Detection" system has been developed, which integrated One-health into disease surveillance activities in community level. The aim of PODD system is to early detect and response the animal health, human health and environmental problems in communities by the collaborative efforts of authorities, Local governments (LGs) and people in communities. There are 3 key elements, LG, volunteers and digital system, that are the structure of PODD system (figure 1). Volunteer reporters, who are members of the communities, report abnormal events in their communities through application on smartphone, called "PODD", then an automated system verify the reported and notify all stakeholder (i.e., researchers, provincial and district DLD officers, provincial and district public health officers and LG staff). LGs are the front-line teams of problem response and be supported by authorities, either district or provincial level.

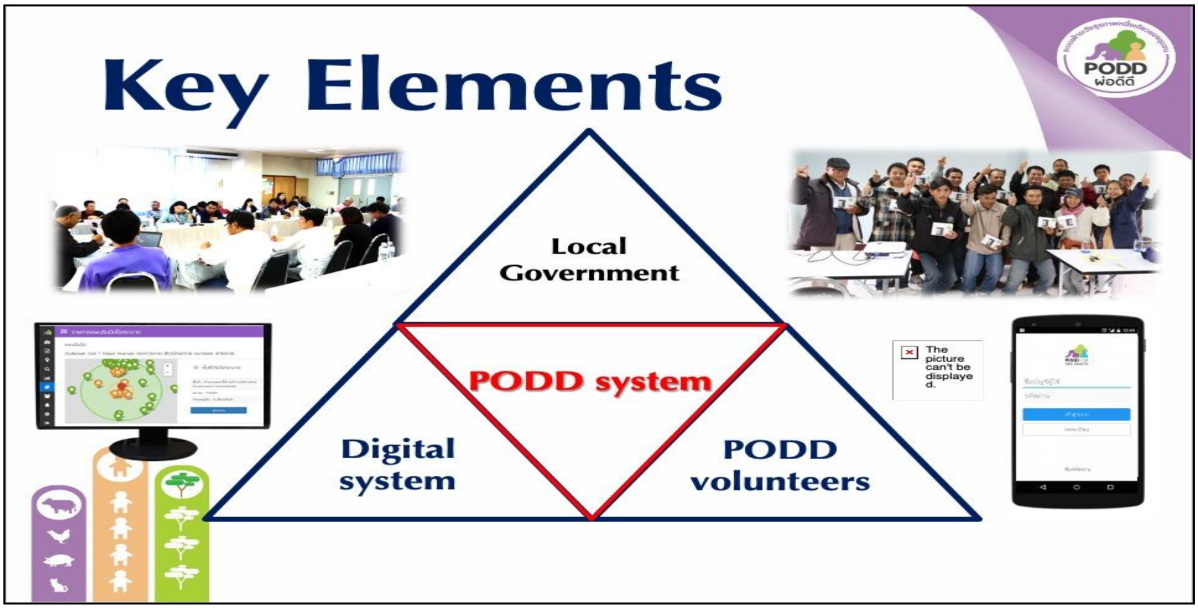

Figure 1 The key elements of PODD system, consist of Local government (LG), PODD volunteers and digital technology.

The primary objective of PODD in pilot phase was to detect abnormal deaths in backyard animal in order to elicit rapid investigation and response. Abnormal numbers or types of death can be a signal of zoonotic diseases which transmits to human and causes pandemic as a subsequence, such as abnormal death in poultry could be an early clinical sign of highly pathogenic avian influenza (HPAI), a potential precursor of an AI pandemic in humans. Use of smart phones and digital technology is one of the key factors making the PODD system workable. The daily reports of poultry health and abnormal poultry death are automatically captured, filtered with predefined case and outbreak definitions, and projected onto a GIS mapping system. The real time analysis of incoming reports allows rapid detection of outbreaks and the generation of automatic SMS warning messages to activate community contingency plans. A disease investigation team is dispatched to confirm the outbreak by clinical examination and, as necessary, laboratory confirmation. The system follows up automatically until 3 weeks after the last report of sick animals or death in the affected area. All stakeholders are notified after complete recovery to normal (figure 2)

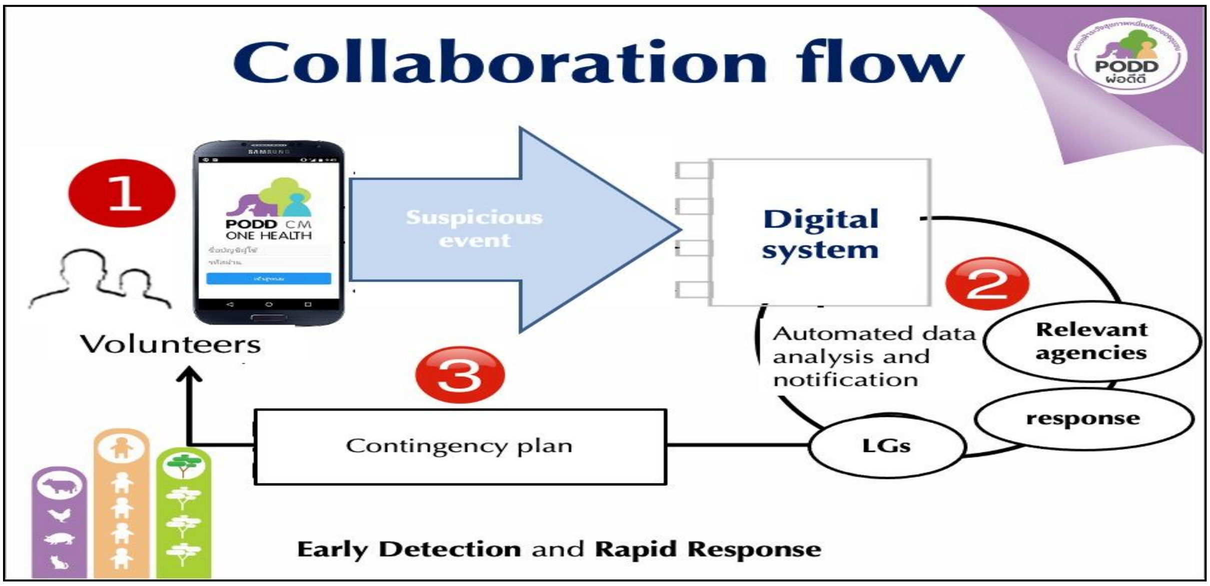

Figure 2 The workflow of PODD system for abnormal health surveillance, which aim to early detect and rapid respond.

Not only animal disease, but human health and environmental health have been added in PODD mobile application. Dengue and zoonosis in human, animal bite which has potential to be rabies, food safety issue, annoyance issues in community and disaster have been expanded the range of reporting. The PODD volunteers can report cover animal, human and environmental health through PODD mobile application (Yano et al., 2018).

The success

The PODD system has been developed and preliminary implemented in 75 LGs in Chiang Mai, Thailand, in early 2015. The community at sub-district level has been engaged to develop and own the system. After two years of implementation, the PODD system has been extended to other provinces throughout Thailand. From January 2015 to August 2021, total of 378,010 reports were sent to PODD system. Those reported included zero report and abnormal event reports. Currently, PODD system has been used in 30 provinces, within 201

LGs, together with the support of 838 active community reporters who uses PODD mobile application.

The PODD system empowered community to prevent, detect and respond disease outbreak, either human and animal, through the One-Health Operation Center and the support from PODD system. In January 2017, NongKhwai and Ban Pae LGs controlled disease outbreak in their area by the operation of the One-Health Operation Center. After PODD volunteer reported an abnormal death in chicken and owner showed flu-like symptoms, the notification was sent to LGs, district livestock and public health officers. The center activated the operation and staffs from LGs were indicated to work in the affected area and the outbreak could be controlled within a week. From August 2016 until March 2017, 38 from 68 One-Health Operation Centers have started their activity and 4 outbreaks can be controlled by the center.

Next step

The PODD research project has been transformed to be the "PODD center" in 2020. The center aims to promote and engage LGs throughout Thailand to use PODD system in their community. The PODD system added more features to reach LG's requirement, such as bedridden patients, accidental risk area or road, larva counting for Dengue prevention, COVID-19 monitoring, etc. For COVID-19 monitoring, the PODD system has been applied to monitor COVID-19 in selected communities since late 2020. The community volunteers report the strangers or people, who is not community member, come into the community, especially the people who do not notify the community headman. In the near future, the tons of data is coming to the PODD center and it will be the asset for the center. The data management and manipulation will be performed to create an impact information for the health society.

Conclusion

The community participatory combine with digital technology can be integrated with One Health approach for early disease detection and rapid response. It also empowers community to encounter the pandemic and establish the collaboration between community and authority to control disease outbreak. These practices can help the global to fight the new diseases in the future.

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INFORMATION NETWORK FOR ANIMAL PRODUCTIVITY & HEALTH

***e-resource provided by*: S. K. Rana**

National Dairy Development Board

In today's ever-changing world, the way you disseminate information assumes great significance. We must provide the right people with right information at the right time. Keeping this in view, an advanced information network has been created that can be easily accessed by all key stakeholders. This technology-driven user-friendly information network would provide reliable and timely information to enable better decision-making for improving productivity. At the heart of such a system is the unique identity assigned to each animal.

Developed and implemented by NDDB, the Information Network for Animal Productivity and Health (INAPH) would support the delivery of animal identification, breeding, nutrition, extension and health services at the doorstep of farmers. The system has multi-lingual capability and is based on best practices and Standard Operating Procedures (SOPs) recommended by domain experts.

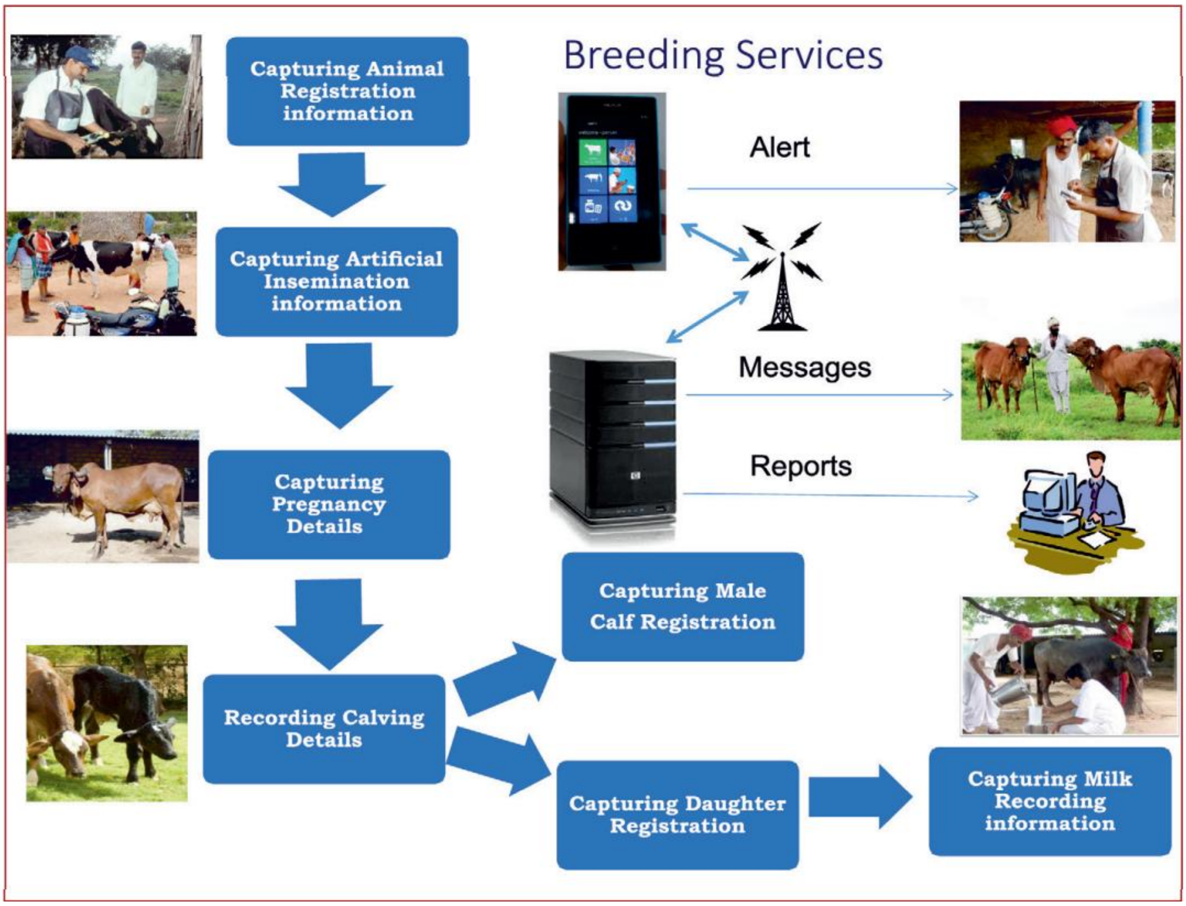
Ear-tagging with a unique 12 digit number is mandatory for each animal registered in the network which enables tracking and monitoring of these animals. NDDB administers and centrally manages the animal identification system in the country.

Animal Breeding

INAPH captures data related to animal registration, artificial insemination (AI), pregnancy diagnosis, calving, milk recording, milk sample collection for component analysis, typing, body measurement for growth rate monitoring and animal movement.

Data captured is processed for use in field activities under Progeny Testing and Pedigree Selection programmes. Operational, review and analytical reports, alerts and SMS messages are generated and forwarded to all concerned.

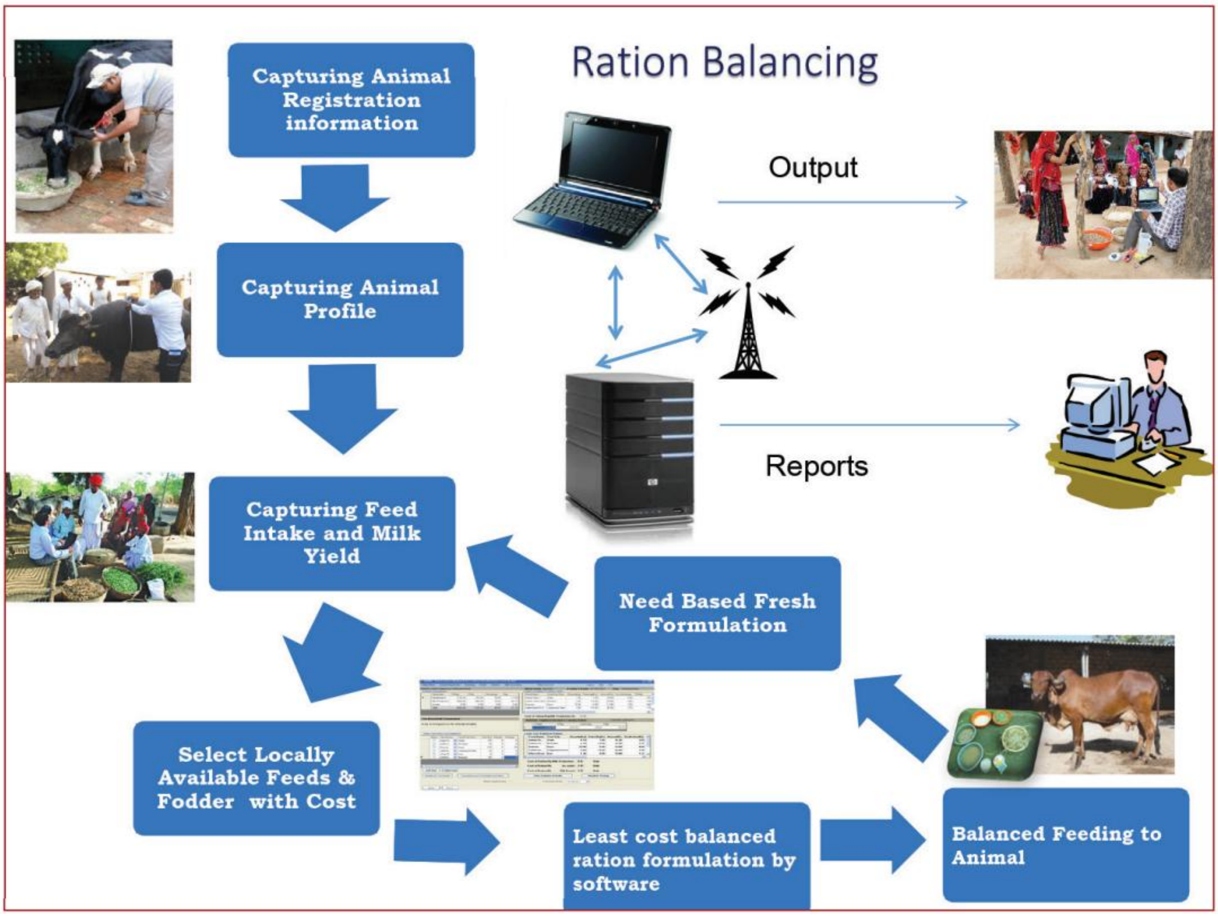
INAPH helps in monitoring AI delivery system to assess and improve conception rate, minimise inter-calving period. It also helps to evaluate breeding values of bulls as well as identification of elite animals.



Animal Nutrition

INAPH supports the Ration Balancing Programme (RBP). It has a data library on chemical composition of commonly available feed resources in India and the nutrient requirements based on body weight, milk yield/milk fat, pregnancy status etc. Based on the feeding practices, prevailing nutrient status can be seen. As per the availability of feed resources and area specific mineral mixture, a least cost ration is worked out, which is then given to the milk producers in local language, in a format easy to understand.

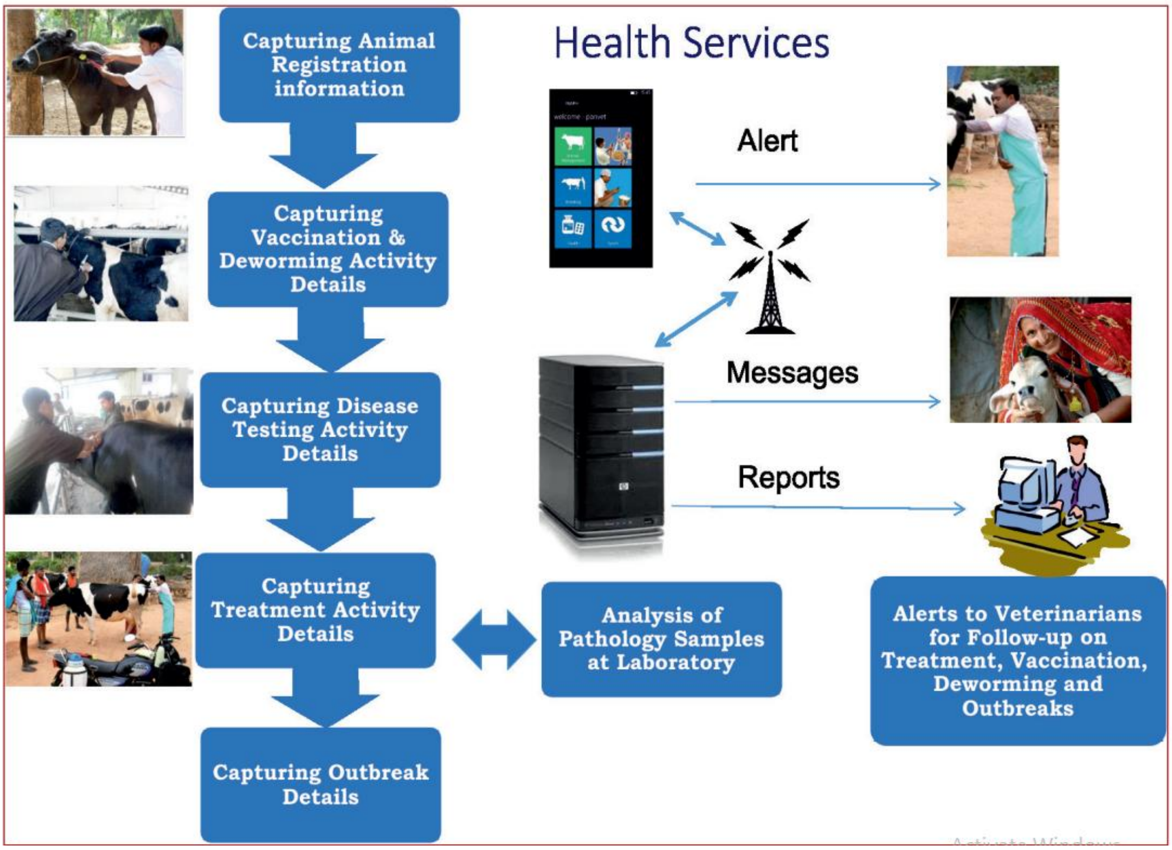
Balanced ration advisory services through INAPH based on data of one and a half lakh cows/buffaloes resulted in increase in net daily income of milk producers between ` 15-35 per animal, by enhancing daily milk yield/milk fat and/or reduction in cost of feeding per litre of milk.



Animal Health

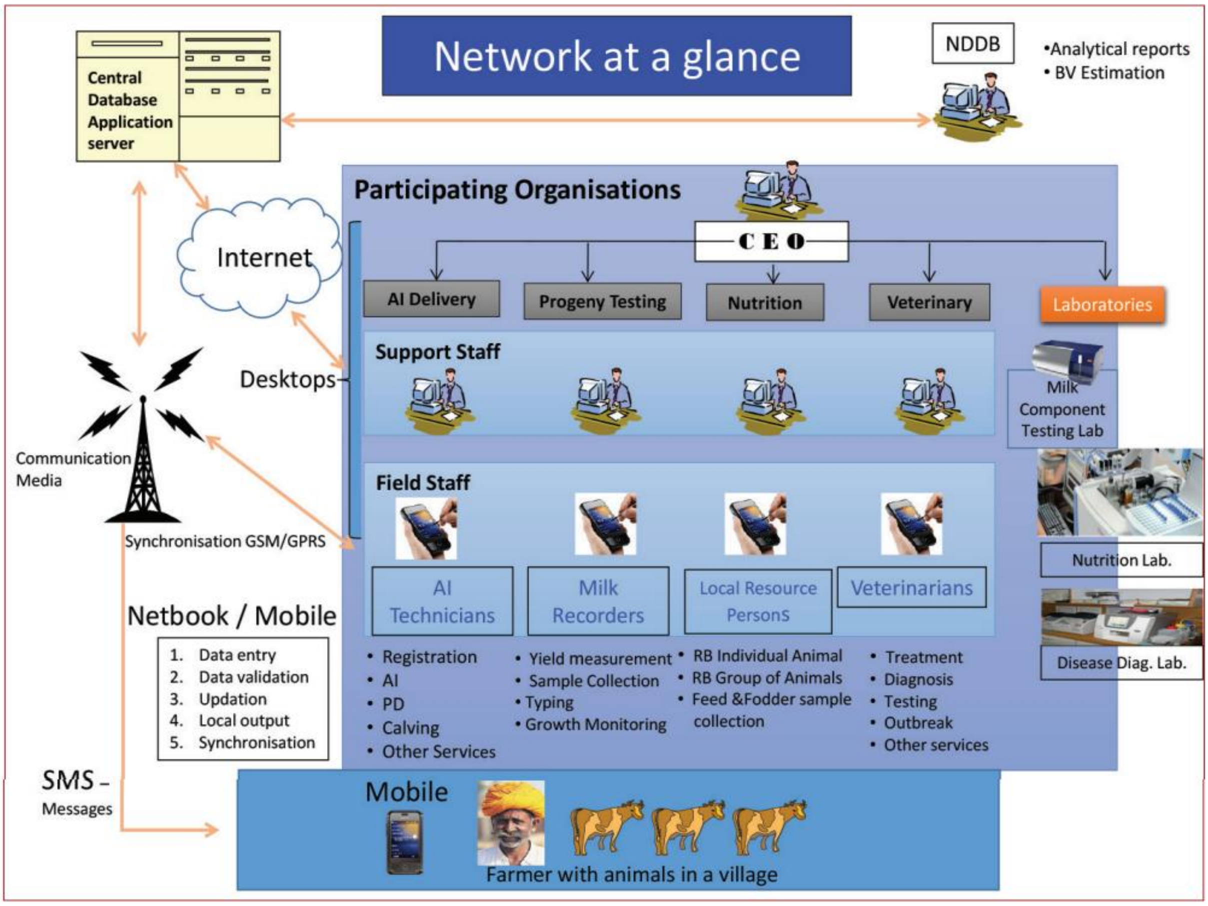
The Animal Health module of INAPH is designed to capture health related data of animals such as vaccinations, de-worming, disease testing, treatment, outbreak management and fertility camps. The complete health profile of each animal is being maintained by the system, enabling better health management and treatment. Data can also be captured at the village level on most health related interventions

INAPH is currently providing support to over 220 lakh animals belonging to around 127 lakh farmers in more than 1.70 lakh villages spread across 29 states. The system is being used by over 1.19 lakh field users in the country.



System Architecture & Deployment

The system is designed to meet the various information needs of farmers, field technicians, End Implementation Agencies (EIAs) such as Milk Unions/Federations, Producer Companies, analysts and policy makers. The application can be operated through computers/netbooks as well as hand-held devices (Android phone & tablets) with internet connectivity. Data collected in the field is stored in the central database at NDDB, Anand. In the absence of network connection (offline mode), there is a provision for data to be captured and stored for later synchronisation with the central server through the GPRS network.



INAPH is equipped to send messages to farmers, providing appropriate advice regarding their animals, when required. Web based reports are available to the managerial team and other decision makers for analysis.

Benefits

- Unique identification of animal along with the pedigree facts, lactation yields and owner details
- Record keeping of all activities related to Breeding, Nutrition & Health
- Identification of superior bull & elite female
- Tracking disease outbreak & disease pattern for different species/breed/village/district
- Healthier/productive animals increase earning of farmers
- Assess the efficiency & effectiveness of AI services & Ration Balancing Advisory Services
- Monitor and follow up genetic improvement and Ration Balancing Programmes

INAPH helps in monitoring AI delivery system to assess and improve conception rate, minimise inter-calving period. It also helps to evaluate breeding values of bulls as well as identification of elite animals.

RESISTANCEMAP: AN ICT BASED TOOL FOR GLOBAL DATA ON ANTIMICROBIAL USE AND RESISTANCE

Geetanjali Kapoor

Research Fellow, The Center for Disease Dynamics Economics & Policy

About ResistanceMap

Resistance Map (ResMap) is a web-based collection of data visualization tools that allows interactive exploration of antimicrobial resistance (AMR) and antibiotic use trends in countries across the globe, now including several low- and middle-income countries (LMICs). CDDEP first developed ResistanceMap in 2010 to display national and some subnational AMR data for the United States, Canada and over 30 European countries for the year 2009, as well as antibiotic use data for United States from 2000 to 2009.

In the current iteration, which is supported by a new grant from the Bill & Melinda Gates Foundation, CDDEP has expanded ResistanceMap to include more up-to-date AMR data from invasive isolates only (blood and cerebrospinal fluid) from the countries included in the previous iteration of ResistanceMap, as well as additional countries including South Africa, India, Thailand, Vietnam, Kenya, Argentina, Chile, Equador, Mexico, Venezuela, Australia, and New Zealand. Where available, data are displayed at the national, subnational or regional level. The primary sources of data are public and private laboratory networks that routinely collect AMR test results.

In addition to updated and expanded AMR data, this iteration of ResistanceMap also includes antibiotic consumption data from 75 countries from years 2000 to 2014 obtained from IQVIA's MIDAS and Xponent databases. Moreover, this iteration includes an update to the web tool itself, so that non-technical users can more easily explore trends in antibiotic use and resistance around the world.

Antimicrobial Resistance Data

Resistance data from 46 countries are represented in ResMap. AMR data are available from 1999 to 2017, depending on the country.

Twelve organisms are included - *Acinetobacter baumannii, Entero bacteraerogenes/ cloacae, Enterococcus faecalis/ faecium, Escherichia coli, Klebsiella pneumoniae , Pseudomonas aeruginosa, Salmonella Typhi/ Paratyphi, Staphylococcus aureus and Streptococcus pneumoniae.* Details of AMR data and methods for calculating resistance proportions are described in the methodology section.

Antibiotic Consumption Data

Antibiotic consumption data from 76 countries are represented. Antibiotic consumption data are available from 2000 to 2015. Sub-national antibiotic consumption data are available only for the United States through 2017. Data sources are IQVIA XPonent and IQVIA MIDAS databases.

Seventeen antibiotic classes are included: aminoglycosides, broad-spectrum penicillins, carbapenems, cephalosporins, chloramphenicols, glycopeptides, glycylcyclines, lipopeptides, macrolides, monobactams, narrow-spectrum penicillins, oxazolidinones, phosphonics, polymixins, quinolones, tetracyclines, and trimethoprim combinations.

Details of antibiotic use data and methods for calculating antibiotic consumption are described in the methodology section.

Citing Resistance Map

Please cite data or figures from ResistanceMap in the following style:

The Center for Disease Dynamics Economics & Policy. ResistanceMap: [Page Name]. 2018. [URL]. Date accessed: [Date].

Methodology

1) Antibiotic Resistance

ResistanceMap (ResMap) aggregates data on antibiotic resistance from several sources. The data have been harmonized to present similar definitions of resistance across countries and regions to enable comparisons between countries. However, comparing resistance rates between countries should be undertaken with some caution as the breadth of testing varies between countries.

The following sections describe the source of the data, the bacterial species included, and the pathogen-antibiotic combinations used to determine resistance rates.

Sources: The underlying data are obtained from multiple sources in one of two formats: (1) microbiology and test data at isolate level; (2) aggregated data listing at a minimum, the number or percentage of isolates resistant and the number of isolates tested. The following table details the source of data for each country.

Bacterial species: Depending on the country, resistance data is currently available for all or some of the following bacterial species:

- *Acinetobacter baumannii*
- *Enterobacteraerogenes/cloacae*
- *Enterococcus faecalis*

- *Enterococcus faecium*
- *Escherichia coli*
- *Klebsiellapneumoniae*
- *Pseudomonas aeruginosa*
- *Salmonella paratyphi*
- *Salmonella typhi*
- *Staphylococcus aureus*
- *Streptococcus pneumoniae*

Isolates were classified as susceptible (S), intermediate (I), or resistant (R). Clinical and Laboratory Standards Institute (CLSI) or European Committee on Antimicrobial Susceptibility Testing (EUCAST) breakpoints were used for antimicrobial susceptibility testing in the laboratories contributing the data. For example, laboratories in the United States use CLSI guidelines, while European countries use EUCAST guidelines.

The data presented on ResistanceMap include only invasive isolates obtained from blood, cerebrospinal fluid or both. In addition, all non-susceptible isolates (I+R) are classified as resistant and the data is presented for a pathogen only when 30 or more isolates were tested against an antibiotic. Some countries do not have data for every pathogen-antibiotic combination listed, and for certain combinations, only a few countries have data. For instance, India is currently the only country with Salmonella data available.

For each data point we calculated the 95% confidence interval using the Wilson score method for binomial data.

Pathogen-antibiotic combinations: Antibiotics are classified into several groups as needed to compensate for the lack of susceptibility data on every antibiotic and to facilitate examination of resistance based on clinical relevance. Antibiotic groups are often classes of antibiotics, but not always. Resistance to an antibiotic group was defined as non-susceptibility to at least one antimicrobial agent in that group, though not all isolates were tested against every antibiotic in a group. The pathogens and the groupings of antibiotic agents against which they are tested can be obtained from methodology on antibiotic resistance.

2) Antibiotic use

Sources: Data on antibiotic use for all countries currently included comes from the IQVIA MIDAS database. This database estimates antibiotic consumption from the volume of antibiotics sold in retail and hospital pharmacies based on national sample surveys done by pharmaceutical sales distribution channels (i.e. from manufacturer to wholesaler to retailer). In each sector, data are collected regularly to estimate direct sales from antibiotic drug manufacturers and indirect sales from wholesalers. The sales estimates from this sample are projected with use of an algorithm developed by IQVIA to approximate total volumes for sales and consumption. The algorithm uses regional, sectorial-specific, and distribution-channel-specific factors to project national estimates of antibiotic consumption. However, precise details of the algorithm are withheld for proprietary reasons.

Data on antibiotic sales in standard units (SUs) and kilograms were obtained from the IQVIA MIDAS database. SU is an IQVIA designation that represents a single dose unit such as a pill, capsule, or equal amount of liquid. Sales expressed in kilograms were converted into defined daily doses (DDDs) using the Anatomical Therapeutic Chemical Classification System (ATC/DDD, 2016) developed by the WHO Collaborating Centre for Drug Statistics Methodology. For molecules not included in the ATC/DDD index, DDD values were estimated from other sources or as the average of DDD unit values by class. DDD unit values were provided in the ATC/DDD index for 199 of the molecules in the IQVIA MIDAS database. When possible, DDD unit values not available through the ATC/DDD index were estimated from other sources. Data in SUs were available for all years, whereas kilogram data were available only for the period 2005-2015. The ratio of SUs to kilograms for 2005-2015 was used to estimate kilograms and DDDs for 2000 to 2004. Countries' annual antibiotic consumption rate in DDDs per 1,000 inhabitants was calculated using population estimates from the World Bank DataBank. In countries where hospital and retail data were both reported for some but not all years (2000-2015), consumption in the missing sector was estimated by interpolation, using the ratio of antibiotic consumption in the hospital and retail sectors for the years data had been reported. Data collection procedures imposed additional limitations for a few countries that could not be (completely) accounted for. For example, some countries had sales data reported for only hospital or retail sectors, and in some cases, certain types of antibiotic sales—such as those in supermarkets or through government channels—were not included.

To allow for a meaningful comparison across countries, standard units/DDDs per 1,000 population was calculated by dividing the reported number of standard units/DDDs by population estimates from the World Bank. Taiwan’s population size data was not available in the World Bank’s database, so the values from Penn World Table 7.1 were used. Antibiotic use data was available only at a grouped regional level for some countries. For the two regional groupings—Central America and French West Africa—that had such data, we pooled the population estimates for the constituent countries to generate standard units/DDDs per 1,000 population.

For the United States, additional data was available at a subnational level. This data comes from IQVIA's Xponent database. The Xponent database contains data on dispensed drug prescriptions collected from retail pharmacies (chain, mass merchandisers, independent pharmacies, and food stores) in the United States. The database covers more than 70% of all prescriptions filled in the United States, and records are then weighted to project 100% of total prescriptions dispensed. Precise details of the weighting algorithm are withheld for proprietary reasons. These data are available at the zip code level and have been aggregated into state-level values. Data were then divided by state population estimates from the US Census to give the number of prescriptions per 1,000 people.

Antibiotics: All the antibiotic products listed in MIDAS and Xponent databases constituted 90 different antibiotic molecule types. These generic antibiotics have been further combined into 18 different classes for comparisons across countries. The distribution of antibiotics into classes can be obtained from methodology on antibiotic use.

3) Drug Resistance Index

The Drug Resistance Index (DRI) is a composite measure that combines the ability of antibiotics to treat infections with the extent of their use in clinical practice. Described by Science Magazine as a Dow Jones for Drug Resistance, the DRI provides an aggregate trend measure of the effectiveness of available drugs, akin to the way composite economic indices are used to track movement in consumer prices and stock market values. DRI was developed by CDDEP researchers led by Professor RamananLaxminarayan.

The DRI can be calculated at the country, region, state, or even hospital level. Country-level DRI estimates were recently published in BMJ Global Health for a subset of countries for a single year to demonstrate the power of the DRI to communicate problems with resistance. Here we present that data, plus additional countries and years for which we have gathered enough data to calculate a composite DRI. The results underscore the urgent challenges facing the globe as DRI values are high (meaning poorer efficacy of antibiotics) in many countries, particularly many low- and middle-income countries. In the highly connected world in which we live, the disparity in efficacy is a threat to global public health as resistant pathogens can rapidly spread between countries. The DRI can also be applied to national and regional data.

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INTEGRATED HEALTH INFORMATION PLATFORM (IHIP) FOR COMMUNICABLE DISEASE SURVEILLANCE

SnehaNaik

State Data Manager, IDSP

Integrated Health Information Portal (IHIP) is designed and developed by WHO at the request of MoHFW in order to have a holistic picture of data reported under different National Health Programmes with "One-Health Approach" on a common platform. It is a web-enabled, near real time electronic health information system that is embedded with all applicable Government of India's e-governance standards, Information Technology (IT), data & meta data standards to provide state-of-the-art single operating picture with geospatial information for obtaining village wise and case-based disease surveillance data in real time mode & managing disease outbreaks in the Country.

The Integrated Disease Surveillance Programme (IDSP) is a nationwide disease surveillance system in India incorporating both the state and central governments aimed at early detection and long-term monitoring of diseases for enabling efficient policy decisions. It was started in 2004 with the assistance of the World Bank. A central surveillance unit has been set up at the National Centre for Disease Control in Delhi. All states, union territories, and district headquarters of India have established surveillance units. Weekly data is submitted from all the peripheral units.

Data from medical colleges, health centres, hospitals, labs, etc. is being utilized for the purpose of tracking and reporting of diseases.The data is being collected on 'S' syndromic; 'P' presumptive; & 'L' laboratory formats using standard case definitions.

Under IDSP data is collected on epidemic prone diseases on a weekly basis (Monday–Sunday) and entered on the IDSP weekly portal. Whenever there is a rising trend of illnesses in any area, it is investigated by the Rapid Response Teams (RRT) to diagnose and control the outbreak.

Currently, IHIP portal is used for online reporting under Integrated Disease Surveillance Programme (IDSP) according to real time bases through peripheral units from different logins.

DISEASE MODELLING AND FORECASTING RISK OF LIVESTOCK DISEASES IN INDIA

(With reference to NADRES $_{V2}$)

K. P Suresh, D. Hemadri and S.S Patil

ICAR-National Institute of Veterinary Epidemiology & Disease Informatics

Bengaluru-560064

Livestock disease Forecasting system is an important component of livestock disease risk management strategies under livestock disease surveillance program. This minimizes the morbidity and mortality of animals and subsequently helps in building efficient production system. India is endowed with vast livestock resources of 535.78 million livestock heads includes 192.49 million cattle population of which 50.42 million are exotic/Crossbreed, 109.85 million buffaloes, 74.26 million sheep, 148.88 million goats, 9.06 million pigs, 4.4 lakhs of Mithun& yaks etc., (20th Livestock Census of India, Department of Animal Husbandry & Dairying (DAHD)under the ministry of Fisheries, Animal husbandry & Dairying, Govt of India) with increased production of milk at 187.75 million tonnes by increase of 6.5% over previous year and per capita availability of milk stood at 394.gms/day(2018-19) compared to previous year 375 grams/day. The main purpose of forecasting system is to assess the risk of disease in given area and issue warnings. Forecasting systems for livestock diseases in India comprises four inter-related elements. 1. Assessment and knowledge of livestock disease risks in the area, 2. Local hazard monitoring and warning service, 3. Disease risk dissemination and communication service and 4. Community response capabilities. This type of multifunctional system improves the community preparedness & awareness for risk of livestock disease occurrence, in terms of both warnings and increased understanding of risks associated and response of policy makers, veterinarians and farmers.

Epidemiological surveillance systems that are ongoing and systematic, that use standardized routines for quality assurance, and that provide for analysis and timely dissemination of of information are critical for Expert system. Human activities are generating wave of change in the natural environment, while new technologies and globalization continue to alter economic and social patterns across the planet. It is known that global climate change and degradation of air, land and water in many areas are capable of endangering animal health. In light of this, it is to examine the potential of these changes to exacerbate the spread of infectious diseases. Systematic climatic and non-climatic observations are an important component of any forecasting system.

Ecological observations and climate forecasts can potentially be used in efforts to predict the appearance of a pathogen and thus allow opportunities to minimize its transmission. This approach is likely to have a much lower predictive value, however, given the uncertainties associated with most climate/disease relationships and the confounding influences of other factors. It is highly unlikely that precise predictions of an epidemic could be made solely on the basis of climate forecasts and environmental observations. Yet, this information can feasibly be used as the basis for issuing an alert (or a "watch") that environmental conditions are conducive to disease outbreak, which in turn can trigger intensive surveillance efforts for the area in question. If surveillance data is available, then one can confirm the presence of the pathogen or an increase in its abundance subsequent warnings could be issued as needed,

An early warning system or forecasting system is an instrument for communicating information about impending risk to vulnerable population before a hazard event occurs, thereby enabling actions to be taken to mitigate potential harm, and sometimes, providing an opportunity to prevent the hazardous event from occurring. Early warning systems are routinely used for hazardous natural events such as hurricanes and volcano eruptions. In contrast, to date very little attention has been paid to the development of such systems for infectious disease epidemics in livestock. The goal of a disease early warning system would be to provide veterinary health officials and the farmers with as much advance notice as possible about the likelihood of a disease outbreak in a particular location, thus widening the range of feasible response options.

Machine Learning (ML) models has background concept which requires fewer assumptions and coherent statistical methods for dealing with overlaps between presence and background points. ML models are numerical tools that combine observations of species occurrence or abundance, it will be used to correlate disease outbreaks with environmental variability. The models will be evaluated using discrimination capacity in which the power of the model is the discrimination of epi units or geo-spaces of outbreaks and no-outbreaks. The reliability of ML models refers to the capability of predicted probabilities to reflect the observed proportion of locations where disease events are measured.

Finally, risk communication used to be viewed primarily as the dissemination of information to the public about health **risks** and events, such as outbreaks of **disease** and instructions on how to change behaviour to mitigate those **risks**. Risk communication has been identified as a core competence for guiding public health responses to infectious disease threats. It is a call to build capacity and a comprehensive understanding of health risks before a veterinary health emergency to allow systematic and coherent communication, response and management. Research studies indicate that while outbreak and crisis communication concepts and tools have long been on the agenda of veterinary health officials, there is still a need to clarify and integrate risk communication concepts into more standardised practices and improve risk communication and health, particularly among disadvantaged populations.

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DISASTER RISK MAPPING USING GEOSPATIAL TECHNOLOGY

Girish Gopinath

Associate Professor (Remote Sensing & GIS)

Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi

Principal Scientist (On lien), CWRDM, Kozhikode

1. Introduction

Geospatial Technology is a blend of computer hardware and software designed to capture, store, display and analyses geographic (Chaudhary, N., 2014). The capturing of geographic data often relies on remote sensing and global positioning technology. Remote sensing is a common term used for data acquisition from platforms such as aircraft or satellites, that provide a bird's eye view Remote sensing (RS) is the observation of an object, surface or phenomenon through the use of a variety of recording devices that are wireless, or not in physical or intimate contact with the object. An aircraft, spacecraft, satellite or ship may be used for this purpose and equipped with recording devices such as camera, laser, radar, sonar etc.

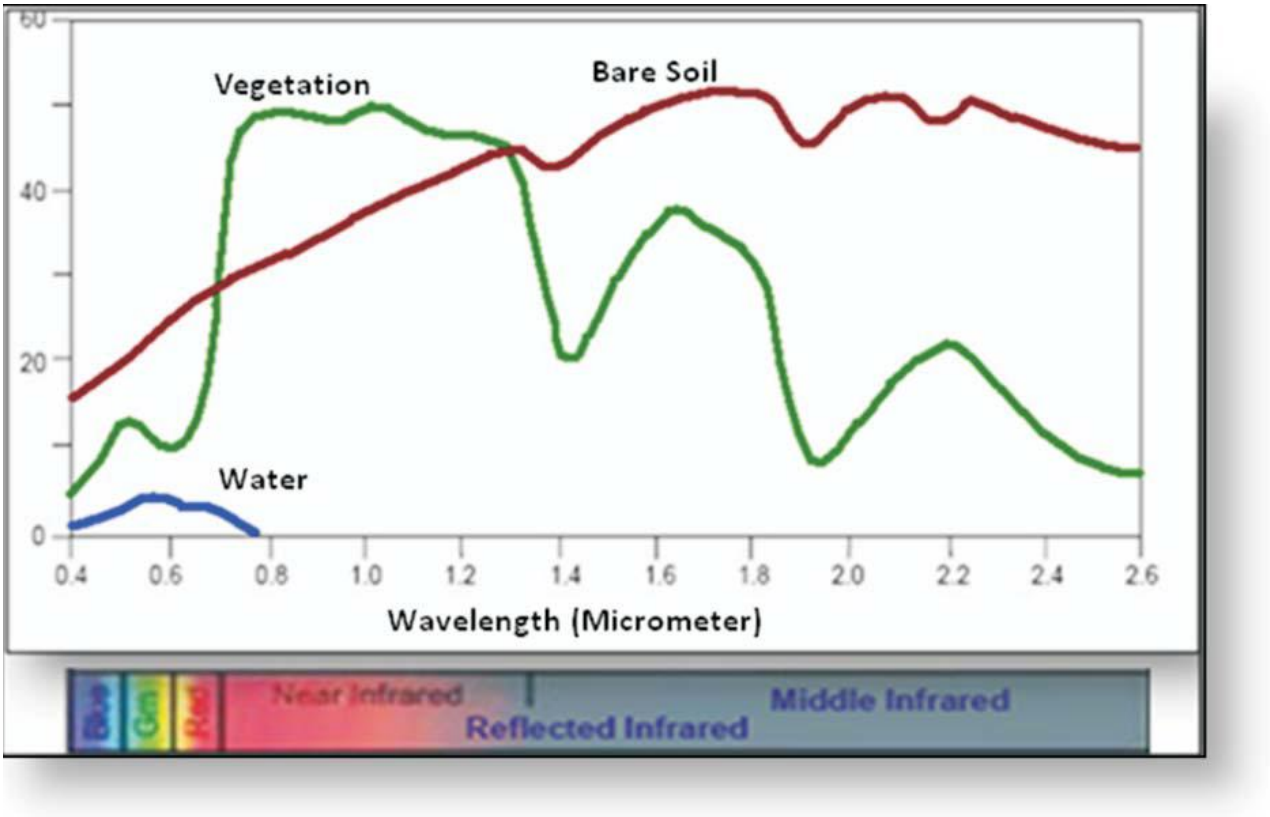
Stages in Remote Sensing

- A source of electromagnetic energy
- Transmission of Energy from the source to the surface of earth
- Interaction with the intervening atmospheres
- Interaction of EMR with the earth's surface
- Transmission of Energy from the surface to the remote sensor
- Sensor Data output
- Data transmission, Processing and Analysis

Remote sensing deals with inventory, monitoring and assessment of natural resources through analysis of data obtained from remote sensing platform. Remote Sensing measures energy such as ultra-violet, infrared, microwave, which that can- not be reached by human vision. Remote sensing data has a unique advantage of multidisciplinary application. The basic principle involved in remote sensing is that different objects reflect or emit radiations in different wavelengths and intensities depending upon properties of the objects serves as the main communication link between the sensor and the objects. All object matter that has temperature higher than absolute zero 0^0 emit EMR continuously. The intensity of the emitted radiation depends upon the composition and temperature of the body. A blackbody is an ideal body that absorbs all radiation incidents on it without any reflection. It represents a continuous spectral emission curve, in contrast to natural bodies that emit only at separate spectral bands. Temperature plays great role on the intensity of blackbody emitted radiation. This relationship is called Wien's displacement Law. Law represents as: max = A/ T where max is the wavelength (cm) where highest radiation occurs. A is constant (= 0.29 cm K) and T is the temperature (K) of the object. Using this law, it can estimate the temperature of objects by measuring the wavelength of peak radiation. The above figure shows spectral distribution of energy radiated from black bodies of various temperatures such as sun, incandescent lamp, fire and Earth. For the Sun max occurs at 0.48 µm, which measures the temperature of the Sun approx. as 6000 K similarly for the earth, the ambient temperature is 3000 K and max occurs at 9.7µm. The ambient temperature of fire is 5000 K and for incandescent lamp it is 4000 K. Most useful regions of the EMR are visible, Infra-red and thermal and microwave for carrying out RS activities. The human eye can detect energy in the visible portion of the electromagnetic spectrum. Photographic cameras are sensitive to broader range of wavelength ranges from 0.3 µm — 0.9 µm, the near ultraviolet to the near infrared. Thermal scanners operate in the thermal infrared portion of the spectrum. Multispectral scanners operate over a broad range of wavelengths from ultraviolet to thermal infrared. Passive microwave and active radar systems operate in microwave portion of the electromagnetic spectrum.

Spectral reflectance signature

The reflectance characteristics of the different features of the earth surface are measured by the incident energy that is reflected by the surface. This spectral reflectance of natural features is collected and stored by satellite sensors. Spectral reflectance of any object usually varies according to the wavelength of the EMR. A graph showing the spectral reflectance of an object for various wavelengths is known as a Spectral Reflectance Curve. It helps in selecting the wavelength bands for identifying the object. Spectral reflectance characteristics are the most important aspect for feature classification in any satellite imagery. Typical spectral reflectance curve for soil, vegetation, water is shown in below graph.



Spectral reflectance of vegetation, soil and water

Geographical Information System (GIS)

GIS is a computer-based system used to digitally represent and analyze the geographical features and events taking place. In ancient time people used maps as a tool to represent and share information about earth surface. Geographic surveyors, navigators, explorers have made many efforts to collect map data for various purposes. Science of map making has undergone many changes. Today there is a new dimension of spatial data handling with respect to various natural resources, and features. A GIS is a collection of computer hardware, software, and geographic data for digitally capturing, managing, analyzing, and displaying all forms of geographically referenced information. It allows us to capture, view, understand, acquire, interpret, and visualize data. The various themes of the same area such as Land cover/ land Use, water, soil, street can be integrated to reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

A GIS is a computer application program that stores Spatial and Non-Spatial information in a digital form. Location Information describes where a particular geographic feature is situated on Earth. Attribute Information describes the feature details like what it is, how much it is, what it contains, etc. Non-Spatial data, also called as attribute data, which refers to information like demographic distribution of a town or a village, daily discharge of a river at a particular place, Traffic contiguity of a road etc. The fundamental key of GIS is that, the association of Geographic features present on earth' surface, which can be geo-referenced with a database related to it. The figure shows the tree location and its description such as age, height, and species. GIS manages all variety of data in a single electronic file in a computer by storing different spatial features as sub-files. These sub-files are called map layers / themes (soil, water, street etc) These map layers are conveniently stored and accessed with the computer in a same scale which are very much helpful for regional planner or any administrative body to accurate study of the earth features. GIS can open all the layers showing all features. It can be displayed and overlaid depending on the requirements. For example, the land-use layer may be displayed along with elevation contours by keeping another layer off.

2. Application of Geospatial technology in drought management

Drought is the major climatic threat that affects agriculture of arid areas. Detection and evaluating the impact of drought with traditional methods has been laborious and time consuming. Recently methods for drought monitoring are improved. Space technology has made substantial contribution in all the three phases such as preparedness, prevention and relief phases of drought disaster management. The Earth Observation satellites which include both geostationary and polar orbiting satellites provide comprehensive, synoptic and multi temporal coverage of large areas in real time and at frequent intervals and 'thus' - have become valuable for continuous monitoring of atmospheric as well as surface parameters related to droughts and floods (Jeyaseelan, 2003). Geo-stationary satellites provide continuous and synoptic observations over large areas on weather including cyclone monitoring. Polar orbiting satellites have the advantage of providing much higher resolution imageries, even though at low temporal frequency, which could be used for detailed monitoring, damage assessment and long-term relief management. Advancements in the remote sensing technology and the Geographic Information Systems help in real time monitoring, early warning and quick damage assessment of both drought and flood disasters.

Monitoring and assessment of drought through remote sensing and GIS depend on the factors that cause drought and the factors of drought impact. Based on the causative factors, drought can be classified into Meteorological, Hydrological and Agricultural droughts. An extensive survey of the definition of droughts by WMO found that droughts are classified on the basis of: (i) rainfall, (ii) combinations of rainfall with temperature, humidity and or evaporation, (iii) soil moisture and crop parameter, (iv) climatic indices and estimates of evapotranspiration, and finally (v) the general definitions and statements.

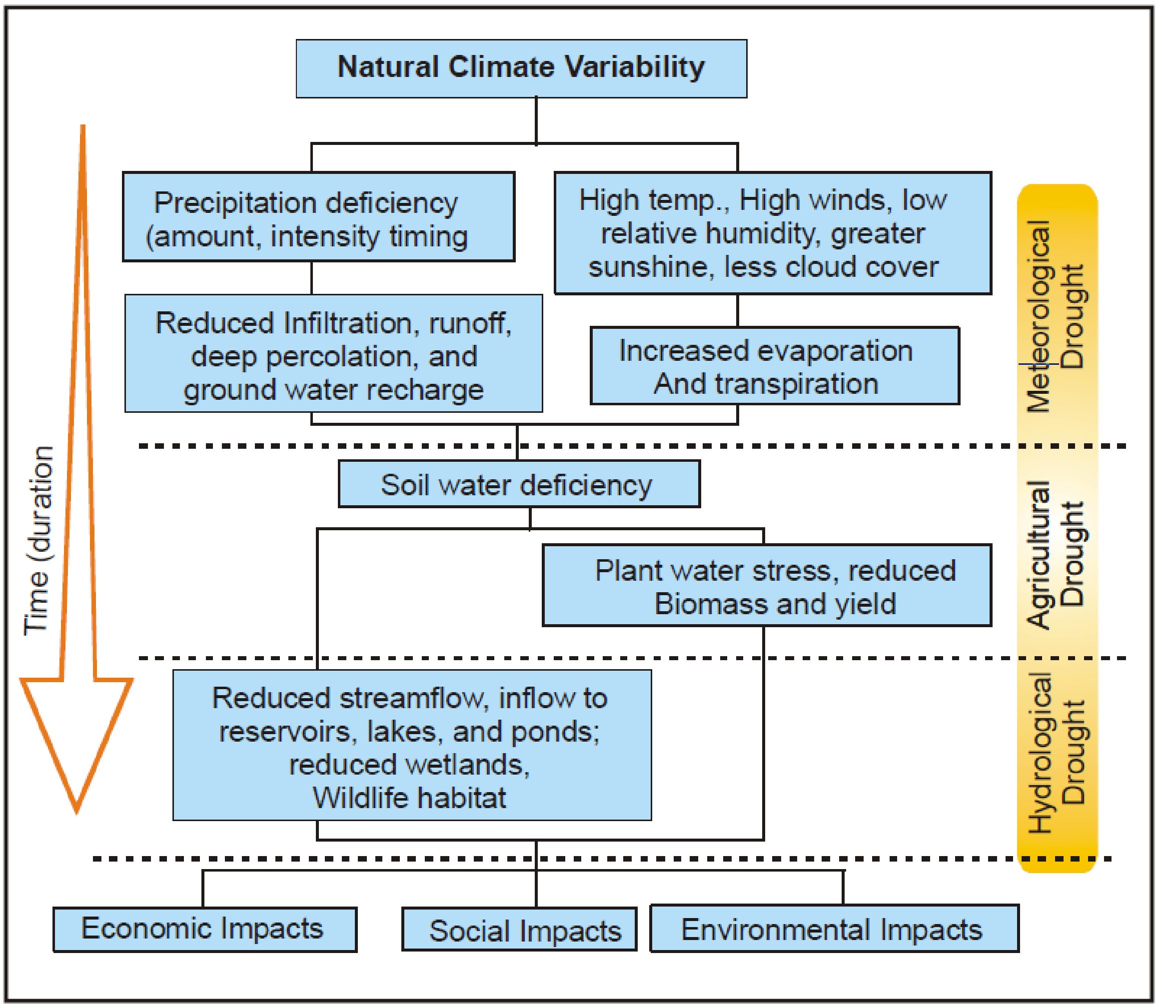


Figure 1: Sequence of Drought impacts

Drought is a normal, recurrent feature of climate and occurs in all climatic zones, although its characteristics vary significantly from one region to another. Drought produces a complex web of impacts that span many sectors of the economy and reach well beyond the area experiencing physical drought. Drought impacts are commonly referred to as direct or indirect. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish.

Drought Preparedness Phase

Long before the drought event occurs, the preparedness in terms of identifying the drought prone / risk zone area and the prediction of drought and its intensity is essential. Drought Prone/Risk zone identification. The drought prone area or risk zone identification is usually carried out on the basis of historic data analysis of rainfall or rainfall and evaporation and the area of irrigation support. The conventional methods lack identification of spatial variation and do not cover man's influence such as land use changes like irrigated area developed and the area affected due to water logging and salinity. The remote-sensing based method for identification of drought prone areas (Jeyaseelan and Chandrasekar, 2002) uses historical vegetation index data derived from NOAA satellite series and provides spatial information on drought prone area depending on the trend in vegetation development, frequency of low development and their standard deviations.

Drought prediction

The remote sensing use for drought prediction can benefit from climate variability predictions using coupled ocean/atmosphere models, survey of snow packs, persistent anomalous circulation patterns in the ocean and atmosphere, initial soil moisture, assimilation of remotely sensed data into numerical prediction models and amount of water available for irrigation. Nearly-global seasonal climate anomaly predictions are possible due to the successful combination of observational satellite networks for operational meteorological, oceanographic and hydrological observations. Improved coupled models and near-real time evaluation of in situ and remote sensing data - allows for the first time physically-based drought warnings several months in advance, to which a growing number of countries already relate their policies in agriculture, fisheries and distribution of goods.

The quality of seasonal predictions of temperature and precipitation (NCRC) of United States, the European Centre for Medium Range Weather Forecasts (ECMWF), the India Meteorological Department (IMD), the National Centre for Medium Range Weather Forecast of India (NCMRWF) is a function of the quality and amount of satellite data assimilated into the starting fields (e.g., SST from AVHRR and profiles from TOVS on NOAA satellites, ERS-2 scatterometer winds, SSM/I on DMSP satellites and all geostationary weather satellites: Geostationary Operational Environmental Satellites (GOES), i.e. GOES-East, GOES-West of USA, METeorologicalSATellite (METEOSAT) of Europe, Geostationary Meteorological Satellites (GMS) of Japan, Indian National Satellites (INSAT) of India etc.). The new assimilation techniques have produced a stronger impact of space data on the quality of weather and seasonal climate predictions. The potential contribution by existing satellites is by far not fully exploited, since neither the synergy gained by the combination of satellite sensors is used nor all the satellite data are distributed internationally. For example, better information flow is needed from satellite data producers to the intermediary services such as CLIPS (Climate Information and Prediction Services) project of World Meteorological Organisation (WMO), and prediction centres including the European Centre for Medium Range Weather Forecasts (ECMWF), National Centres for Environmental Predictions (NCEP), Japan Meteorological Agency (JMA), India Meteorological Department (IMD), National Centre for Medium Range Weather Forecast, India (NCMRWF) etc. to local services and ultimately to end users. Further the drought predictions need to be improved with El Niño predictions and should be brought down to larger scales. anomalies by various centres such as the National Climate Research Centre.

Drought Prevention Phase

Drought Monitoring and Early Warning

Drought monitoring mechanism exists in most of the countries based on ground-based information on drought related parameters such as rainfall, weather, crop condition and water availability, etc. Earth observations from satellite are highly complementary to those collected by in-situ systems. Satellites are often necessary for the provision of synoptic, wide-area coverage and frequent information required for spatial monitoring of drought conditions. The present state of remotely sensed data for drought monitoring and early warning is based on rainfall, surface wetness, temperature and vegetation monitoring. Currently, multi-channel and multi sensor data sources from geostationary platforms such as GOES, METEOSAT, INSAT and GMS and polar orbiting satellites such as National Oceanic Atmospheric and Administration (NOAA), EOS-Terra, Defense Meteorological Satellite Program (DMSP) and Indian Remote Sensing Satellites (IRS) have been used or planned to be used for meteorological parameter evaluation, interpretation, validation and integration. These data are used to estimate precipitation intensity, amount, and coverage, and to determine ground effects such as surface (soil) wetness. In addition, web based real time drought assessment is also proposed by Gopinath et al. (2015) and Gopinath et al (2020).

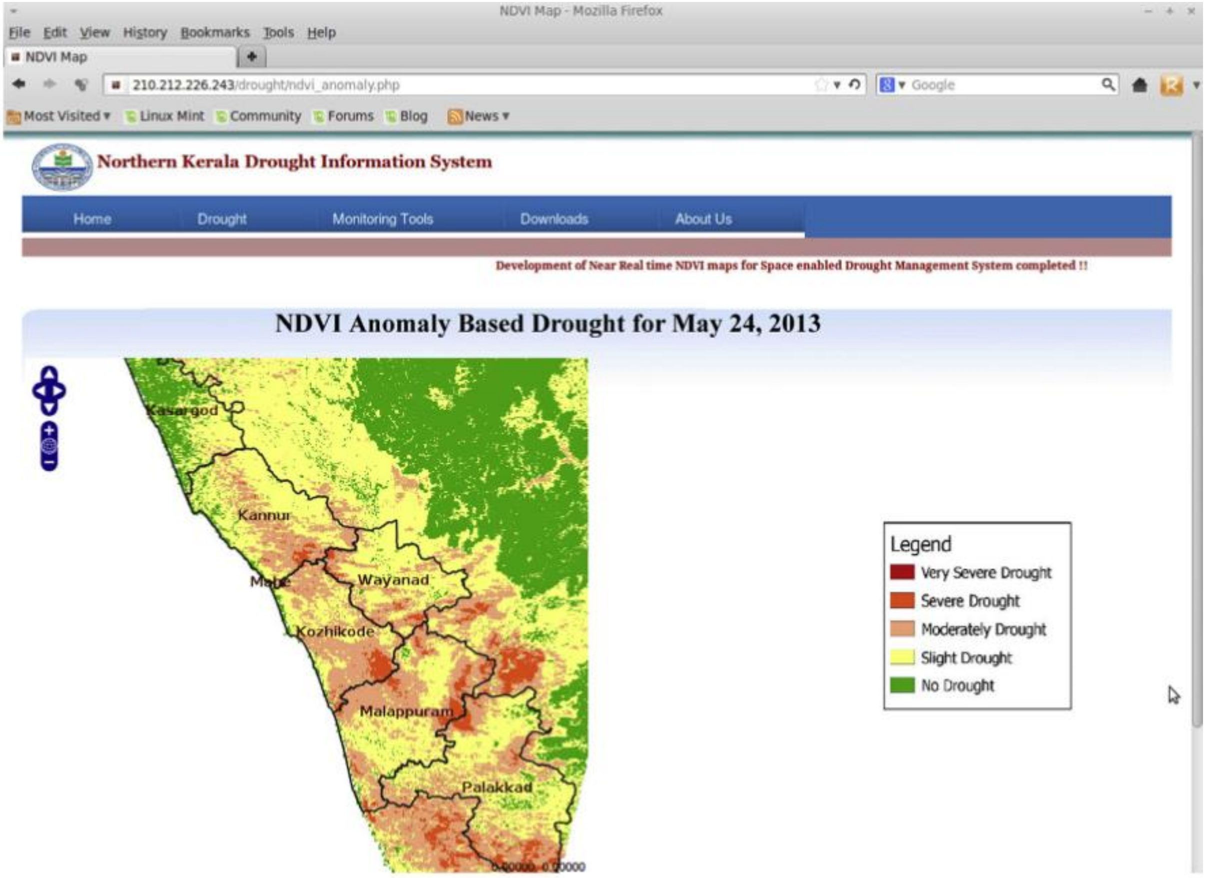
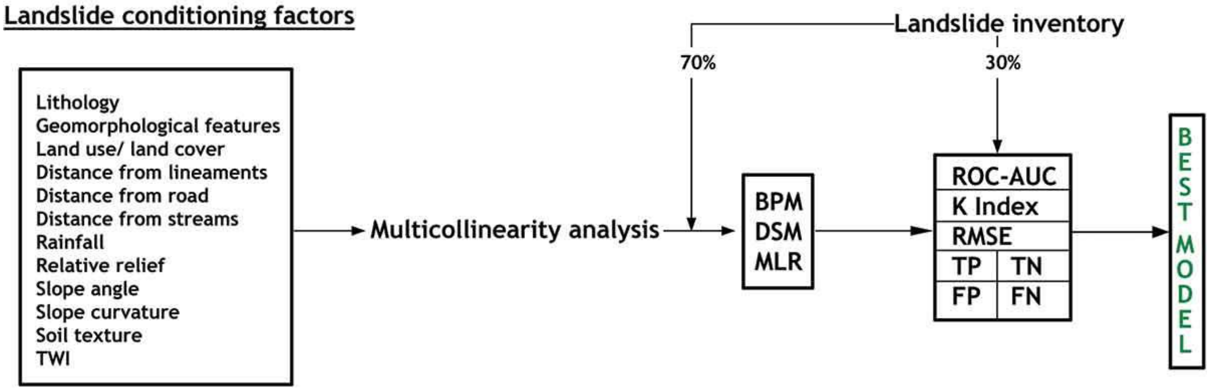


Fig. 3. Screenshot of the recent NDVI Anomaly map displayed on the Web page.

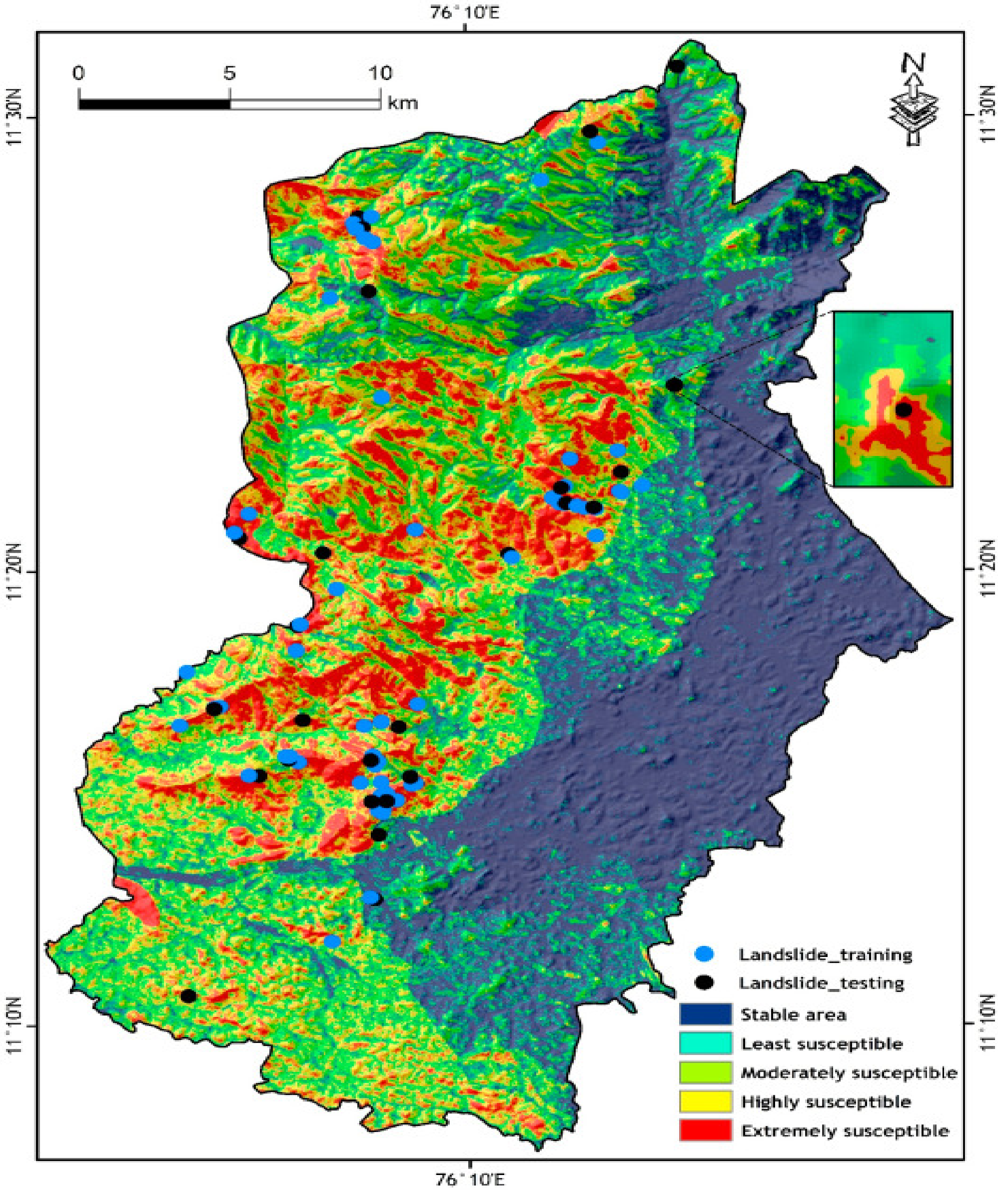
Source Gopinath et al., 2015.

3. Application of geospatial technology in Landslide susceptibility mapping

A landslide is a type of mass wasting process that acts on natural and engineered slopes. It is the movement of a mass of rock, debris, or earth down a slope, under the influence of gravity. Landslides involve flowing, sliding, toppling, falling, or spreading, and many landslides exhibit a combination of different types of movements, at the same time or during the lifetime of the landslide. Landslides are present in all continents, and play an important role in the evolution of landscapes. In many areas they also pose a serious threat to the population (Petley, 2012; Swetha& Girish Gopinath 20220; Achu et al., 2021a). Landslides are complex geomorphic processes influenced by several geo-environmental factors such as regional lithology, morphological characteristics, soil type, rainfall, slope and land use pattern, makes is difficult to predict the spatial and temporal occurrences. However, with the introduction of geospatial technology, many researchers predicted landslide susceptibility (likelihood of occurrences) by applying various heuristic, deterministic and statistical methods (Achu et al., 2020: Feby et al., 2020; Pham et al., 2021).The landslide susceptibility modelling have three major phases, starting from collecting previous landslide location, finding the suitable landslide influencing parameters like slope angle, lithology etc and modelling the probability of occurrences using weighted overlay/AHP or other statistical/ machine learning modellings as shows below.



A general methodology for landslide susceptibility analysis (Source Achu et al., 2020)



Example of landslide susceptibility map (Source Feby et al., 2020)

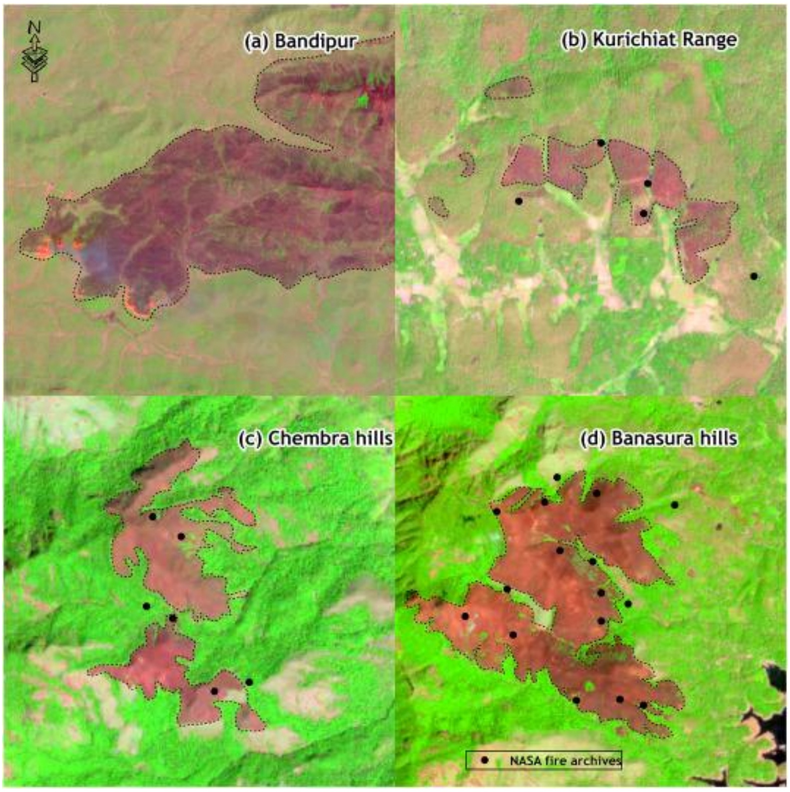
4. Application of Geospatial technology in forest fire prediction and mapping

Forest Fire is a natural phenomenon. It is part of the nitrogen cycle and it helps forests to grow healthy. However, “wildfire” is a huge and out of control fire which destroys human wealth and therefore, it is kind of disaster. The very first strategy to defend the forests against wildfire is to avoid it. So fire risk maps are produced and even prescribed burning is done. Nevertheless, wildfire happens and the only choice in this case is to control it. Knowing the fire behavior, one can use forest fire simulation to predict and control the wildfire. Nowadays application of Geospatial Information Systems (GIS) in disaster management has extended considerably and, in some cases, it is even unavoidable. Forest fire happens from time to time and this has given human a chance to observe and develop different models for forest fire behavior. GIS as a powerful tool for management of spatial information, has also proved its potential in forest fire management. There are different applications of GIS in forest fire management out of which the most important ones are hazard map production, forest fire simulation and resource management. Simulation by itself has a main role in the management of forest fire. GIS uses various information layers such as Digital Elevation Model (DEM) and index of flammability along with different models for the purpose of forest fire management. Models can be simple or complex. Simple models have few parameters and can be implemented even without GIS, however, because of their simplicity their results are not so reliable. On the other hand, very complex models which use detailed physical characteristics of fire are not reliable either as there is not either enough or up to date information on their parameters. So, finding an optimum model that takes advantage of sufficient number of parameters while has an acceptable level of simplicity is very important.

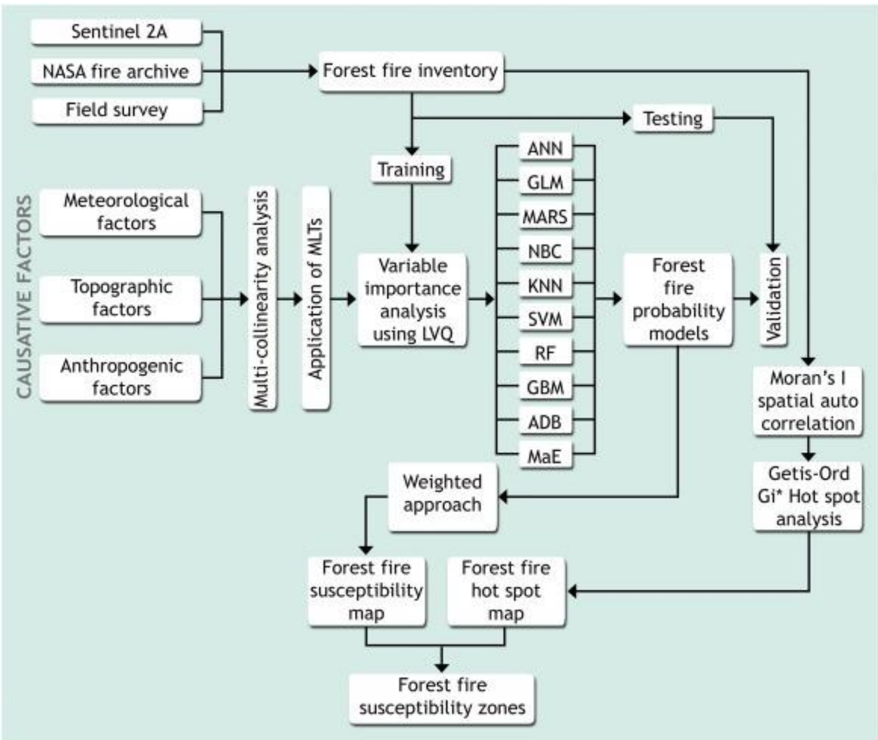
GIS is a powerful spatial processing tool which is used to solve many complex problems. In the context of forest fire some applications of GIS are as following:

1. GIS in fire risk/probability assessment
2. GIS in prescribed burn planning
3. GIS in preventing fire and its spread
4. GIS in fire simulation
5. GIS in post fire assessment and monitoring
6. GIS in disaster management

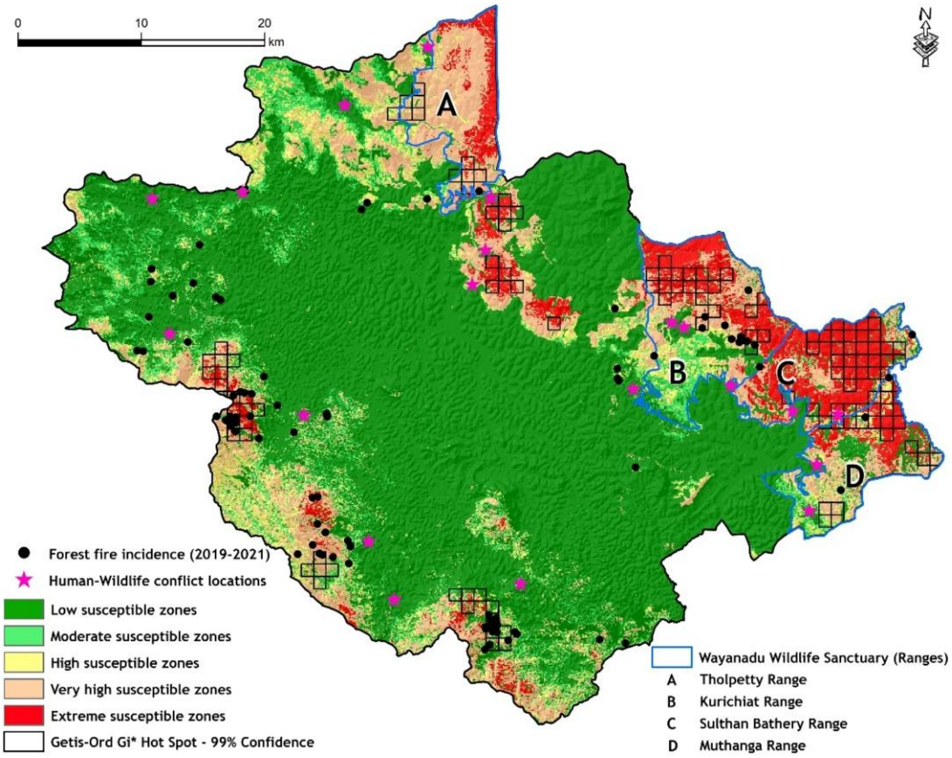
Below figure shows a live tracking of active forest fire and other burned areas in Wayanad district using Sentinel 2 Satellite images.



Forest fire inventory: Sentinel 2A 12-8-4 band combination with NASA fire archive data (a) Bandipur National Park, (b) Kurichiat forest range, (c) Chembra hills and (d) Banasura hills. (Source AchuA L 2021b)



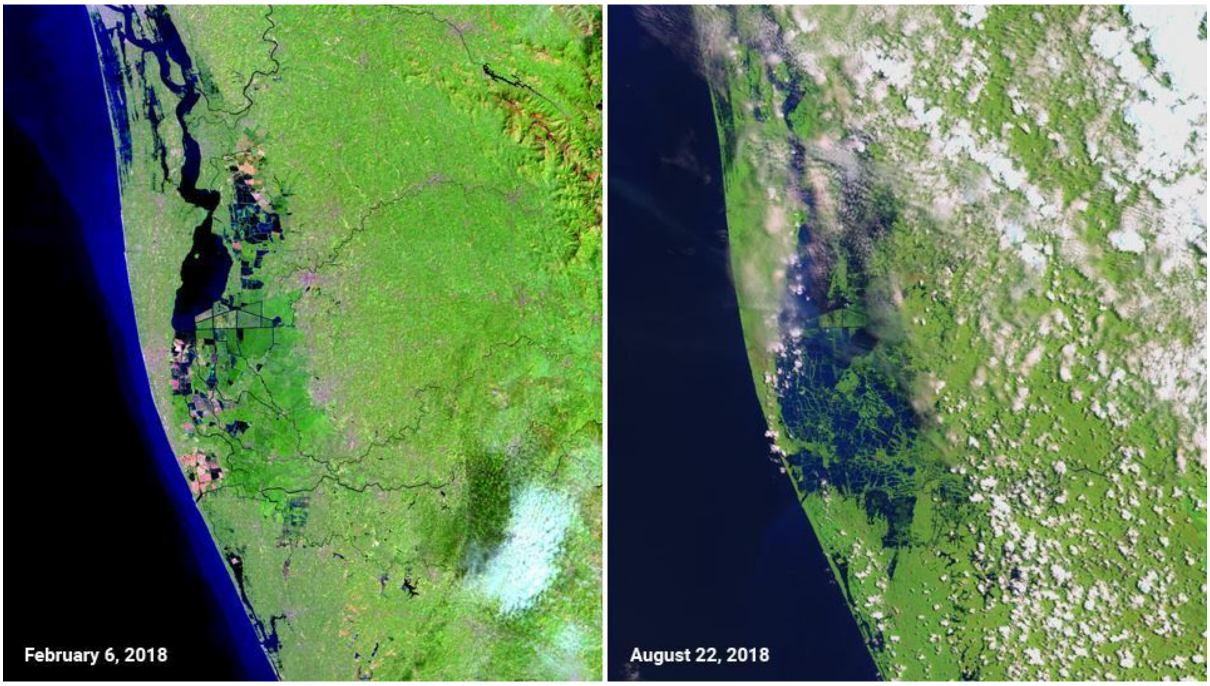
Methodology flow chart for forest fire susceptibility modelling using machine learning models (Source Achu et al., 2021b)



Forest fire susceptibility map using machine learning models in Wayanad district (Source Achu et al., 2021b).

Application of geospatial technology in flood modelling and mapping Kerala flood

Accurate and current floodplain maps can be the most valuable tools for avoiding severe social and economic losses from floods. Accurately updated floodplain maps also improve public safety. Early identification of flood-prone properties during emergencies allows public safety organizations to establish warning and evacuation priorities. Armed with definitive information, government agencies can initiate corrective and remedial efforts before disaster strikes. GIS is ideally suited for various floodplain management activities such as, base mapping, topographic mapping, and post-disaster verification of mapped floodplain extents and depths. For example, GIS was used to develop a River Management Plan for the Santa Clara River in Southern California. A GIS overlay process was used to further plan efforts and identify conflicting uses along the river and areas for enhancing stakeholder objectives. A 1 inch = 400 ft (1 cm = 122 m) scale base map was created to show topography, planimetric features, and parcels. Attribute data were entered into a separate database and later linked to the appropriate map location. Six layers were created for flood protection related work: 100-year floodplain, 100-year flood way, 25-year interim line, existing facilities, proposed facilities, and flood deposition. The lessons learned from this mapping project indicate that GIS is useful in capturing and communicating a vast amount of information about the study area and the river. While the use of GIS and the process to gather and record data were not without problems, the overall value of GIS was found to overweigh those challenges.

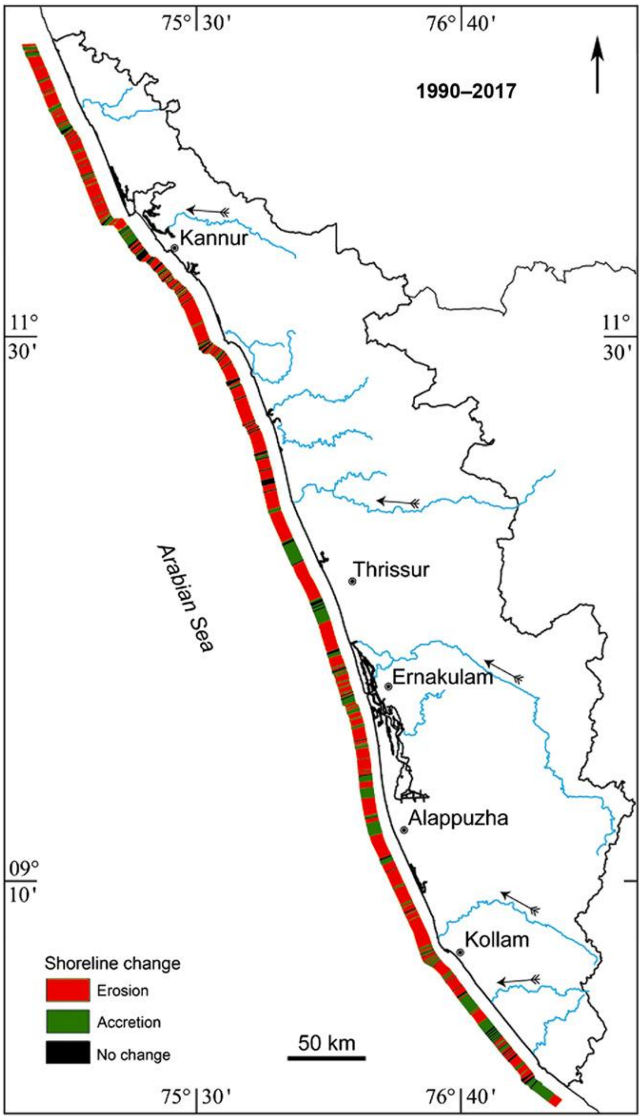


Kerala flood (Source NASA 2018)

Spatial probability of flood occurrence can be computed using GIS, often called flood susceptibility modelling.

5. Application of Geospatial technology in coastal vulnerability mapping

Coastal zone for the purpose of this paper, shall mean the area, on both side of the actual land water interface, where both territorial as well as Marine environmental influences each other. In addition, interaction between various natural processes and human activity are important factor in the coastal area. The coastal zone shows high population density with large number of urban conglomeration and in consequence, a fast population growth. Again, as a consequence, coastal zone are characterized by a high concentration of economic and, in particular, industrial activities with all the resulting problems of resource consumption, waste management and technological risk. On coastal water side, fisheries and aquaculture exploits a generally highly productive system. Very specific, and valuable as well as vulnerable, typical coastal ecosystems include estuaries, salt marshes, mangroves, coral reefs etc. Offshore activities such as oil and gas, as well as mining, are additional forms of exploitation of the coastal zone. In addition, the coastal zone is also the recipient of all water borne waste streams, primarily attributable to agriculture, its fertilizers and agrochemical, and all treated and untreated waste water the hinter land produce in their respective catchment. Determining the accurate length of the coastline is important for such coastal zone management application as shoreline classification, monitoring erosion, mapping biological resources, habitat assessment and for the planning and response to nature (e.g., storm surges) and man-made disasters (e.g. oil spills). Coastal zone management, by definition, is spatial management. Geo referenced spatial data is map data in a digital form which mean that each of the earth's features that are stored as spatial data has a unique geographic reference such as latitude and longitude. The increasing use of spatial data and GIS (Geographic Information System) by organizations and researchers is a valuable tool to help solve the planning and management issues in the coastal zone. There are many different Geographic Information Systems in use today and they tend to differ in certain aspects such as "how they link geographic location with information about those locations, the accuracy with which they specify Geographic location, the level of analysis they perform and the way they present information as graphic drawing". Following is an example of shore line changes along the coast of Kerala using time series satellite images.



Map showing the changes along the Kerala state during 1990–2017 (source Kumar et al., 2019)

Coastal region	**Time Interval**	**Erosion Length (km)**	**Accretion Length (km)**	**Stable Length (km)**	**Area lost by Erosion (km^2)**	**Area gained by deposition (km^2)**	**Net Loss (km^2)**
Kerala State	1990-2017	327	172	91	23	10	13

Source: Kumar et al., 2019

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APPLICATION OF ICTs IN LIVESTOCK PRODUCTION AND HEALTH MANAGEMENT

Dr.Vivek M. Patil

Associate Professor & Head, Dept. of Livestock Production and Management, Veterinary College Hebbal, Bangalore, Karnataka, India

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Information and Communication Technologies (ICT) is a broader term as compared to Information Technology (IT), and refers to all communication technologies, including the internet, wireless networks, cell phones, computers, software, middleware, video-conferencing, social networking, and other media applications and services enabling users to access, retrieve, store, transmit, and manipulate information in a digital form (FAO, 2021).ICT encompasses both the internet-enabled sphere as well as the mobile one powered by wireless networks. It also includes antiquated technologies, such as landline telephones, radio and television broadcast -- all of which are still widely used today alongside cutting-edge ICT pieces such as artificial intelligence and robotics (Pratt, 2019).

Modern ICTs applications are made up of four layers, namely the cloud, edge, physical, andnetwork layers. The cloud layers is made up of the virtual server with the presence ofbig data analytics. There is also the presence of database clusters with potential for datavisualization and enabled machine learning (ML) and artificial intelligence (AI) potentials.The edge layer is where the users' computational activities are enabled with the existenceof ML and AI models and data processing capability.The physical layer is the layer responsible for enabling the sensors that are placed on the animalsand fittedinto farm equipment to collect data. The network layer performs thefunction of offering the gateway to allow data communication and connectivity (Akhigbe *et al.*, 2021).

ICT-enabled applications which enhance the efficiency of livestock farms and aid in precision farming can be broadly grouped into four categories – Sensors, Automation, Decision Support Systems (DSS) and Information dissemination.

A. **Sensors**: These can be of various types depending on the requirement.Bio-sensors can either be wearable (neck, ears, legs, tail, skin surface) or implanted (sub-cutaneous, intra-ruminal, intra-vaginal). They can record temperature, pH, activity (accelerometer), heart rate, respiration rate, mounting pressure, GPS location, biomarkers etc. depending on their location and utility. External sensors which can record animal data comprise video camera, microphone, thermal infrared camera and load cells. Other sensors record environmental parameters like temperature, humidity, air speed, light intensity and levels of noxious gases. In dairy farms, special sensors in the milking parlour can record milk quantity, flow rate, temperature, composition, electrical conductivity, somatic cell count, progesterone levels and antibiotic residues. In most cases, a combination of sensors is utilized to achieve desired management objective.

B. **Automation**: In view of the rising costs and unreliability of skilled labour, and the reduction in prices of automatic farm equipment, many livestock farms have adopted automation in routine operations milking, feeding, livestock handling, weighing, body condition scoring and climate control. This enables timely and precise farm operations. The data generated from automatic farm equipment is vital for handling large herds/flocks.

C. **Decision Support Systems**: Data from biosensors, environmental sensors and external sources is fused to form a Decision Support System which aids the farmer in taking appropriate management decisions. These can in the form of livestock breeding, feeding, herd management and disease control. Computerization of these process increases speed of decision making and reduces errors. Incorporation of ICTs leads to change in livestock management strategy from Reactive to Proactive to Predictive, with the system being able to predict the best management response in the future based on past data.

D. **Information Flow**: Creating awareness about scientific livestock management practices is vital for enhancing efficiency and saving of scare national resources. With the advent of wider mobile network coverage and low-cost smartphones and internet data, mobile apps have become the preferred route for information dissemination as compared to earlier technologies like information kiosks or CDs. They have advantages in the form of multi-lingual text, audio and video content, and timely updates and notifications. In addition to extension activities, critical information regarding extreme weather events, emerging diseases and vaccination drives can also be shared using ICT tools. Access to market information and online trading of livestock, livestock products and inputs like feed ingredients etc. can greatly enhance the profitability of farmers by removing middlemen.

Advanced digitalization technologies can help modern farms optimizeeconomic contribution per animal, reduce the drudgery of repetitivefarming tasks, and overcome less effective isolated solutions. Thereis now a strong cultural emphasis on reducing animal experiments andphysical contact with animals in-order-to enhance animal welfare andavoid disease outbreaks. This trend has the potential to fuel moreresearch on the use of novel biometric sensors, big data, and blockchaintechnology for the mutual benefit of livestock producers, consumers,and the farm animals themselves (Neethirajan and Kemp, 2021).Some of the ICT-enabled applications which enhance the efficiency of livestock farms and aid in precision farming are given below:

1. **Identification**: Development and commercialization of animal identification systems has reached a very advanced state. A variety of systems based on Radio Frequency Identification (RFID) are available, some of which work reasonably well and have been adopted at the country level. These systems greatly facilitate the traceability and certification of products, particularly of meat, and therefore are crucial tools to minimize the losses and market disruptions caused by localized diseases. RFID systems communication with other ICT enabled systems to aid data logging in milking, feeding, and weighing equipment.

2. **Instrumentation***:* This involves acontrol system that consists of sensors that measure variables related to the system's state and actuators that provide input of mass, momentum or information to the system towards directional modification of the state. Animal state is estimated by the history up to a recent time, position, activity, temperature, live weight and other physiological variables of all individuals in the herd. This is especially observed in commercial poultry farms where controlled environmental conditions are essential for the profitability in high producing lines.

3. **GPS**: The use of GPS collars for livestock and wildlife has opened the possibility of recording detailed position information for long periods of time, thus allowing a more complete understanding of the habits and causes of spatial distribution of ruminants. Current commercial GPS technology can determine position of individual animals with a precision of 10 m or better. The position information can be stored on small flash cards together with large amounts of behaviour and physiological data and it can be transmitted to a management centre in real time or in periodical sessions.

4. **Animal behaviour sensors**: The data recorded by these sensors is somewhat ambiguous, but models can be developed to infer activity. Various types of sensors are necessary for a detailed record of behaviour. Accelerometers have been useful to document not only head movements but also walking and lying behaviour. Sensors have been tested for measuring head angle, head acceleration, leg acceleration, steps (pedometers),

swallowing, jaw movements, biting and chewing sounds, weight, heart rate, core temperature etc.

5. **Health monitoring**: Sensors and techniques for heath monitoring are well developed for dairy production under confined conditions. Behaviour and changes in behaviour can be used to detect health problems before disease affects animal productivity. Sensors were able to detect 80% of health problems related to ketosis, locomotion and lameness at least one day sooner than the farm staff by analysis of short-term feeding. Use of the estrus mount detectors, pedometer and advanced time series analysis to detect oestrus in dairy cows has been quite successful. Mastitis detection using in-line sensors which evaluate electrical conductivity and somatic cell count have proven to be very effective in detecting sub-clinical mastitis. Rumen pH sensors enable early detection of acidosis and aid in proper feeding. Thermal infrared imaging, especially of the eye region can monitor stress and detect disease 4-6 days earlier than traditional methods (Neethirajan and Kemp, 2021). Other devices like thermometers, accelerometers, and microphones, and camerasallow farmers to monitor temperature, activity levels, sound levels in the barn (e.g., vocalizations, sneezing, and coughing) and specific behaviors (e.g. aggression in pigs, pain estimation using 'grimace scale').

6. **Weighing**: Body weight measurement, either using statically or walk over load cells, or through captured digital images have very good accuracy and minimise the stress associated with restraint and body weight measurement.

7. **Body Condition Scoring**: This can be done either with image processing from video cameras or using thermal imaging. The captured images and associated expert score are used to train the computer neural network model, which can predict BCS of animals with very high accuracy.

8. **Lameness score**: This can be measured using data from load cells during milking or while the animal is walking over a grid of load cells. Newer techniques use video tracking and gait analysis; these, however, need an unobscured view of the flank of a single cow. Accuracy of these methods is still not adequate for commercial use.

9. **Herd management software:** The ability to digitally store herd information is a valuable tool for all farms. Data can be entered into this software application manually or automatically through the use of other digital devices (such as milk meters, cow weighing scales) linked to this database. This enables the farmer to easily view, analyze, manipulate and sort data. Such information storage and manipulation capabilities provide farmers with an extremely valuable resource to aid them in their farm management activities and decisions.

10. **Big data analytics and Machine learning:**The use of biometric sensors and biosensors for monitoring the health and welfare of livestock results in huge amounts of data that need to be processed and analysed to provide meaningful insights for animal management.Precision livestock farming relies upon proper use of big data analytics and modelling to inform management about nutritional needs, reproductive status, and declining trends in productivity, that may indicate animal health and welfare issues. Big data models extract information from sensors, process it, and then use it to detect abnormalities in the data that may be affecting the animals. Machine learning technology allows computer algorithms to progressively learn from sensor big data sets and improve themselves accordingly, eliminating the need for a human data analyst(Neethirajan and Kemp, 2021).

11. **Blockchain**: This technology provides several important benefits to livestock agriculture, including decentralized, automated transactions that could contribute to more efficient auditing systems for certification and regulatory organizations, system integration, organized records of chain transactions throughout the life of an animal from farm to table and greater traceability and transparency within livestock agriculture.

Conclusions

Livestock production is in a period of rapid adjustment and development, both regionally and globally. ICT has the potential to change the economy of livestock, agriculture, and rural artisans in India. There are intense pressures and concurrent opportunities associated with the need to produce safe and environmentally friendly livestock products. This has created the need and opportunity to use ICTsin the form of computer software, sensors and other electronic material in regards to livestock disease control, dairy herd management, livestock production, and marketing of livestock and livestock produce.

Simultaneously, advances in electronic communications and GPS technologies have driven major declines in prices and improvements in performance, opening a window of opportunity to create cost-effective systems for large scale precision livestock production.

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EPIDEMIOLOGICAL SURVEILLANCE AND DISEASE MODELLING

Pankaj Dhaka, J.S. Bedi and Deepthi Vijay

Centre for One Health, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141004, Punjab, India

Public Health surveillance can be described as *"the ongoing, systematic collection, analysis and interpretation of health-related events or data with the a priori purpose of preventing or controlling health hazards (disease outbreaks) and identifying unusual events of health importance, followed by the dissemination and use of such information for public health action"* (Bordier*et al.*, 2020). Effective health surveillance systems require reliable, high-quality, and timely data for decision making.

Why animal health surveillance is important?

The important objectives of animal health surveillanceare (Hoinville*et al.*, 2013):

- It helps in protection of animal health and welfare. The effective surveillance also provides the real scenario on the health status of the livestock population which helps in the upliftment of national and international trade in animal and animal food products
- To protect the public health by informing our understanding of incidences of zoonoses and its prevention and assuring food safety to the consumers.
- To fulfil the requirements of international organizations, *viz.* World Organization for Animal Health (OIE)– such as reporting of outbreaks, preparing emergency reports, weekly updates etc.

The data collection, analysis and dissemination are important components of surveillance system. The various types of widely used surveillance systems are depicted in Table 1.

Table 1. Types of Surveillance systems with their description

Surveillance Category	**Brief description**
Active surveillance ('Proactive surveillance')	It includes 'investigator-initiated' collection of targeted disease data using a defined protocol to perform scheduled actions. *Disadvantage:* Not economical, especially for rare diseases where large sample sizes are necessary because of the low expected prevalence.
Passive surveillance	It includes 'observer-initiated' provision of health data (e.g., voluntary notification) or the use of pre-existing data for surveillance.

(‘Reactive surveillance’)	*Disadvantage:* In practice, apart from underreporting, the sensitivity and timeliness of passive surveillance are often not optimal.
Sentinel surveillance	Depending on the objective, sentinel surveillance can either be passive or active. It comprises the group of unexposed non-vaccinated population/regions that are managed at fixed locations and sampled regularly for investigation of the disease.
Vector surveillance	Systematic identification of potential vector(s) can be correlated with particular relevance to targeted vector-borne diseases in a given ecology. *Disadvantage:* Not recommended as routine procedure due to its labour-intensive protocols.
Serological surveillance	Detection of antibodies against specific diseases is highly effective method to detect infection in a population. However, the positive results must be interpreted carefully within one of the 04 categories, *viz.*, natural infection, maternal antibodies, vaccination, false positive
Syndromic surveillance	It is based on the use of pre-diagnostic indicators which can be used for early detection of health events in a population (e.g., clinical cases, high mortalities, post-mortem findings) which can be defined as syndromes. *Disadvantage:* The indicators used in syndromic surveillance are not very specific and can lead to many false positives.
Targeted surveillance and **Risk-based surveillance**	It is recommended when the frequency of given health event is higher in target group. In risk-based surveillance, exposure and risk assessment methods can been applied together with traditional design approaches. *Disadvantage:* It can be expensive as it uses structured epidemiological surveys and needs a clear definition of the objectives.
Scanning surveillance	In scanning surveillance, the health services records can be used to obtain relevant information. *Disadvantage:* Underreporting and low-quality data are the limitations.
Event-based surveillance	It is organised collection of unstructured *ad hoc* information regarding health events or risks and is a functional component of early warning and response systems. *Disadvantage:* The information collected is diverse and originate from multiple sources
Indicator-based	It is routine collection of structured data of ‘indicators’ in health-based

surveillance	formal sources and usually measure the impact of health programmes *Disadvantage:* The data cannot be employed for early warning and response systems

As per Dufour and Audige (1997), the important set of criteria for the classification of surveillance networks are:

1. The type of disease to be monitored (exotic disease *versus* endemic diseases)
2. The number of diseases to be covered: focused networks *versus* broad networks (including multiple health events)
3. The area to be covered(regional, national or international)
4. The population to be monitored (suspected, susceptible, infected etc.)
5. Sampling strategy: sample-based networks *versus* exhaustive networks covering large population
6. Method of data collection (active or passive)
7. Network management (autonomous management *versus* integrated networks)

Key considerations for surveys and use of diagnostic tools in surveillance system: The choice of sample size, required design prevalence and confidence interval for surveys should be justified based on prevailing epidemiological situations. The sample size should be large enough to detect the infections even at a predetermined minimum rate (Bedi*et al.*, 2021).

The proper validation of the sensitivity and specificity of the diagnostic tests for targeted species should be exercised. In addition, it is important to differentiate 'vaccinated *versus* infected' animals by the diagnostic test for interpretation of the surveillance data. The surveillance framework can be supported by development of inexpensive, rapid and reliable screening tests along with the expansion of powerful information management systems to disseminate the information to the stakeholders.

Disease modelling

"A model is a representation of a system, which allows the behaviour of that system to be simulated, and manipulated, under controlled conditions". Models are used to test (verify) and improve the understanding of a system, and to analyse the behaviour of different components of the complex system (Power and Sharda, 2007).

To build a model of an infectious disease outbreak, the knowledge of epidemiological aspects of disease is very crucial so that the components of the model can be put together correctly. In animal health settings, the infectious disease models can be used for retrospective analysis of the past epidemics, contingency and resource planning, can be used as 'virtual epidemic simulators' for training purposes, and real time decision support (Potter, 2019).

Modelling disease transmission

The epidemiological models make better use of existing and potential data sources for early warning surveillance.The epidemiological models can be classified as:

1. *Deterministic and stochastic models:* The deterministic models use single point value for inputs and hence outputs; whereas the stochastic models include the 'uncertainty and variability' by using range of values for inputs and hence can produce varying outputs. The stochastic models are considered as more appropriate for modelling the real-life biological systems (Garner and Hamilton, 2011).
2. *Compartmental (or state-based) and individual-based (agent-based) models:* The compartmental (or state-based) models group individuals into different states as per the characteristics of the infectious disease processes. E.g., SIR (susceptible–infected–recovered) model and its variant. Whereas, the individual-based (agent-based) models explicitly represent the differentiation in biology or behaviour of individuals. Being stochastic, they offer more value when individual heterogeneity in transmission and structure of intervention is important.

Example of Compartmental (or state-based) model:

The infectious disease can be modelled as a state-transition model using an iterative approach. The common three states of transitions in basic **S-I-R models** are: susceptible, infected and recovered (immune) or removed.

$$S \xrightarrow{\text{ß x I x S/N}} I \xrightarrow{\gamma \text{ x I}} R$$

ß = Infection rate (transmission rate)

I = Number of infections

S/N = Proportion of susceptible

1/γ = Infectious period

In the outbreak of a contagious disease, the new cases of disease in a population occur as a result of infected units having 'effective contact' with susceptible units. These effective contacts are depending on many underlying factors like:

- the number of infected units
- the population density and intensity of mixing of the population – determined by the management system and environment
- the intensity of contact needed to be 'effective' – a property of the disease itself

It is important to understand the spread of disease in terms of basic reproduction number (R_0), that is, '*the number of new cases produced by each infected person*' (assuming that no one is immune in the population). Most of the disease control programs aim to reduce R_0 to < 1, such that each infected human/animal, on average, transmits to less than one other human/animal.

In simple equation, $\mathbf{R_0 = C \times P \times I}$

C = Contact rate (i.e., how many people get contact with infected person in unit time)

P = Probability of transmission for a given contact

I = How long an infected person can transmit the infection (infectiousness of disease)

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ROLE OF MASS MEDIA AND ICT TOOLS ON DISASTER MANAGEMENT IN ANIMALS

Jess Vergis, Arya P.R., VarshaUnni, Abishad P.M., Prejit and Asha K.

Department of Veterinary Public Health, College of Veterinary and Animal Sciences, Pookode, KVASU, Wayanad, Kerala- 673 576

Centre for One Health Education Advocacy Research and Training (COHEART), Pookode, KVASU, Wayanad, Kerala- 673 576

Introduction

The term disaster was originated from the Greek word '*krinon*' which implies a turning point, specifically in terms of diseases and dangeroussituations in political, social, and economical problems (Soltani, 2015). Usually, disaster is regarded as a turning point that could lead to an inevitablechange (Said and Rezapour, 2010). Disasters are often followed by an unexpected series of covert and overt consequences so that thedisaster managers must always be well prepared to deal withthese consequences in a suitable manner (Ali, 2002). Hence, the mass media along with various ICT tools is regarded as the first organization by frequent reporting and reviewing all incidents and rescue actions during disasters afterward and thus became the most significant strategic tools in disaster management.

Although the complexity of health- related communication through mass media exposes professionals to the significant challenges in diverse disciplines, mass media are often considered as important tools for the transfer of various ideas and information to the public, and even contributes for achievement of public health goals. It is believed that the catastrophic impacts of disasters on animal and human sufferings can considerably be reduced through an international devoted system of co-operation, incorporating public health education, improved early warning systems, proper disaster preparedness and mitigation (Sonet, 2018).

Mass media could indulge in any stage of disaster risk reduction (DRR) cycle, starting from the pre-disaster phase to the preparedness phase, response, and immediate relief phase, finally ending in a post- disaster phase. Within a fraction of second, people around theworld are informed about the horrific news reports at their fingertips, communicated by various sources of the media at the speed of light. Immediately after a few moments of any disaster, public might have perceived the news and would anxiously be awaiting the updates and facts, from all the corners of theworld (An and Gower, 2009).

It is therefore clearly convincing that the mass media could effectively perform the bridging and channelling between people and other coordinating bodies along with NGOs and any other community level organizations in successfully dealing with disaster risk reduction cycle (Hardjosoekarto*et al*., 2013). Hence, by creating new insights regarding disasters and promoting the belief that mutual help and co-operation can bring down the adverse effects of disasters among the public, mass media has now become an inseparable part of disasters (Williams and Oliniranb, 2002). Moreover, a complete coordination and effective working relationship between media and disaster management organizations has to be established and well maintained for the fulfillment of disaster risk reduction roles of the media. Despite the sensitivity makes media into a subsidiary power of bases, it clearly focusses on the necessity of careful, and calculated planning toturn itself into a tool that enables the effective remedy to the problem insteadof making things worse (Taherian, 2009).

Technology in media

The two types of media that exists nowadays are electronic media and print media. Among the electronic media, radio and television are the most prominent players, whereas newspaper, magazines and journals form the integral components of the print media.

Technology plays a crucial role in the acquisition of information, analysis, forecasting as well as its dissemination. Newer advancement in information communication technologies (ICT) offer considerable improvement both in the prediction of sudden onset of disaster as well as dealing with its consequences. However, communication itself virtually underlines all elements of hazard mitigation. Nowadays, the capabilities of communications, data gathering and data management technology have leaped forward in parallel with our increasing knowledge in tracing out the origins and behavior of natural hazards as well as mitigation of these effects. In addition, recent advancements in the telecommunications and computer sciences are the major contributors for the recognition of the most appropriate technology which can significantly reduce the impacts of natural hazards.

The use of super computers along with the deployment of geosynchronous satellites for telecommunications and earth observation for the analysis of data gathered from space has led to the development of highly sophisticated models of tropical storm formation and providing earlier information for planning evacuations and hazard mitigation strategies. Moreover, the changes in the color of earth's surface can be effectively monitored by remote sensing, thereby enabling insect infestation. Similarly, seismological devices linked with super computers also provide updated knowledge about earthquake propagation. This updated information related to the anticipation of disasters will enable us in time to give early warnings to get prepared and plan mitigation strategies for various meteorological events (Dave, 2004).

Role of mass media:

1. **Providing early warning to people**: Electronic media like radio and television can provide early information about the likely disasters and could thereby save lives of human beings and livestock. Besides, the loss brought about to the property can also be minimized to a considerable extent. Indeed, it can also play a significant role in preparing the community by means of training and making them aware about do's and don'ts during disasters.
2. **As a watchdog on disaster machinery**: During the rehabilitation works of post-disaster, media plays the crucial role of a watch dog. In the present democratic set up, the pressure of media is tremendous, and it should be utilized in a constructive and responsible manner for the benefit of the society. The responsibility of supplying resources necessary for rehabilitation such as relief materials, search and rescue equipment and money lie with the government. Nevertheless, sometimes the system becomes lethargic, and all these responses takes some time to effect. Specifically, during these circumstances, media plays a vital role by continuous monitoring of rehabilitation works by being a watch dog and keeps the disaster machinery active.
3. **In creating an appeal to the people**: The responsive image of media in front of public can be effectively utilized for the generation of resources to help disaster management efforts. Additionally, the real pictorial depiction of miseries through the media acts as an eye opener to the people to come forward to render help in various ways.
4. **In the prevention of panic and rumors**: During the post-disaster period, with the complete breakdown of communications, rumors can have a negative impact on the relief work. By conveying the right information regarding the immediate measures to be taken, media can considerably reduce the spread of rumors.
5. **Facilitating the creation of early warning systems**: By providing information on the risks and existing technologies, media can help the disaster mitigation experts for the creation of early warning systems. Emergency Alert System (EAS) consisting of radio, television and cable network across USA for providing early warning prior to disasters is one such example.

6. **Aid prioritization of disaster risk issues**: By influencing the government in prioritization of disaster risk issues, it strictly ensures that the political interests are not emphasized at the expense of the wide population.
7. **Increase of international donations**: Media pushes the government to increase the budgetary allocations of disaster response programs. Additionally, the media invites international attention for donations subsequent to the disaster occurrence.
8. **Co-ordination of risk assessment activities**: Media can make a considerable improvement in co-ordination of risk assessment activities between policy makers and donor communities. The increased resource availability and improved work programs created as a result of integrated efforts pave the way for saving lives of vulnerable communities of affected population.
9. **Control of law-and-order situation**: The antisocial elements trying to take advantage of situations can be highlighted by the media. In addition, they can assist the law-and-order machinery in peace restoration and harmony of the affected community (Soltani, 2018)

Impacts of media

It is the media who informs the and highlights its awareness among the public. This awareness created by the media play a pivotal role in determining the plan of disaster management actions which is to be executed and level of attention that the relief agencies have to pay for it (Dave, 2004).

Positive effects of media

1. Trusted source of updated information
2. Continuous and factual coverage of events during and after disaster aids in evoking immediate response and decision making, thereby saving lives
3. Rapid dissemination of information regarding public safety at times of disaster
4. Gives a glimpse of affected communities to the outside world

Negative effects of media

1. Exaggeration of events and creation of unnecessary panic
2. Chances of bias due to manipulation of certain matters for personal or political gains
3. Biased coverage by irresponsible news reporters for purposeful sensationalism
4. Create chances of looting and lawlessness

Role of ICT tools for disaster risk reduction in Indian scenario

Disaster management and supporting IT infrastructure is firmly rooted at the state/local level in the Indian scenario. Being the responsible authority during the disaster events, it is the responsibility of the state government to provide most of the resources, infrastructure and personnel; majority of these ICT infrastructure would be used by the state government. In addition, the crucial role for facilitation of ICT infrastructure necessary for linking state-central and state-state government organizations along with standards and guideline protocols to be followed by each state is instituted by the national government. In fact, the ICT design, adoption and acquisition on pan- India basis for the purpose of disaster management is quite challenging due to the distributed responsibility of disaster management and geo-political diversities across the country within the Indian system (Dave, 2012).

The EOC network

The Government of India has integrated administrative strategy for disaster management at the national, state and sub-district levels.

At the event of disaster, the state government affords the basic responsibility of undertaking rescue, relief and rehabilitation measures. The efforts of state government are supplemented with the financial and logistic support. The departments of relief and rehabilitation handles the relief at the state level. These coordinated efforts have been restructured to form the State Disaster Management Authority (SDMA), which indulges in the relief and rehabilitation activities besides preparedness and mitigation. Moreover, the lead role in managing response during disasters goes to the administrative hierarchy of government revenue departments.

At the district level, the same system is followed by the district co-ordination and relief committee and the district magistrate would the major coordinating officer to coordinate these activities. The incident response system (IRS) guidelines issued by the NDMA recommends the network of emergency operation center (EOC) up to the district level in each state for ensuring seamless coordination, communication and collaboration activities during the disaster management cycle.

EOC is an offsite facility functioning from the National/State/District headquarters encompassing an augmented control room with data acquisition, analysis, compilation, risk assessment, video projections, and communication, alert and warning facilities to accommodate various ESFs. The EOC analyzes emerging situation and facilitate assessment, identification, mobilization and deployment of required resources. It is on the basis of EOC service requirements and geographical coverage considerations, the ICT infrastructure for emergency response and disaster management need to be planned and established.

GIS and decision support system

GIS and spatial data have characteristic role in preparing, detecting, responding and recovering from the natural as well as technological disasters (Amdahel, 2002). As the spatial data are major inputs for GIS and Emergency Response Modelling and Simulation Systems (ERMSS)s, in their absence the process of disaster management will be ineffective. Furthermore, with recent advancements in geomatic engineering and spatial data management incorporating information communication technology (ICT), with integration of Remote sensing, Geographical information services (GIS) and Global positioning system (GPS), the different phases of disaster management have undergone significant improvement (Dave, 2012).

Conclusions

The media plays a quintessential role in all stages of disaster management from before disaster to after disaster and during rebuilding efforts. For effective achievement of disaster management roles, a well-built institutional framework and close working relationship has to be established between the disaster management agencies and the media. It is necessary that the media as well as ICT tools should emphasize on the close linkages with disaster mitigation community and shares their information gathering and transmission resources with these organizations. In addition, media can educate people and increase the awareness among the public, leading to increased involvement of different parts of society and can also help use these new involvements in disaster risk reduction and minimizing its adverse effects. Taking the fact into consideration that the disasters can happen at any moment and anywhere, it is advised to make use of the mass media for improving the society's involvement in disaster management and its prevention or else help to lessen its adverse effects. Moreover, a new group of disaster correspondents, as a part of disaster journalism, can improve the supply of information about nature and high-tech hazards.

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WILDLIFE MONITORING AND MANAGEMENT USING REMOTE SENSING AND GIS

Laxmi N. Goparaju

Vindhyan Ecology and Natural History Foundation, Mirzapur, Uttar Pradesh, India.

Introduction

Mapping the wildlife and monitoring their habitats has long been one of the aims of Geospatial technology. Traditional methods of inventorying wildlife have always left some lacuna and hindered in providing a good database. The advent of remote sensing satellites has eased this labour intensive task by making use of satellite data which is measured remotely with sensors and cameras in different spatial, spectral and temporal resolution. Thus, this serves as the quickest possible method for inventorying and observing the natural resources. The advantage of remotely sensed data is that it provides synoptic, regular, near real time and quite accurate data which can be utilized by the wildlife managers for assessing the species-habitat relationship and how they are impacted by the environment (Keller et al., 2014). The latest satellite images provide with higher spatial, spectral and temporal resolutions which are now made available for free via USGS, NOAA and Copernicus portal (https://earthexplorer.usgs.gov/; https://www.copernicus.eu/en).Besides, availability of big data in cloud has made computations easier. One such platform is Global Forest Watch which is based on Google Earth Engine platform and makes use of Landsat data from the past 40years. It helps in analyses by indirect methods such as species occurrence indicators for example forest fragmentation (Riiters et al., 2014). The progress made in other technologies like in in situ sensors for example bioacoustics, tags and camera traps help in providing non – destructive and partially automated ground surveying opportunities (Lausch et al., 2016; Hansen et al., 2013). Animals are associated with their environments at different spatial and temporal scales, and they differ in having specific ranges. Animal locations on ground coupled with remote sensing data and its analysis in Geographic Information System (GIS) domain provides us with better results regarding their habitat and ranges and also their interaction with the environment. Thus, conservation policies can be benefitted from such technological solutions.

Learning Outcomes

- Wildlife Habitat Suitability analysis using remote sensing and GIS

- Some online interactive web applications like Map of Life, FIRECAST, Global Forest Watch and Half-life.

Before going further, I would like to introduce what is satellite remote sensing and GIS?

Remote sensing satellites

A satellite with remote sensors to observe the Earth and its features is called a remote-sensing satellite, or Earth observation satellite. They are characterized by their altitude, orbit and sensor. The data is available in various types of resolution; they are spectral, radiometric, spatial and temporal resolution. Resolution is defined as the ability of an entire remote-sensing system, including lens antennae, display, exposure, processing, and other factors, to render a sharply defined image.

1. **Spectral Resolution**: of a remote sensing instrument (sensor) is determined by the band-widths of the Electro-magnetic radiation of the channels used. High spectral resolution, thus, is achieved by narrow bandwidths width, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad bandwidth.
2. **Radiometric Resolution**: is determined by the number of discrete levels into which signals may be divided. Thus, it is a measure of how many grey levels are there between pure black and pure white. It is measured in bits, 7bit (0-127); 8bit (0-255); 9bit (0-511) and 10bit (0-1023). Examples: IRS -1A/1B (1988, 1991) measure images in 7 bits. Cartosat -2 (2007) produces images in 10-bit radiometric resolution.16-bit images are obtained from IRS -P3 (1996) MOS –A, MOS –B and MOS – C.
3. **Spatial Resolution**: in terms of the geometric properties of the imaging system, is usually described as the instantaneous field of view (IFOV) that is defined as the maximum angle of view in which a sensor can effectively detect electro-magnetic energy.
4. **Temporal Resolution**: is related to the repetitive coverage of the ground by the remote sensing system. For example, the temporal resolution of Landsat 4/5 is sixteen days.

Remote Sensing science and application can be summarized in the following segments: 1) Source of electromagnetic energy (sun, transmitter carried by the sensor) 2) Transmission of energy from the source to the surface of the earth and its interaction with the intervening atmosphere 3) Interaction of energy with the earth surface 4) Transmission of the reflected/emitted energy to the remote sensor placed on suitable platform 5) Detection of the energy by the sensor converting into photographic image or electrical output 6) Transmission/recording of the sensor output 7) Preprocessing of the data for generation of data products 8) Collection of ground truth and other collateral information and 9) Data processing and interpretation.

Geographic Information System

The main components involved are computer software and hardware systems for creating, managing, manipulating, evaluating, condensing, and displaying spatial data. Many GIS packages represent geographic features in the form of points, lines and polygons. This format is known as vector as illustrated by points, lines and polygons which are connected to each other by vectors (directional line segments). Each feature in GIS database has its own identity and is associated with its coordinates and attributes. It is capable of querying and answering searches based on one's interests. The biggest advantage of GIS is that it integrates various thematic layers and finally displays as a single map for better comprehension and visualization.

Google Earth Engine

The problem of big data management was overcome by the Google Earth Engine which goes a long way in providing solutions within a smaller time frame. Large datasets can be used from local to regional levels, reduced the computation time. A repository of coves written in Javascript helps the researchers to utilize them with proficiency even though not being a professional. Active online support of developers is also commendable. The limitations of desktop computing are overcome, the major role is played by Application Programming Interface (API) and a web based Interactive Development Environment (IDE) (Tamiminia, 2020). The time series analysis (Time-lapse of GEE) and Climate Engine App helps in monitoring temporal changes.

Wildlife Habitat Suitability

Traditional methods and ground based studies have been employed in studying wildlife habitat and corridor use (Bhat and Rawat 1995, Johnsingh and Joshua 1994, Mishra and Johnsingh 1996). They are time consuming and inefficient in hilly and inaccessible areas. Studies in wildlife using geospatial technology have been gaining importance since the past few decades in India and have emphasized its role in habitat evaluation, identification and management of wildlife corridors (Khanna et al. 2001, Kushwaha and Hazarika 2004, Nandy et al. 2007).

From the conservation point of view, if wildlife habitats are known those areas can be protected and conserved from degradation and destruction. GIS platform helps in modelling wherein various parameters are included like water, land use and land cover, forests, roads, railways, streams, drainage and slope. Various criteria are decided by the researcher/analyst based on literature and ground knowledge. All the thematic layers are combined using weighted overlay technique in GIS is used to derive a suitability map. Species distribution models are prepared using various data, which identify other regions with similar environment conditions which can be potential habitat for a specific species. Such models use raster based layers such as land use/land cover and other above mentioned layers. This data is then combined with ground based information and statistical computations which predict the suitability and potentiality of the habitat (Goparaju et al., 2017; Ahmad et al., 2018).

Map of Life: Putting Biodiversity on the Map.

Utilizing various sources of data which describe species distribution worldwide, The Map of Life plays a major role in integrating them. Various organizations like International Union for Conservation of Nature (IUCN), World Wide Fund for Nature (WWF), Global Biodiversity Information Facility (GBIF) have provided data like expert species range maps, species occurrence points, ecoregions, and protected areas which have been put together into a cloud platform where the data is stored, managed, backed up and also can be accessed. Thus, one of the target areas where Map of Life is focusing is "the best – possible" species range information and species list for any geographic area. Besides, by accumulating a wide range of knowledge about species distributions and their dynamic state over a period of time, it also aims to support effective global biodiversity education, research and monitoring and guiding decision support system for policy makers.

MoL (https://mol.org/) provides

- Information on Species range and species list for any geographic area on Earth.
- There are multiple tools to assist in exploring species habitat and trends in biodiversity.
- There is also a Mobile App which can be used for discovering, identifying and recording biodiversity.

- https://www.gbif.org/ GBIF provides free and open access to data regarding all type of lifeform throughout the world.

Forest health assessment: Web based systems like Fire Information for Resource Management System (FIRMS) and FIRECAST

This is a web-based platform which disseminates Near Real Time active fire data within 3 hours of satellite overpass. It also generates web-based fire maps, email alerts and also has provision for active fire data download (SHP, TXT, and KML). FIRECAST utilizes satellite data observations to track ecosystem disturbances such as fires, fire risk conditions, deforestation and protected area encroachment, and ensure the details are delivered to decision makers via E-mail alerts, maps and reports. It also detects active fires (MODIS AND VIIRS), satellite-based weather conditions are also studied (https://firecast.conservation.org).

GLOBAL FOREST WATCH (https://www.globalforestwatch.org/)

The best available data about forests is available for free on Global Forest Watch Platform. Global Forest Watch (GFW) is an online platform that provides satellite data and other tools for monitoring forests. Alerts informed via E-mails and community participation has help governments and companies accountable for illegal activities. It was launched in 2014, its aim for to provide transparent data and scientific information about the forests to preserve them and decimate deforestation. GFW is free and user friendly, enabling anyone to create customized maps, analyze the changes in forest and study the trends from local to regional scale, subscribe to alerts, or download data for their local area or the entire world. Users can also contribute to GFW by sharing data and stories from the ground via GFW's crowdsourcing tools, blogs, and discussion groups.

Half – Earth Project: (https://www.half-earthproject.org/)

This is a combined initiative of ESRI and Sir E. O. Wilson's Biodiversity Foundation which aims to conserve half the earth's lands and seas in order to protect 85 percent or more of the planet's biodiversity to reverse the current species extinction crisis. According to Wilson, out of the 10million species present on the earth, only 2 million have been successfully documented. They have introduced the concept of National Report cards which will evaluate countries based on conservation efforts taken by them. It is expected that this innovative way will help theEarth restore back its green cover and could save many more species.

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INNOVATIVE SOLUTION OF VECTOR, DISEASE SURVEILLANCE, MONITORING & ENHANCING CURRENT STRATEGIES OF INTERVENTIONS

Satish Cherukumalli

Co-Founder; CEO

Technology Background

Mosquito sensor system is based on multiple classification rules to separate mosquitoes from other flying insects. It is widely known that mosquitoes can be identified by measuring their wing beat frequency (Batista, G *et al*., 2011; Chen, Y *et al*., 2014). The use of sound to detect and classify flying insects was first reported in the literature from work done at Cornell University in 1945. Since then, many other researchers (see references below) have shown that the wing beat frequency can be used as one of the parameters to classify the flying insect. In fact, wing beat frequency alone can yield 75% to 85% accuracy from other insect populations. If wing beat frequency is converted from the time domain to the frequency domain, then increased accuracy can be obtained. Work at Iowa State University (Raman, D *et al.,* 2007) and at the University of California, Riverside has been instrumental in developing algorithms that a can be used in the accurate classification of flying insects using relatively inexpensive sensors and be light weight enough so the computations can be done by the sensors' microcontroller. Previously mosquito classification devices, such as the device developed by NASA (NASA Tech. Briefs., 2007) made use of an on-sight computer and expensive hardware and software from NI Labview or MatLab. Our sensor makes use of a lightweight transform and probability algorithms to carry out most of the classification at the sensor level before sending the data to our cloud-based server.

Wing beat frequency will be measured by the disturbance of light on a phototransistor array as a mosquito enters the target zone of the sensor. Large flying insects will be prohibited from entering the zone by a 7 mm screen. Light is emitted from a constant light source. This light is reflected back onto phototransistors. Any disturbance of the light on the phototransistors is detected as a change in the current from the transistors (Unwin, D.M and Ellington, C.P., 1979).

Our sensor system uses several other measures for classification of mosquitoes. It makes use of the time of intercept and classifies on the basis of the known differences in circadian rhythm. It is known for instance that the circadian rhythm for the Aedes mosquito is different from the anopheles mosquito. The frequency spectrum for the Aedes and the Culex mosquito genus has significant overlap. As a result, frequency alone is not as accurate as needed. If the time of intercept is in the morning the *AedesAegypti*may be distinguished from the Culex. In the evening however, the *CulexPipien* and the *Aedes Detritus* are both active. By combining both the frequency spectrum and the time of intercept, the probability accuracies are increased (Kim, D *et al*., 2021).

The system also makes use of location of intercept. Different genus and species are found in different locations. By adding just these three factors in classification, accuracy can be improved beyond 95%. Location of intercept initially is based on what is known about the types of mosquitoes in the area. As data is collected for area or even a sensor location, the accuracy can be increased based on the continually expanding history. Although the frequency of the Aedes and Culex genus has significant overlap, the central tendency for the one is higher than for the other. This can shift the weighting of the frequency based on the specific sensors' location and history. Another obvious location factor is the terrain. Some mosquitoes are more prevalent in urban areas and others are more prevalent near water.

Coloration, light, sound and location will be used to help attract mosquitoes to the sensors. It is important to realize for any given sensor in a specific location, the data collected prior to and after vector control measures can be compared. The comparison can be made as a repeated measure on a particular sensor as well as across numerous sensors in a specified area of concern.

Solution:

Moskeet solution is a Smart Mosquito Diseases Control System that uses state-of-the-art sensors (IoT) and Artificial Intelligence (AI) technology to operate autonomously and provides real-time mosquito population data both by location and species. We believe that you must understand the problem before you solve it, and our network does just that. There are four key components to the solution - Sensor network, Social network, Real-time analytics, and Predictive analytics. The network of sensors (traps) across the communities identifies where problems exist, the efficacy of control methods, and when to reapply. Moskeet sensors use novel artificial intelligence (AI) algorithms to classify mosquitoes. The application provides density heat maps, conditions affecting breeding, health information, and vector control history. The platform is designed to capture data across several areas like epidemiology, entomology, human population, socioeconomic conditions, location, and the weather to help in the effective management of diseases. Using advanced assays and RT-

LAMP to identify disease-related RNA in mosquito saliva, we can pinpoint the most urgent areas and the type of vector control needed to reduce disease.

Moskeet platform integrates several stakeholders like citizens, governments, pest control and pesticide companies, hospitals, research agencies, foundations etc., to share and consume real-time data to promote efficient & transparent vector & disease control operations. TrakitNow's approach is to disrupt the Health Security sector by shifting the focus to "prevention" from "treatment" using deep technologies – AI (Artificial Intelligence) and Sensors (IoT – Internet of Things).

Moskeet platform provides situational awareness through its "always on", surveillance of mosquito population count, species make-up, and disease pressure showing the effectiveness of control measures against the vectors of infectious mosquito-borne disease. By providing historical, current, and predictive data, it allows agencies to make data-driven decisions as to what efforts are working, what efforts need to be improved, and where/when more effort is required. Getting mosquito-borne diseases under control and monitoring for potentially new diseases by exclusion requires a unified view shared across multiple activities with multiple agencies. Our system allows such a view, scalable to add new relevant data from emerging sources and to be analyzed with the latest AI and analytical tools including result graphing and geospatial mapping.

Impact:

The activity of collecting species-specific population data provides an output showing the increase or decrease the potential of the vector which is used to determine if the vector control methods are working and how efficiently. Another outcome of this activity is determining when reapplication is required, whether the application is being appropriately applied or the population is becoming resistant to pesticides.

The activity of determining the viral or parasitic load present at a given location provides an output showing where vector control needs are critical to curtailing outbreaks. The outcome of further control can lead to alerting the health community to take steps to reduce the disease potential by working with the potentially affected population of mitigating steps they can take. The activity of combining all known relevant data into a unified, holistic view provides the output of actionable data which can lead to an outcome of better understanding the impact of the vector control activities, leading to revising their strategies and focusing their resources more effectively. These outcomes can all lead to a long-term goal in the reduction of mosquito-borne disease and reduce the physical, emotional, and economic impact thereof.

Surveillance is borne on the premise that control requires being able to observe and then measure the targeted event. Our system provides the ability of stakeholders to observe and measure the effectiveness of their control activities on several levels of disease prevention.

Patents:

World Intellectual Property Organization International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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Discussion:

Moskeet's major benefit is to reduce the disease burden. A single disease occurrence in a family can push it into poverty and force the kids to stop school and go to work. Other key benefits include lowering the cost of control operations, reduce pesticide usage thereby reducing the impact of pesticides on the environment, facilitate awareness campaigns and reduce the health care costs at public and family levels. Data generated across the public and private is also shared with leading pest control & pest repellent companies. This approach helps to sustain and expand the platform thereby reaching out to a large percentage of the population. This in turn helps us to be cost-effective and provide better strategic value to customers. Our data from our initial deployments indicated the following trends,

1) Improve pesticide effectiveness
2) Reduce pesticide usage
3) Reduce operational costs
4) Lower disease burden
5) Reduction in mosquito populations

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INDIAN NETWORK OF FISHERIES AND ANIMAL ANTIMICROBIAL RESISTANCE (INFAAR)- UNDERTAKING SURVEILLANCE OF AMR IN ANIMAL HEALTH SECTOR

Rajesh Bhatia

FAO Consultant

"Antimicrobial resistance (AMR) is a global threat to health, livelihoods and the achievement of the Sustainable Development Goals (SDG)," the statement by UN Secretary Generalduring May 2019 in relation to SDG Goal 3 "Good Health and Wellbeing" (https://undocs.org/en/A/73/869) was enough to raise alarm bells of shift in human pathogen interactions. World Health Organization has called AMRas one of the most important public health threats of the 21st century. Currently, death of 700,000 people per annum is linked to AMR and is estimated to rise to10 million annual deaths by 2050[1]. The AMR is projected to cause $100 trillion loss to global economy by 2050 which is equivalent to 3.5% reduction in global GDP[1]. In May 2015, the sixty-eighth World Health Assembly endorsed the Global Action Plan on AMR (https://apps.who.int/gb/ebwha/pdf_files/WHA68-REC1/A68_R1_REC1-en.pdf#page=27). India responded with a National Action Plan (NAP) on AMR which was launched by Ministry of Health and Family Welfare in 2017 (https://www.ncdc.gov.in/WriteReadData/linkimages/AMR/File645.pdf).

Antimicrobial resistance (AMR) is the ability of micro-organisms to resist the effects of antimicrobials. AMR can occur naturally as all microbes can adapt to their surrounding environment. However, AMR is increasing by inappropriate and excessive use of antimicrobials in both human healthcare and the animal sector. In 2014, India was the highest consumer of antibiotics in human sector, followed by China and the United States (Reference and please recheck if it is highest quantity used or number of doses). India was the fifth largest consumer of antibiotics in food animals in 2010. Antibiotic consumption is projected to grow by 312%, making India the fourth-largest consumer of antibiotics in food animals by 2030[2].

Antimicrobials are used in animal production practices to manage animal and fish health, and also as growth promoters at a sub-therapeutic level. In recent decades, the intensification of animal production due to the increasing demand for animal protein has led to an increasing overall use of antimicrobials. AMR makes disease treatments ineffective, increase severity of disease, reduces productivity and leads to economic losses. In addition, more than half the quantity of antimicrobials used in animals/fish are excreted in waste contaminating soil, water and the environment. This also contributes to the emergence and spread of AMR through selection pressure on pathogens in environment. Besides, antimicrobials residues can be present in animal/fish products which also increases public health risks.

Currently, there is limited data available on AMR in livestock and aquaculture sector in India, which is based on individual studies with limited geographical coverage, samples and questionable quality. Thus, it is important to quantify the burden of AMR in food producing animals and aquaculture through structured surveillance with pan India coverage. Implementation of a systematic approach to generate AMR data has been initiated through forging and operationalization of the Indian Network for Fisheries and Animal Antimicrobial Resistance (INFAAR) is aimed to document antibiotic resistance levels in different production systems, describe the spread of resistant bacterial strains and resistance genes, identify trends in resistance and generate hypotheses about sources and reservoirs of resistant bacteria. The crucial data emerging on spatial level will be input to formulate strategies and policies to prevent and reduce the spread of AMR in farmed animals and fish and subsequently to human population.

INFAAR is a technical collaboration program between Indian Council of Agricultural Research (ICAR) and Food and Agricultural Organization (FAO) since August, 2018 with financial support from the ICAR, State agriculture Universities and the USAID. In INFAAR network, ICAR-NBFGR, Lucknow, is the leading institute for Fisheries and ICAR-IVRI, Bareilly for Animal Science. To assure maximum national coverage, INFAAR is being operationalized through 21 centers (18 ICAR and 3 State agriculture Universities) with 8 partners from fisheries and 13 from livestock sector. The INFAAR envisions to (i) undertake surveillance of antimicrobial resistance (AMR) in target microorganisms isolated from healthy farmed animals and fish/shellfish with an aim to quantify its burden and monitor the spatial and temporal trends of AMR in India. (ii) improve awareness and understanding of AMR among the farming community, veterinary and fish health professionals and policy makers, through effective communication, education and training so as to promote judicious use of antimicrobials in farmed food animals and fish.

The priority microorganisms identified under fisheries component of INFAAR are *E. coli*, *Staphylococcus aureus*, other Coagulase negative *Staphylococcus* species (CONS) and *Aeromonas* species in farmed freshwater fish; and *E. coli*, *S. aureus*, CONS and *Vibrio* species including *Vibrio parahemolyticus* in farmed shrimps and cage cultured marine fish.

Standard operating procedures (SOP) for isolation, identification and antibiotic sensitivity testing (AST) of microorganisms for fisheries sector has been developed for use by partners[3]. A field-based questionnaire is used to survey of farms to establish link between AMR data and actual use of antibiotic in culture practices. The results are analysed using internationally accepted WHONET software.

The issue of AMR also needs to be addressed by raising awareness amongst all stakeholders and especially farmers and industries on AMR and by implementing good practices to reduce the need for antimicrobials. Every year INFAAR creates awareness on "judicious use of antibiotics" among public focusing on farmers, students, school children, especially during "World Antibiotics Awareness Week" celebrated between 18-24th November in different parts of the country and world. INFAAR has launched a dedicated website (www.infaar.icar.gov.in), which provides the latest information on AMR in the country specifically on policy meetings, trainings, and other activities related to INFAAR its SOP, as well as recent and forthcoming activities of INFAAR.

The functioning and the activities of INFAAR are being regularly guided and reviewed, twice a year, by the INFAAR Advisory Board established by the Government of India.

The INFAAR is working towards safe food production for human consumption without the risk of transmitting AMR to humans through food production cycle. Safe food production without AMR risk will promote healthier human and animal health; and clean environment. The data generated by INFAAR will lead to identification of strategies to prevent and reduce the development and spread of AMR in aquaculture and food animals. Successful implementation of the program will be a key component of National Action Plan on AMR for protection of human health, animal health and food safety in India.

ONE HEALTH APPROACH AND REGIONAL DISEASE SURVEILLANCE NETWORKS

Prejit, Officer-in-Charge,
Centre for One Health Education, Advocacy Research and Training
Kerala Veterinary and Animal Sciences University, Pookode, Wayanad- 673576

The One Health (OH) approach is about collaboration between the different sectors such as human medicine, veterinary medicine, and environmental sciences. The world is experiencing increasing interaction of people and domestic animals in the last few years that led to events of emerging and re-emerging infectious diseases. Zoonotic diseases have always been, and are still today, a major burden for human and animal populations (Morens *et al*., 2004). This burden is particularly high in low middle income countries (Molyneux *et al*., 2011), and India is considered as the hot spot for many infectious diseases (Kessler and Peterson, 2008). Understanding the ecology of zoonotic diseases at the human–animal interface is a complex challenge. Furthermore, increasing incidence of antimicrobial resistance (AMR) has been recognized as a serious public health and animal health threat. The challenges of EIDs and AMR require a One Health approach that supports a holistic, multisectoral, coordinated and collaborative network. The international organizations such as WHO, FAO, OIE (under Tripartite agreement), and other international non-governmental organizations (NGOs) such as Rockefeller Foundation, the SGTF and the Bill and Melinda Gates Foundation, amongst others have been supporting One Health approach and establishment of regional networks for early detection and sharing of information, and responding to outbreaks in a coordinated and collective manner by multiple countries.

Animals can be used as surveillance tools for monitoring naturally occurring environmental & human health hazards. They are ideal surveillance tools because they share the same environment as humans & spend more time outdoors than humans increasing their exposure risk. Identifying the biological and environmental factors that cause interspecies pathogen leaps to predict the future zoonotic outbreaks has so far been cumbersome. But even with growing understanding of pathogen behaviour along with data pointing to regions where spillover might occur, precise outbreak predictions cannot be guaranteed. Connecting Organizations for Regional Disease Surveillance (CORDS) is an international non-governmental organization focused on information exchange between disease surveillance networks in different areas of the world. By linking regional disease surveillance networks, CORDS, an umbrella network organization based in France, builds a trust-based social fabric of experts who share best practices, surveillance tools and strategies, training courses, and innovations. CORDS exemplifies the shifting patterns of international collaboration needed to prevent, detect, and counter all types of biological dangers – not just naturally occurring infectious diseases, but also terrorist threats. Representing a network-of-networks approach, the mission of CORDS is to link regional disease surveillance networks to improve global capacity to respond to infectious diseases. The regional networks (Southeast Asia, East Africa, South East Europe, Southern Africa, and Middle East) were created in many regions of the worlds

The One Health approach

COVID-19 is one of the baleful pandemic the world had ever witnessed. The continued emergence and re-emergence of zoonoses point to the need for changes in the disease monitoring and management systems and the best solution is adopting one health approach. In 2010, recognizing the need for multidisciplinary collaboration to address health threats at the human–animal–ecosystem interface, the FAO-WHO-OIE formalized their collaboration and identified zoonotic diseases as a priority area to collaborate (OIE, 2017). The success of One Health approaches was reported in many instances such as, controlling Cysticercosis in Portugal (Fonseca *et al.,* 2018), Rabies in the Serengeti ecosystem (Cleavelandet *al.,* 2003), Brucellosis in Mongolia (McDermott *et al.,* 2013) and Malta (Buttigieg*et al.,* 2018), West Nile in Northern Italy (Paternoster *et al*., 2017). In consonance with IHR (2005), One Health approach has been advocated by the WHO, FAO and OIE for combating health threats to humans and animals and a tripartite agreement between these three organizations has been in vogue since 2010 to apply One Health approach (WHO, 2017; OIE, 2017) . The essence of One Health approach is that the actions are more strategically and collaboratively planned rather than having a reactive approach. A close networking between veterinary and medical laboratories and professionals at different levels has to be developed, along with sociologist, epidemiologists, environmentalists and climatologists. All the concerned professionals must become part of Rapid Response force to investigate epidemics of zoonoses and to formulate and enforce control strategies. The inter-faces that exist between man, livestock, wildlife, and environment are recognized as the hotspot for emerging infectious diseases. Such hotspot is considered as multifaceted problem zone that calls for multifaceted solutions where no one particular discipline can act wisely to control such threats (Prejit, 2017). We need to break the silos and plan a joint strategy by integrating ideas of the connections among humans, animals and ecosystems within the political, economic and social systems in which they operate. A clear advantage of One Health is that interventions in animal populations can result in public health and societal benefits more cost-effectively than just interventions in humans (Prejit, 2017).

Regional Disease Surveillance networks

The Asia-Pacific Strategy for Emerging Diseases (APSED) develops Member State and regional surveillance and response capacity through a policy of intersectoral collaboration and coordination, with FAO and OIE, for detection and control of zoonotic disease emerging at the human/animal/ecosystem interface. Some of the active regional disease surveillance networks includes, ***The Mekong Basin Disease Surveillance network (MBDS)***(established in 2003)comprised of Cambodia, Southern China, Lao PDR, Myanmar, Thailand, and Vietnam, coordinates efforts to mitigate H5N1, cholera, and Dengue Hemorrhagic Fever, and to develop joint strategies for containing disease in the region. ***Middle East Consortium on Infectious Disease Surveillance (MECIDS)*** (established in 1999) is a disease surveillance network made up of public health experts and ministry of health officials from Israel, the Palestinian Authority, and Jordan. This group has had success in finding common ground across borders in conflict and has acted together to meet disease threats, including 2009 H1N1 influenza. ***The Southern African Centre for Disease Surveillance (SACIDS)*** (established in 2009)includes diseaseexperts from Tanzania, Mozambique, Zambia, Democratic Republic of Congo, and South Africa, works to improve the capacity of African institutions to detect, identify, and monitor infectious diseases affecting humans and animals, including new infectious diseases of animal origin. The network has partnered with a number of institutions, includingSokoine University of Agriculture (SUA), the Royal Veterinary College, and the London School of Hygiene and Tropical Medicine, to create an interdisciplinary network that embodies the One Health approach for collaboration between human and animal health sectors. ***The East African Integrated Disease Surveillance Network (EAIDSNet)*** (established in 2000)is a regional, inter-governmental collaborative initiative of the national ministries responsible for humanand animal health as well as the national health research and academic institutions of the five East African Community Partner States, namely the Republic of Burundi, the Republic of Kenya, the Republic of Rwanda, the Republic of Uganda, and the United Republic of Tanzania. The main objectives of EAIDSNet are to: (1) enhance and strengthen cross-country and cross-institutional collaboration through regional coordination of activities for the prevention and control of both human and animal diseases under the One Health Initiative; (2) promote exchange and dissemination of appropriate information; (3) harmonize integrated disease surveillance systems in the region; (4) strengthen capacity for implementing integrated disease surveillance and control activities; and (5) ensure continuous exchange of expertise and best practices for integrated disease surveillance and response (CORDS.2011)

Conclusion

Although we face many outbreaks of emerging zoonoses, it is also true that the world has made significant strides in tackling major public health challenges over the last several decades. One of the reasons are the collaboration among stakeholders between different disciplines, efficient and timely conveyance of information to various strata associated with disease control, and imparting proper training to public health workers and susceptible population. Effective surveillance and timely multidisciplinary action should be coupled with education and research for shackling emerging and re-emerging zoonoses. This is possible by certain strong networks that work in an One Health mode like CORDS, which unites regional disease surveillance networks from critical hotspots around the world to promote exchanges of best practices in surveillance and catalyze innovation in early disease detection. Such collaborative surveillance unit cultivates networks of professionals who have the collective strength to translate information into near-real-time action during emergency situations. The need for innovations and more effective scale-up of existing ICT tools is required so that we can control many of the emerging diseases.

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PROSPECTS OF TELEMEDICINE IN VETERINARY PRACTICE

Dr Sooryadas S, Assistant Professor,
Department of Veterinary Surgery and Radiology, CVAS Pookode
Kerala Veterinary and Animal Sciences University, Pookode, Wayanad- 673576

World Health Organisation defines telemedicine as the delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities. While telehealth is defined as the delivery and facilitation of health and health-relatedservices including medical care, health information services and self care via telecommunications and digital communication technologies.

Tele veterinary medicine can be defined as extension of veterinary medical service to a remote location, using information and communication technologies. In general, the term tele veterinary medicine can be used to denote veterinary clinical services delivered by a registered veterinary practitioner while the term tele veterinary health can be used to denote use of technology for delivery of veterinary health and health related services including tele veterinary medicine. The registered veterinary practitioner or specialist may use any telemedicine tool suitable for carrying out technology-based consultation eg. telephone,video, devices connected over LAN, WAN, Internet, mobile or landline phones, chat platforms like WhatsApp, Facebook Messenger, etc., or Internet based digital platforms for telemedicine or data transmission systems like Skype/email/fax etc. irrespective of the tool of communication used, the core principles of tele veterinary medicine practice remain the same.

Let us divide Telemedicine in Veterinary practice into

Real-time telemedicine - Here, the consulting veterinary expert or specialist will see and discuss the case real-time with the referring veterinarian.

Store-and-forward telemedicine - Here, electronically stored information related to a case is forwarded to a consultant who reviews the case later.

A variant of the above two where the electronically stored information related to a case is sent to a specialist and the referring vet discuss the same with the specialist over telephone for getting the interpretation of the case and for decision making.

Few disciplines where Telemedicine can be practised in Veterinary are

1. Tele radiology
2. Tele ultrasonography
3. Tele ECG
4. Tele pathology
5. Tele ophthalmology
6. Tele cytology
7. Tele dermatology
8. Tele endoscopy
9. Tele-guided surgery

The prospects of this emerging field in veterinary practice are plenty. The paper describes a basic knowhow, possibilities and challenges of telemedicine in veterinary practice, along with experience of tele-guiding few surgeries abroad for correction of challenging surgical conditions in puppies.

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Maritime Climate Change: Physical Drivers and Impact, *Series Editor: Neloy Khare*

Climate Change in the Arctic

An Indian Perspective

edited by

Neloy Khare

CRC Press
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Climate Change in the Arctic

Maritime Climate Change: Physical Drivers and Impact

Series Editor:
Neloy Khare

As global climate change continues to unfold, the two-way links between the tropical oceans and the poles will play key determining factors in these sensitive regions' climatic evolution. Now is the time to take a detailed look at how the tropical oceans and the poles are coupled climatically. The signatures of environmental and climatic conditions are well preserved in many natural archives available over land and ocean. Many efforts have been made to unravel such mysteries of climate through many natural geological archives from tropics to the polar region. This series makes an effort to cover in pertinent time various depositional regimes, different proxies – planktic, benthic, pollens and spores, invertebrates, geochemistry, sedimentology, etc., and emerged teleconnections between the poles and tropics at regional and global scales, besides sea-level changes and neo-tectonism. This book series will review theories and methods, analyse case studies, identify and describe the evolving spatial-temporal variations in climate, and provide a better process-level understanding of these patterns. It will discuss significantly, generalisable insights that improve our understanding of climatic evolution across time – including the future. It aims to serve all professionals, students and researchers, scientists alike in academia, industry, government and beyond.

Climate Change in the Arctic
An Indian Perspective
Neloy Khare

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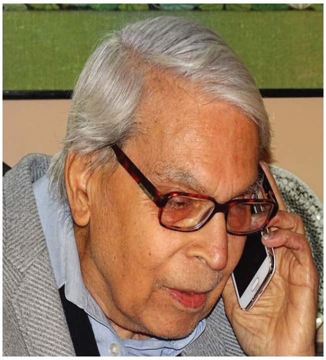

Late Prof Shashi Bhushan Bhatia

(18.03.1980–01.05.2021)

Prof Shashi Bhushan Bhatia was born on 18 March 1930 at Lucknow. Prof Bhatia post graduated in 1950 from the Lucknow University, obtained Ph.D. degree from the London University and D.I.C. from the Imperial College of London. He joined the Lucknow University as a Lecturer in 1953. In 1958, he was selected in the Geological Survey of India. Subsequently in 1959, Prof Bhatia was appointed as a Reader in the newly created Department of Geology in the Panjab University, Chandigarh, where he superannuated as a Professor and then continued as an Emeritus Professor.

Prof Bhatia's contributions to the Indian geology cover a vast time span. Foraminifera was his original field of specialisation. He is credited with the first discovery of the Permian foraminifera in India. Later he made important contributions to the study of Cretaceous and Paleogene ostracods. His research on the Cretaceous sediments aided in determining the time of extinction of the dinosaurs and initiation of the Deccan Volcanicity. Another important input to the Cretaceous was the report of bryozoa in the Neelkanth Formation – considered at that time a part of the Tal Group. The most important contributions made by Prof S. B. Bhatia, however, are to the Palaeogene sediments of the Himalaya. He studied fauna of the Subathu, Dagshai and Siwalik sequences. His findings precisely fixed the lower age limit of the Kakara sediments at 56.5 Ma, which signifies the time of collision of the Indian and Asian Plates. His research on the Subathu and the Dagshai formations makes significant contributions to the biostratigraphy, event stratigraphy and environment of deposition of that time. He put India on the world map of Chara studies.

Prof Bhatia had around 250 publications in reputed journals. He guided a dozen students for Ph.D. degree. He was a highly decorated scientist. In 1958, he was appointed as Indian Correspondent of the Journal of Micropaleontology. He was a Fellow of the prestigious Indian National Science Academy and recipient of L. Rama Rao award. Oil and Natural Gas Corporation decorated him with a silver plaque. He was an excellent teacher with exceptional skills of communication. He was a perfectionist and demanded the best from his students.

Prof Shashi Bhushan Bhatia breathed his last peacefully on 1 May 2021. His death is a great loss to Indian geology.

Contents

Foreword

Undertaking research in the Polar Regions is complex and challenging. The sustained vitality of polar research is intrinsically linked to the specialised logistics and infrastructural support available, which allows scientists to work in a challenging environment. It necessitates strong international cooperation and sharing of resources and infrastructural facilities. Ny-Ålesund at Svalbard in the Arctic has emerged as a vibrant symbol of international partnership. The Norwegian Government has ably guided many non-Arctic countries to research new areas of Arctic Science.

Having achieved a long and resilient experience in Antarctica, India forayed into Arctic Science over a decade back and recently joined the Arctic Council as an Observer. In collaboration with Norway, India has established its research base ‘Himadri’ at Ny-Ålesund, the well-known ‘Science village’ in the Arctic. With more than a decade’s effort, many exciting findings and results have emerged, especially in the science of climate change as evident in the Arctic region. With quality scientific output in a short period, India has made its presence strongly felt in Arctic Science and has contributed significantly to the knowledge base of Arctic research. Indian scientists have attempted to unravel the past and understand the present in order to elucidate the future trends on climate change patterns.

The multi-sectoral climate issues associated with Arctic change transcend national boundaries. The stakeholders including governments, indigenous communities, civil society, policymakers and industry need to be equally concerned. For any adaptation and mitigation efforts, informed decisions on the Arctic must be evidence-based and not geopolitically driven. Scientists, therefore, have a cardinal role to play in providing insightful data that can be translated to enable policy paradigm and sound advisory mechanism on climate change and its impact on the globe.

The Indian efforts made in Arctic climate science must be synthesised so that a comprehensive picture could emerge. The present book *Climate Change in the Arctic: An Indian Perspective* is an illustrious effort in this direction, covering a wide range of topics addressing various aspects of climate change in the Arctic. As changes in the Arctic region will have a profound effect on human life on Earth, there is a need for our polity and people including the industry leaders to have up-to-date and robust information on the science of Arctic climate change. This book amply provides a clear picture of the ongoing global climatic changes, their impacts on the Arctic and how the changing Arctic will influence the rest of the world. The message conveyed is clear: we must collectively work to reduce our carbon footprint to save one of the last frontiers on planet Earth, the Arctic.

Arbinda Mitra
Scientific Secretary
Date: June 2021
Place: New Delhi

Preface

The Polar Regions are an essential focus of research as unique systems, but they also play a pivotal role in global Earth systems. Situated at the northernmost part of *Earth*, the Arctic is a spectacular *polar region*. It is a unique area among Earth's ecosystems. The unique characteristics and cultures of the Arctic indigenous peoples are an adaptive mechanism to cope with the cold and extreme conditions. Historically, the Arctic regions' scientific activity is intimately linked with the post-World War II and the subsequent Cold War era's geopolitical circumstances. It has always been a pristine environment owing to least human interventions. For many years, the Arctic region was designated as a North 'dead land' that was not perceived as a place for living or economic activities. However, the situation during the past few decades has changed significantly. Now the Arctic is connected to global natural and anthropogenic chemicals via winds, ice movement and marine currents. Global warming has made the Arctic region more accessible and desirable. It is a complex region that is experiencing unprecedented changes. Based on long-term monitoring, it has been found that the Arctic is warming up much faster than expected, essentially due to Arctic amplification of the worldwide warming scenario. The Arctic holds the world's largest remaining oil and gas reserves, an enormous untapped mineral wealth.

A reduction in Arctic summer ice cover has become more intense in recent years, culminating in an area of a record low of 3.4 million square kilometres in 2012. Ice melting opens a place for new research and economic activities. It allows for exploring the possible amount of natural resources in the Arctic region.

The Arctic's responses to global change are too sensitive. It may be capable of initiating dramatic climatic changes through alterations induced in the oceanic *thermohaline circulation* by its cold, southward-moving currents or through its effects on the global *albedo* resulting from changes in its total ice cover.

Many scientific disciplines and engineering applications have significantly advanced based on the knowledge gained from polar research. Many of the discoveries that took place over Polar Regions have provided a critical understanding of direct benefit to humanity and served the society. It makes sense that access to the polar areas is fundamentally vital from its scientific viewpoints. Evidence continues to accumulate that the scientific value of the Arctic warrants significant investment for polar research. Sustained efforts must be on to continue and indeed flourish over the next several decades.

The Arctic Ocean is primarily surrounded by land and has difficult, terrain and adjacent shorelines. The ice and extreme weather conditions make it further challenging to reach. The logistics constraints make it difficult to conduct research on land and coastal areas; thus, such observations tend to be sparse.

Atmospheric processes in the Arctic are distinctive and scientifically significant. Among many, the transport and disposition of solar radiation, the formation and persistence of clouds, and variability in the atmospheric pressure fields exhibit large-scale patterns that influence the global climate.

A more detailed understanding and representation of these global climate models' processes are essential to improving future climate predictions. It requires intensive observations of the Arctic atmosphere over the oceans with specialised (ice breaker) vessel support.

Similarly, sea ice provides the interface between atmosphere and water, and it is one of the essential components of the system. Inadequate spatiotemporal observations limit our ability to describe the variability, change, and extremes of the polar region environment. Records of past environmental conditions, retrieved from paleo-archives such as ice cores or sediments, provide clues to nature's response to climate change force. Still, these too are incomplete, especially in terms of spatial coverage.

The Arctic Basin plays a pivotal role in the global carbon balance. Nonetheless, the mechanism by which this carbon is transported from the Arctic continental shelf to the deep basin is yet to be adequately understood.

The apparent changes are occurring in the intricate balance between Pacific's and Atlantic's waters. These may bring out a subtle change in the thermohaline profile features because the heat and salt balance prevents melting of surface ice.

The tectonics of ocean gateways, which allow passage of warm and cold currents between oceans, is useful for understanding climate changes in the Arctic region. India takes the honour to have a separate ministry dealing with the Earth System Sciences under which the entire gamut of polar science and logistics falls. Having acute concern on the global climate change issues and the significance both poles carry in a deeper understanding of the climate change system holistically, India opted to adopt a bipolar scientific approach by venturing into Arctic Science. The rich scientific and logistics experience gained through a glorified and meaningful journey of launching more than 40 annual scientific expeditions to the icy continent 'Antarctica' was an ambitious plan to launch unique scientific expeditions to the Arctic region addressing diversified climate-related issues apart from many other scientific objectives to be accomplished through Arctic Science. As a humble beginning, India deputed an exploratory team to visit the Arctic and establish tie-ups with the Norwegian colleagues as the site identified for India was the Norwegian territorial region. Having fruitful, supportive and healthy linkages with the Norway, India was initially allowed to use Norway's International Research Facilities at Ny-Ålesund, Svalbard. And a full-fledged Indian Arctic Research base namely 'Himadri' was finally set up in 2008 at Ny-Ålesund amidst the research bases of other participating countries. During this period, Indian researchers visited the Arctic a number of times in a year and conducted their exceptional dedicated experimentation to obtain observational data. Many significant studies have been undertaken by Indian Climate Scientists focusing on the Arctic Climate changes and their global relevance including Indian tropical climates, specialising in the Indian Summer Monsoon (ISM).

This book titled *Climate Change in the Arctic: An Indian Perspective* highlights some of the most exciting Arctic research conducted by Indian scientists ever since India entered the Arctic Science foray. Indian polar researchers have contributed to a wide range of disciplines, in a bid to get an insight into the essential information about Earth's systems and how they operate. Nevertheless, the research conducted by Indian scientists addressing various facets of the climate change occurring over the

Arctic region has exclusively been collated in 15 chapters to put forth Arctic climate changes through an Indian perspective.

Accordingly, **Khare** introduces the theme in the first chapter highlighting the overall climate change assessment over the Arctic through the Indian Polar Programme. Under Arctic Atmosphere Weather and Climate Change theme, **Maheskumar and Sunitha Devi** discuss in detail the Arctic weather and climate patterns, **Gwal et al.** investigate GPS-derived total electron content (TEC) and Scintillation Index for the Arctic and Antarctic Stations, and **Sonbawne et al.** monitor the atmospheric aerosols to help assess their sources and effects on Arctic climate.

To get an insight into the signatures of climate change through sediments, **Singh et al.** concentrate on the sedimentary parameters of the Arctic region in space and time to reconstruct past climatic conditions. On the contrary, **Choudhary et al.** have identified biogenic silica as an indicator of paleo productivity in lacustrine sediments of Svalbard, Arctic. They provide a comprehensive review of the studies that dealt with the biogenic silica over the Arctic region. **Tiwari and Megan Da Lima Leitao** touch upon the critical role of persistent organic pollutants and mercury in the Arctic environment. Also, they discuss about the indirect impact of these pollutants on climate change. Besides, **Gopikrishna et al.** studied the fjord sediments for their contamination and Implications for the Arctic Climate changes.

The impact of climate change on Arctic life has been assessed by **Hatha and Krishnan** who reported non-polar isolates in the Arctic fjords and Tundra and pointed out a warming trend in the Arctic environment. Simultaneously, **Jasmine Purushothaman et al.** concentrate on the Mesozooplankton community structure in Kongsfjorden, the Arctic, and assess impacts of climate changes through space and time. On the contrary, **Aswathy Shaji and Anu Gopinath** characterise the humic acids isolated from diverse Arctic environments.

The most critical aspect of the great potential Arctic microbes possess for pharmaceutical purposes lies in the biotechnological processes which have various characteristics. Such aspects have been detailed by **Dubey and Babel**. Interestingly, bio-optical characteristics in relation to phytoplankton composition and productivity in the Arctic fjord ecosystem have been highlighted by **Tripathy**.

In the Polar Regions, the present-day Circum-Arctic region comprises a variety of tectonic settings due to varied geophysical conditions: from active seafloor spreading in the North Atlantic and Eurasian Basin, and subduction in the North Pacific, to long-lived stable continental platforms in North America and Asia. A detailed account on the recent advances in seismo-geophysical studies conducted so far for the Arctic region in different tectonic environs has been provided by **Mishra et al.** in a bid to understand the efficacies of various geophysical and seismological tools.

On the contrary, **Luis and Roy** have addressed the impact of climate change on sea ice. They have studied the decadal Arctic Sea-Ice Variability to observe the pattern and its implication to climate change.

As Arctic Science advances, more and more challenging scientific questions will require sustained and continuous observations and measurements in the Arctic regions. It will help us understand the evolution of northern climates. Prediction of future changes can be based only on a full understanding of the Arctic and Antarctic systems.

This book collates recent scientific findings and sights related to the ongoing climate change in and around the Arctic region from the Indian perspective. This book will help satisfy the curiosity; usually, young minds carry. These youngsters and budding researchers will get an insight into the ongoing climate changes taking place over the Arctic region.

Neloy Khare
Date: June 2021
Place: New Delhi

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Neloy Khare
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Place: New Delhi

Editor

Dr Neloy Khare, presently Adviser/Scientist G to the Government of India at MoES, has a unique understanding not only of administration but also of quality science and research in his areas of expertise covering a large spectrum of geographically distinct locations like Antarctic, Arctic, Southern Ocean, Bay of Bengal, Arabian Sea, Indian Ocean, etc. Dr Khare has almost 30 years of experience in the field of paleoclimate research using palaeobiology and palaeontology/teaching/science management/administration/coordination for scientific programmes (including Indian Polar Programme). Dr Khare has completed his doctorate (Ph.D.) in tropical marine region and Doctor of Science (D.Sc.) in southern high-latitude marine regions.

Dr Khare has been conferred Honorary Professor and Adjunct Professor by many Indian universities. He has an awe-inspiring list of publications to his credit (125 research articles in national and international scientific journals; three special issues in national scientific journals as Guest Editor; edited a special issue of *Polar Sciences* as its Managing Editor). The Government of India and many professional bodies have bestowed him with many prestigious awards for his humble scientific contributions to past climate changes/oceanography/polar science and southern oceanography. The most coveted award is the Rajiv Gandhi National Award – 2013 conferred by the Honourable President of India. Others include ISCA Young Scientist Award, Boys Cast Fellowship, CIES French Fellowship, Krishnan Gold Medal, Best Scientist Award, Eminent Scientist Award, ISCA Platinum Jubilee Lecture, and IGU Fellowship. Dr Khare has made tremendous efforts to popularise ocean science and polar science across the country by delivering many invited lectures, giving radio talks, and publishing popular science articles. Many books authored/edited on thematic topics and published by reputed international publishers are testimony to his commitment to popularise science among the masses.

Dr Khare has sailed in the Arctic Ocean as a part of ‘Science PUB’ in 2008 during the International Polar Year campaign for scientific exploration and became the first Indian to sail in the Arctic Ocean.

Contributors

Priyanka Babel
Department of Biotechnology
Mohanlal Sukhadia University
Udaipur, Rajasthan

Purushottam Bhawre
Department of Physics
Govt. Sanjay Gandhi P.G. College
Ganjbasoda, India

Kailash Chandra
Protozoology Section
Zoological Survey of India
Kolkata, India

Shabnam Choudhary
National Centre for Polar and Ocean Research
Goa, India

Suryanshu Choudhary
Department of Physics
Rabindranath Tagore University
Raisen, India

Tara Megan Da Lima Leitao
National Centre for Polar and Ocean Research
Goa, India

P.C.S. Devara
Centre of Excellence in Ocean-Atmospheric Science and Technology and
Environmental Science and Health
Amity University Haryana (AUH)
Gurugram, India

Chetan Anand Dubey
Centre of Advanced Study in Geology
University of Lucknow
Lucknow, India

Rajesh Kumar Dubey
UGC-Human Resource Development Centre
JNV University Jodhpur
Rajasthan, India

Gopikrishna VG
School of Environmental Sciences
Mahatma Gandhi University
Kerala, India

Anu Gopinath
Department of Aquatic Environment Management
Kerala University of Fisheries and Ocean Studies
Kochi, India

A.K. Gwal
Department of Physics
Rabindranath Tagore University
Raisen, India

Kannan VM
School of Environmental Sciences
Mahatma Gandhi University
Kerala, India

Neloy Khare
Ministry of Earth Sciences
Govt. of India
New Delhi, India

Krishnan KP
National Centre for Polar and Ocean Research
Goa, India

Alvarinho Luis
National Centre for Polar and Ocean Research
Goa, India

R.S. Maheskumar
Ministry of Earth Sciences
Govt. of India
New Delhi, India

G. Meena
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

O.P. Mishra
National Centre for Seismology
New Delhi

A.A. Mohamed Hatha
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology
Kochi, Kerala

Mahesh Mohan
School of Environmental Sciences
International Centre for Polar Studies
Mahatma Gandhi University
Kerala, India

G N Nayak
Marine Sciences, School of Earth, Ocean and Atmospheric Sciences
Goa University
Goa, India

G. Pandithurai
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

Haritha Prasad
Protozoology Section
Zoological Survey of India
Kolkata, India

Priya Singh
National Centre for Seismology
New Delhi

Jasmine Purushothaman
Protozoology Section
Zoological Survey of India
Kolkata, India

Rasik Ravindra
National Centre for Polar and Ocean Research (Formerly)
Goa, India

Neelakshi Roy
National Centre for Polar and Ocean Research
Goa, India

and

Centre of Excellence for Natural Resources Data Management System, Department of Remote Sensing and GIS
Kumaun University
Almora, India

P.D. Safai
Cloud-Aerosol Interaction and Precipitation Enhancement EXperiment
Indian Institute of Tropical Meteorology
Pune, India

S.K. Saha
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

Aswathy Shaji
School of Ocean Science and Technology
Kerala University of Fisheries and Ocean Studies
Kochi, India

Anoop Kumar Singh
Centre of Advanced Study in Geology
University of Lucknow
Lucknow, India

Dhruv Sen Singh
Centre of Advanced Study in Geology
University of Lucknow
Lucknow, India

S.M. Sonbawne
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

Sunitha Devi S
India Meteorological Department
New Delhi, India

Anoop Kumar Tiwari
National Centre for Polar and Ocean Research
Goa, India

Sarat Chandra Tripathy
National Centre for Polar and Ocean Research
Goa, India

Abbreviation List

A.O.	Arctic Ocean
AAS	Atomic absorption spectrometry
ABL	Atmospheric boundary layer
AMDEs	Atmospheric mercury depletion events
AMAP	Arctic Monitoring and Assessment Programme
ANOVA	Analysis of variance
AQUA-GAPS	Global aquatic passive sampling
ASE	Accelerated solvent extraction
ATOS	Antarctic Tourism Opportunity Spectrum
BDL	Below the detection limit
BSTFA	N,O-Bis(trimethylsilyl)trifluoroacetamide
BTBPE	1,2-Bis(2,4,6-tribromophenoxy)ethane
BWP	Brake wear plastics
CA	California
CAA	Canadian Arctic Archipelago
CEC	Capillary electro-chromatography
CFCs	Chlorofluorocarbons
CG	Congeners in the gas phase
CUPs	Current-use pesticides
CVAFS	Cold vapour atomic fluorescence spectrometry
D.M.	Diabetes mellitus
DB_XLB	Type of GC column
DB-5	Type of GC column
DBA	Dibromoanisole
DCM	Dichloromethane
DDC-CO	Dechlorane plus
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DF	Detection frequency
DOC	Dissolved organic carbon
DPTE	2,3-Dibromopropyl-2,4,6-tribromophenyl ether
ECD	Electron capture detection
EDGARv4.tox2	Emission Database for Global Atmospheric Research v4.tox2
ENV	SPE Cartridge Bond Elut-ENV for extraction of polar residues
ESSO	Earth System Science Organisation
Et-FOSA	N-Ethyl perfluorooctane sulphonamide
Et-FOSEs	Ethyl perfluorooctane sulphonamido ethanols
ETHeBB	2-Ethyl-1-hexyl-2,3,4,5-tetrabromobenzoate
EVA	Ethylene-vinyl acetate copolymer
FLD	Fluorescence detection
FOSAs	Perfluorooctane sulphonamides
FTAs	Fluorotelomer acrylates

FTIR	Fourier transform infra-red spectrometry
FTOHs	Fluorotelomer alcohols
G.C.	Greenland Current
GC-MS or GC/MS	Gas chromatography-mass spectrometer
GEM	Gaseous elemental mercury
GFFs or GF/Fs	Glass fibre filters
GOM	Gaseous oxidized mercury
GRAHM	Global/Regional Atmospheric Heavy Metals
HBB	Hexabromobenzene 2,3-dibromopropyl-2,4,6-tribromophenyl ether
HCBs	Hexachlorobenzenes
HCH	Hexachlorocyclohexanes; Hexachlorocyclohexane
HDPE	High-density polypropylene
HFRs	Halogenated flame retardants
HNPs	Halogenated natural products
HP/H.P.	Hewlett Packard
HPLC	High-performance liquid chromatography
HS-SPME	Headspace solid-phase microextraction
HVS	High-volume samplers
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
ICP/OES	Inductively coupled plasma - optical emission spectrometry
ICP-AES	Inductively coupled plasma atomic emission spectrometry
L/minute	Litre per minute
LCCP	Long-chain chlorinated paraffins
LDPE	Low-density polyethylene
LOD	Loss on drying
LRAT	Long-range atmospheric transport
LVS	Low-volume sampler
MCCP	Medium-chain chlorinated paraffins
Me-FBSA	N-Methyl perfluorobutane sulphonamide
Me-FBSE	N-Methyl perfluorobutane sulphonamidoethanol
Me-FOSA	N-Methyl perfluorooctane sulphonamide
Me-FOSEs	Methyl perfluorooctane sulphonamido ethanols
MeHg	Methylmercury
MEKC	Micellar electrokinetic chromatography
merB, hgcA	Methylation genes and analogues
Mg/a1	Penetration of light/penetration depth unit
MMHG or MMHg	Monomethyl mercury
MoES	Ministry of Earth Sciences
MPs	Microplastics
MSD	Mass spectrometer detector
MSD GC-ECNI-MS	Mass spectrometer detector gas chromatography with electron capture negative ion mass spectrometry
NBFRs	New/novel brominated flame retardants

NCP	Northern Contaminants Programme
NCPOR	National Centre for Polar and Ocean Research
NEEM	North Greenland Eemian Ice Drilling
NIC	Nippon Instruments Corporation
NILU	Norwegian Institute for Air Research
NU	Nunavut
OBPs	Organo-brominated pesticides
OCPs	Organo-chlorinated pesticides
OCS	Oxidation of carbonyl sulphide
ODE	Ozone depletion events
–OH	Hydroxyl functional group
PAD-3	Type of polymer resin cartridge
PAHs	Polycyclic aromatic hydrocarbons
PBBz	Pentabromobenzene
PBDEs	Polybrominated diphenyl ethers
PBM	Particulate bromine mercury
PBT	Pentabromotoluene
PCBs	Polychlorinated biphenyls
PCDD/Fs	Polychlorinated dibenzo-p-dioxins and furans
PCI	Positive chemical ionization
PDM	Pic du Midi
PFAAs	Perfluoroalkyl acids
PFAS	Polyfluoroalkyl substance
PFBA	Perfluorobutyrate; Perfluorobutanoic acid
PFBS	Perfluorobutanesulphonic acid
PFCAs	Perfluorinated carboxylates
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanesulphonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulphonic acid
PFRs	Organophosphorus flame retardants
PFSAs	Perfluoroalkyl sulphonic acids
PFTE	Polytetrafluoroethylene
pH	Potential of hydrogen
PL	Pacific Mode Layer
PML	Polar mixed layer
POPs	Persistent organic pollutants
PPE	Polypropylene
PUFs	Polyurethane foams
QM-A	High-purity grade for particulate matter 10 sampling and analysis
RGM	Reactive gaseous mercury
SBSE	Stir bar sorptive extraction
SCCP	Short chain chlorinated paraffins
SFC	Supercritical fluid chromatography

SIM	Selected ion monitoring
SOAs	Secondary organic aerosols
SOM	Soil organic matter
SPE	Solid-phase extraction
SPSS	Statistical software
SVOCs	Semi-volatile organic compounds
TBA	Tribromoanisole
TBPH	Bis(2-ethyl-1-hexyl) tetrabromophthalate
TCMX	2,4,5,6-Tetrachloro-m-xylene
TGM	Total gaseous mercury
THg	Total mercury
TLC	Thin-layer chromatography
TMS	Trimethylsilyl
TWP	Tyre wear plastics
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
XAD	Adsorbent resin for dioxins and furans

1 Climate Change Assessment over the Arctic Region

Initiatives through Indian Polar Programme

Neloy Khare
Ministry of Earth Sciences

CONTENTS

The Arctic Ocean, surrounding the North Pole, which consists of a large ocean surrounded by land, is like no other ocean on earth because of its unique location and climate. It is the region above the Arctic Circle (at approximately 66° 34′N). The sun does not set on the *summer solstice* and does not rise on the *winter solstice* above the Arctic Circle.

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The industrial revolution produced an excess of carbon dioxide and other greenhouse gas emissions. The rising temperatures in the Polar regions result in the rapid melting of the glaciers. The glaciers are diminishing from the land, calving off into the sea (http://www.sciencemag.org/news/2013/08/scienceshot). The impact of changing climate over the Arctic region is reflected in the Arctic amplification and reflected by the Arctic Ocean's shrinking sea ice cover in summer. Decrease in the snow cover over land in the Arctic, especially in spring, and glaciers in Alaska, Greenland and northern Canada is retreating. The permafrost, also known as the frozen ground in the Arctic, is thawing due to warming. Scientists began gathering evidence of changes in Arctic climate since the 1980s, which have become much more pronounced. The Arctic is experiencing unprecedented extremes in sea ice, temperature and precipitation, which remained unreported in the historical records and emerged as an enigma of climate mystery. Indubitably global warming has severely impacted the Arctic's climate, with many strange climatic events such as witnessing a rainy season almost equal to India's and up to 10 months without snow.

Since the late 1970s, the sea ice in the Arctic has decreased dramatically. According to National Snow and Ice Data Center, the Arctic summer sea ice extent in September 2012 was a record low, shown (in white) compared to the median summer sea ice extent for 1979–2000 (shown in orange) (Figure 1.1).

Climate change is a reality and has exhibited dramatic patterns across the Arctic (The National Oceanic and Atmospheric Administration (NOAA) and its partners – Annual Arctic Report Card – 2019). Some salient findings of this report (https://arctic.noaa.gov/Report-Card/Report-Card-2019) are enumerated below:

- The average annual surface air temperature in the Arctic from October 2018 through August 2019 was the second warmest in the observational record. Satellite recorded the second-lowest Arctic sea ice extent in 2019.

FIGURE 1.1 The Arctic summer sea ice extent measured in 2012 (white outline) compared with the observed changes from 1979 to 2000 (orange outline). In 2013, the Arctic summer sea ice extent rebounded somewhat but was still the sixth smallest extent on record. (Source: National Snow and Ice Data Center)

- The Bering Sea saw record low winter sea ice in 2018 and 2019.
- Birds are being affected, including the breeding population of ivory gull in the Canadian Arctic falling 70% since the 1980s.
- Greenland's ice sheet also experienced rapid melting in 2019, beginning earlier than usual and reaching 95% of the surface.

Arctic's climate changes are significant because the Arctic acts as a barometer of global climate change. Such ongoing changes in the Arctic climate harm the food chain, including phytoplankton and many marine mammals. It includes seals, walrus, whales, and polar bears. Well-known feedback mechanism acting in the Arctic region may lead to further warming. The Arctic *amplified response* to global warming is the repercussion of global temperature rise. Consequently, Greenland's ice sheet is shrinking drastically at an alarming rate (http://news.uga.edu/releases/article/study-2015-melting-greenland-ice-faster-arctic-warming-0616/, Tedesco et al. 2016).

1.1 FEEDBACK MECHANISM AND ARCTIC AMPLIFICATION

Due to sea ice melting in summer, dark open water areas are exposed, absorbing more heat from the sun (Figure 1.2). More ice melts due to excess heat. The sea ice's loss is one of the Arctic amplification drivers (Figure 1.3) (Slivka 2012; Goldenberg 2012). Permafrost may also play a role in positive feedbacks. As the thawing of permafrost starts, plants and animals frozen in the ground begin to decay. Their decomposition releases carbon dioxide and methane back to the atmosphere. It can further induce warming. The shifting Arctic vegetation also affects the surface brightness and adds up to warming. More water vapour is held up due to more warming of the

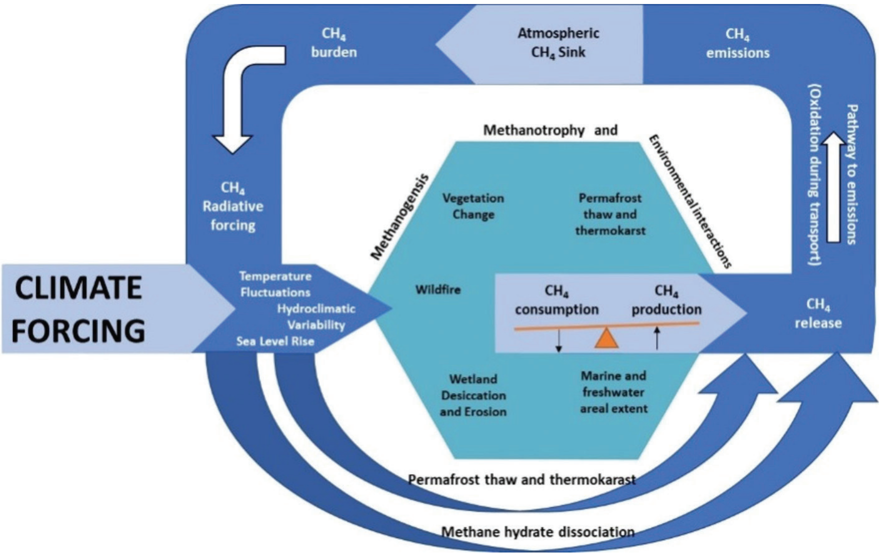

FIGURE 1.2 Feedback mechanism at the Arctic.

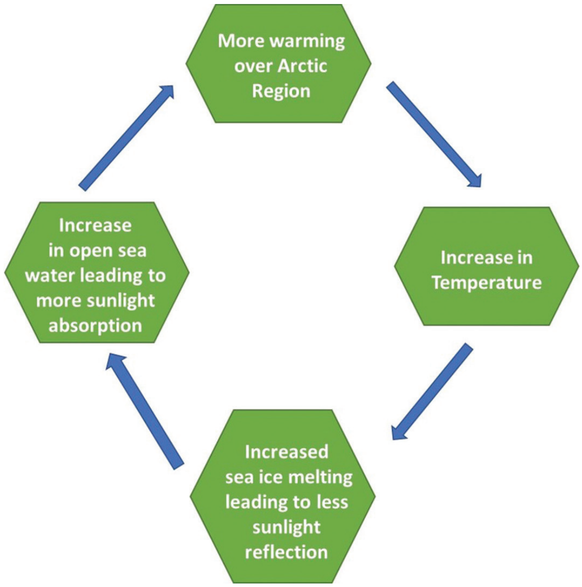

FIGURE 1.3 Arctic amplification.

Arctic atmosphere, which is an important greenhouse gas (Slivka 2012; Goldenberg 2012). In the Arctic, warming is causing further warming in the following manner.

There is no doubt that global warming tends to increase temperatures in the Arctic. It tends to melt ice, decreasing the area covered by sea ice and expanding the scope of darker exposed ocean, which tends to reduce sunlight reflection, as ice is far more reflective than the newly exposed Ocean. It tends to increase the sunlight that is absorbed by the sea. It tends to add to global warming, and the cycle repeats.

Other feedbacks from the loss of Arctic Ocean ice, ranging from a possible slowdown of the so-called "global ocean conveyor belt" to significant shifts in the northern hemisphere's jet stream, could also have severe climatic impacts.

The main consequences of global warming on the Arctic are the increase in temperatures (air and sea), *loss of sea ice* and melting of the *Greenland ice sheet* with a related *cold temperature anomaly*, observed since the 1970s (Foster 2012; Slivka 2012; Goldenberg 2012). Ongoing climate change over the Arctic region is also expected to impact ocean circulation changes, increased input of freshwater (Graeter 2018; Rabe et al. 2011) and ocean acidification (Qi et al. 2017), potential methane releases through the thawing of *permafrost* and methane clathrates (Schuur et al. 2015).

It has also been postulated that due to the potential climate teleconnections to mid-latitudes, these regions are expected to witness a greater frequency of extreme weather events (flooding, fires and drought) (Cohen et al. 2014). It will lead to ecological, biological and phenological changes. Other factors include physical migrations and extinctions (Grebmeier 2012), natural resource stresses, human health, displacement and security issues.

1.2 INDIA AND THE ARCTIC

India's engagement with the Arctic dates back to a century. It was in 1920 when British overseas Dominions signed the Treaty with other signatories like the US, Denmark, France, Italy, Japan, the Netherlands, Norway, Great Britain, Ireland and Sweden concerning Spitsbergen's 'Svalbard Treaty' in February 1920 in Paris.

India has been closely following the Arctic region's developments in the backdrop of the emerging opportunities and challenges due to the global warming-induced melting of the Arctic ice cap. Science, environment, commerce and strategy are the main concerns of India in the Arctic region.

India paved its way in the Arctic by launching a research programme in 2007 to thrust on climate change in the circumpolar north. The primary objectives of the Indian research in Arctic region are as follows:

1. To study the hypothesised teleconnections between the Arctic climate and the Indian monsoon by analysing records archived in the sediment and ice cores from the Arctic glaciers and the Arctic Ocean.
2. To characterise sea ice in the Arctic using satellite data to estimate the effect of global warming on the northern Polar region.
3. To research Arctic glaciers' dynamics and mass budget focusing on the impact of melting glaciers towards sea level changes.
4. To assess the Arctic flora and fauna vis-à-vis their response to anthropogenic activities. Besides, a bi-polar comparison is proposed to be undertaken in life forms.

India launched its first scientific expedition to the Arctic Ocean in 2007. A research base named "Himadri" was established at Ny-Ålesund, Svalbard, Norway, in July 2008 for researching disciplines like glaciology, atmospheric sciences and biological sciences. The area used for the Indian research base is the International Arctic Research Base at Svalbard. A Memorandum of Understanding (MOU) has also been signed with the Norwegian Polar Research Institute of Norway, for cooperation in science, as even with Kings Bay (a company of the Norwegian Government) Ny-Ålesund. It provides logistics and infrastructure facilities for undertaking Arctic research and maintaining the Indian research base 'Himadri' in the Arctic region.

Several scientists from various national institutions have participated in our Arctic programme. India became a member of the Council of the International Arctic Science Committee (IASC) in 2012. India's claim for Observer Status received attention in 2012 with widespread support from all member countries. In recognition of India's commitment and sustained interest in Arctic science, during the Eighth Biennial meeting of the Arctic Council held in Kiruna, Norway on 1 May 2013, under Sweden's Chairmanship, India was provided Observer Status to the Arctic Council.

1.3 BLACK CARBON

In contrast to most atmospheric aerosols, black carbon (BC) aerosols are good candidates for absorbing solar radiation. Due to such absorption, a warming effect on the planet is perceived. On the contrary, other aerosols such as sulphate aerosols provide the cooling effect due to scattering. BC aerosols play a critical role in affecting the climate system by changing and heating the clouds (semi-direct effect) or acting as cloud condensation nuclei (indirect effect). BC aerosols have emerged as third among the most extensive human-generated causes. CO_2 and CH_4, having a present-day radiative forcing of ~0.40 W/m^2 which is ~25% more of the pre-industrial period (Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2014).

Despite its importance, only a few modelling studies have addressed BC aerosols' effectiveness in warming the planet relative to CO_2 forcing (e.g. Roberts and Jones 2004; Cook and Highwood 2004; Hansen et al. 2005; Stjern et al. 2017; Smith et al. 2018). The results indicate that the BC aerosols are less effective in warming the earth than CO_2 (Yoshimori and Broccoli 2008). The concept of 'efficacy' to measure forcing agents' effectiveness was introduced by Hansen et al. (2005). The efficacy of BC aerosols emitted by burning of fossil fuel and biomass was 0.930 and 0.80, respectively, when effective radiative forcing (ERF) definition is used to estimate the radiative forcing (Hansen et al. 2005). This cloud enhancement in the lower troposphere dramatically reduces the direct warming effect of the BC aerosols. Stjern et al. (2017) found that multi-model median efficacy of the BC aerosols is less than one (0.80).

The decrease in efficacy with BC aerosols' altitude has been found in some recent studies (Ban-Weiss et al. 2012; Samset and Myhre 2015). Ban-Weiss et al. (2012) showed that near-surface BC aerosols cause warming. On the contrary, when BC aerosols are at heights, the varying climate response from BC aerosols at different sizes arises primarily due to various fast climate adjustments. These are defined as the climate response before any change in the average surface temperature globally (Bala et al. 2010; Ban-Weiss et al. 2012). BC warms the surface through diabatic heating. At heights in increased longwave radiation without heating the body, the absorbed solar radiation is lost to space. We note that the efficacy decreases with the size of BC aerosols. BC aerosols' efficiency to exert more significant radiative forcing due to the direct aerosol effect strengthens with altitude (Samset and Myhre 2011, 2015).

Because of the above, it may be postulated that the in-modulating Arctic Climate BC aerosols play an influential role in further strengthening the feedback mechanism, leading to Arctic amplification, and therefore a detailed investigation on this aspect must be made.

The consequences of the impact of rapid changes in the Arctic region go beyond the coastal states. To respond to such challenges warrants the active participation of all those actors who have a stake in global commons' governance. It requires a legitimate and credible mechanism. The interplay between science and policy can significantly contribute to addressing the complex issues facing the Arctic. India, which has significant expertise in polar research matters due to its long experience of launching annual scientific expeditions to the Antarctic and association with the Antarctic Treaty System, can play a constructive role in securing an influential position in Arctic affairs. As a permanent observer in the Arctic Council, India is committed to contributing to evolve and strengthen the effective cooperative partnerships that can contribute to a safe, stable and secure Arctic.

The warming of the Arctic region has recently gained worldwide attention due to its projected impacts on the global climate system. The effect of anthropogenic BC aerosol on snow is of enduring interest due to its role in aerosol radiative forcing (ARF) and further consequences for the Arctic and global climate changes. Having demonstrated its sincere pursuit of Arctic science ever since the Indian research base is set up at Ny-Ålesund (Svalbard), India has been continuously generating data on BC aerosol over the Arctic region. MoES-Indian Institute of Tropical Meteorology (IITM), Pune (India), participated in the Arctic expedition to study BC over the Himadri research base, Ny-Ålesund. Similarly, CSIR-National Physical Laboratory, New Delhi (India), participated in the Arctic expedition to measure the concentration of carbon monoxide (CO) over the Arctic region to compare it with the CO concentration in the Antarctic area. We discuss here briefly some of the Indian contributions to the assessment of BC and CO in a bid to help understand Arctic climate change and associated amplification vis-à-vis its teleconnection with the tropical countries like India.

1.4 ASSESSMENT OF BLACK CARBON AEROSOLS AND SOLAR RADIATION OVER HIMADRI, NY-ÅLESUND

India ventured into assessing the BC and measuring solar spectral at 'Indian Arctic Station, Himadri', Ny-Ålesund, during 2011–2014. The contribution from long-range transport of pollutants from far-away places is found to dominate the local sources such as emissions from shipping and power plants to the annual cycle with maximum BC mass concentration during winter/early-spring season and minimum during the summer season. Moreover, higher BC concentrations were observed during 2012 as compared to other years during the study period. The aerosol optical depth's (AOD) spectral variations observed during the summer months indicate an immense contribution of fine-mode aerosol particles to the BC mass concentration, particularly during 2012. Further, the zenith skylight spectra in the spectral range of 200–1100 nm indicate maximum particle scattered intensity around 500 nm (Dr. S.M. Sonbawne, personal communication). These results play a vital role in the earth-atmosphere radiation balance and hence exhibit profound influence on regional and global climate changes (Stohl et al. 2013).

Raju et al. (2011) attempted to study the BC radiative forcing over the Indian Arctic Station, Himadri, during the Arctic summer of 2012 by using an aethalometer. Measurements of BC aerosols were carried out continuously over the Indian Arctic Station, Himadri, during the Arctic summer (23 July to 19 August) of 2012. The monthly mean BC mass concentration during July and August was 0.093 ± 0.046 and 0.069 ± 0.050 μg/m^3, respectively. BC mass concentration showed maximum loading during 0800–1600 LT. Transport from distant sources (as observed from air mass back trajectories) apart from some local anthropogenic activities (emissions from shipping and power plants) could be the possible sources for the observed BC concentration at Himadri. Using the OPAC and SBDART models, optical properties and ARF in the spectral range of 0.2–4 μm for composite aerosol and without-BC aerosol at the top of the atmosphere, surface and atmosphere were computed. The presence of BC resulted in positive radiative forcing in the atmosphere leading to a warming effect (+2.1 W/m^2), whereas cooling was observed at the top of the atmosphere (−0.4 W/m^2) and surface (−2.5 W/m^2). BC formed about 57% of atmospheric ARF.

1.5 PRODUCTION OF CARBON MONOXIDE FROM ICE PACKS

Carbon monoxide is the most critical atmospheric gas which is produced due to the combustion of fossil fuel. It is also produced in large amounts by industries and motor vehicles. Carbon monoxide is a poisonous gas that has a short composition in the atmosphere. The hydroxyl radical (OH) gets combined with it chemically and converts it into non-poisonous material. It helps in monitoring the quantity of the hydroxyl compound. Hydroxyl being an oxidiser controls the composition of many greenhouse gases of the atmosphere. Recent studies show that carbon monoxide is continuously produced and liberated in large amounts in glacier areas. Indian scientists also conducted experiments related to carbon monoxide at Indian Research Centre, Maitri, situated in Antarctic Islands. With the help of various experiments, they know about the regular production cycle of carbon monoxide because of regular consideration of solar actinic rays. Consequently, scientists realised that carbon monoxide production is due to a photochemical reaction in Antarctic glaciers (Dr B.C. Arya, personal communication).

It is considered that some organic materials, like formaldehyde (HCHO), that are entrapped in ice crystals are decomposed through photochemical reactions and produced CO. Carbon monoxide, oxygen, nitrogen oxide analyser, solar photometer, portable climate centre, pyrometer, etc. are the main instruments on which experiments are generally conducted in Polar regions.

Indian scientists performed various experiments to produce carbon monoxide from snowpacks and came to know about the regular alterability in carbon monoxide production in Ny-Ålesund in 2008, especially in March and August. Despite all, Indian scientists also measured the concentration of BC, the size, distribution and composition of aerosols, and the amount of water vapour in the atmospheric air of Ny-Ålesund. In the summer of 2008, ozone analyser was used to measure surface ozone concentration (Dr B.C. Arya, personal communication).

Lucknow University, Lucknow, Birbal Sahni Institute of Paleosciences, Lucknow, Jawahar Lal Nehru University, New Delhi, Indian Institute of Technology, Kharagpur, Wadia Institute of Himalayan Geology, Dehradun, and MoES-National Centre for Polar and Ocean Research, Goa, among many others, have participated in the research and contributed to the understanding of climate change in the Arctic regions and its global impacts. Some of the significant Indian initiatives to address climate change issues impacting Arctic regions are detailed below.

1.6 CLIMATE CHANGE AND ARCTIC GLACIERS

Many changes of glaciers of the Arctic have been noticed in previous years. Indian scientists have also shown much interest to get information related to these changes in glaciers. They have studied West Craig, Borger, and Mindralavan Glaciers in this reference.

1.7 GEOMORPHOLOGY AND SEDIMENTOLOGY OF DIVERSIFIED MORPHOLOGICAL ZONES OF GLACIATED TERRAIN OF THE NY-ÅLESUND

Diversified surface processes of the Ny-Ålesund region carve the landscape and exhibit distinguished Arctic's landforms. Many studies are done on climate change using various proxies. Yet, meagre attention has been paid to geomorphological and sedimentological parameters. Sediment characteristics, AMS^{14}C dates and geomorphic features have been used to reconstruct paleoclimate. Based on the landforms and sediments, this region has been classified into five morphological zones: glacial (moraines GL), proglacial (lacustrine deposits LD), outwash plain (sand deposits OWP), fluvial deposits (FD) and coastal cliff (CC). The glacial moraines (GL) suggest devoid of any sedimentary structures and coarse-grained, matrix-supported boulders, and it is composed of unconsolidated, unstratified, massive.

In contrast, OWP, LD, FD and CC are semi-consolidated, stratified, fine-grained layers of sand, silt, and clay with gravels and faint sedimentary structures. CC's and LD's sediments are very poorly sorted, very positively skewed and very leptokurtic, and is comprised of medium to fine sand, silt and clay. The sediment characteristics of various morphological zones' geomorphic features explain that this region was carved and dominated by glaciers (Prof. D.S. Singh, personal communication).

The poorly sorted sediments of all the geomorphological zones explain the depositional environment's fluctuating energy, especially under warm climate at interglacial stages during 44, 27, 12, 10.5 ka BP. It may be inferred that the prevailing environment was not consistent and persistent for an extended period (Schuur et al. 2015).

1.8 QUARTZ GRAIN MICROTEXTURE AND MAGNETIC SUSCEPTIBILITY ASSESSMENT OF THE NY-ÅLESUND REGION

The quartz grain microtexture reveals predominant glacial activities in the top 40 cm of the section, while the middle 40–55 cm part represents some aeolian activities along with glacial signatures. The bottommost part, in addition to glacial markers, exhibits some aqueous evidence as well. The lithology shows medium-grained sand in the upper leg and coarse-grained sand with occasional shell pieces in the lower leg. Angular gravels (2–12 mm) are present throughout with increasing size from top to bottom. Based on the above observations and ^{14}C AMS dates, it can be summarised that after the Last Glacial Maximum (LGM), the pre-Holocene period shows rapid glacial retreat, followed by a warmer period during the early Holocene. Mid- and late Holocene is marked by a predominantly glacial environment characterised by meltwater streams originating from the glaciers and flowing into the fjord. Magnetic susceptibility studies have also been attempted. Four alternate stages of colder and warmer phases have been established (Dr R. Kar, personal communication). Though some similarities among the different climatic phases are discernible between the quartz grain microtexture and magnetic susceptibility studies, they are not entirely compatible, probably due to their different responses to the climatic variations (http://www.sciencemag.org/news/2013/08/scienceshot-arctic-warming-twice-fast-rest-world).

Indubitably, the sea ice is frozen ocean water that grows and melts in the ocean. On the contrary, icebergs, glaciers and ice shelves float in the sea, having originated on the land. Sea ice is typically covered with snow, and Arctic sea ice keeps the Polar regions cool. It also helps modulate and control the global climate. Having a bright surface, 80% of the sunlight that strikes sea ice gets reflected into space. As sea ice melts in the summer, it exposes the dark ocean surface. Therefore, instead of reflecting 80% of the sunlight, the ocean absorbs 90% of the sunlight. Thus, the oceans heat up, and Arctic temperatures rise further.

A slight rise in temperature at the poles leads to still more significant warming over time, thus making the Polar regions the most sensitive areas to a subtle change in earth's climates. Accordingly, both the thickness and extent of the Arctic's summer sea ice have shown a dramatic decline over the past 30 years, consistent with observations of a warming Arctic. The loss of sea ice can also accelerate global warming trends and change climate patterns.

Sea ice extent is a measurement of ocean area where there is at least some sea ice. Usually, scientists define a minimum concentration threshold to mark the ice edge; the most common cut-off is 15%.

The Arctic sea ice extent is focused more closely than other aspects of sea ice because satellites measure the volume more accurately than other measurements, such as thickness. The Arctic's sea ice minimum is considered when the Arctic's sea ice exhibits the lowest areal extent. It occurs at the end of the summer melting season. The Arctic sea ice maximum is regarded as the day of the year when Arctic sea ice reaches its most considerable areal extent. It occurs at the end of the winter cold season.

1.9 REMOTE SENSING OBSERVATIONS AND MODEL REANALYSIS

Applications of remote sensing techniques and modelling have been applied to assess and quantify the Arctic sea ice loss in July–September, with particular attention to September on a daily, monthly, annual and decadal basis.

Coincidently, the 12 lowest extents in the satellite era occurred in the last 12 years. It is attributed to the impacts of land-ocean warming and the northward heat advection into the Arctic Ocean over the past 40 years (1979–2018); actual warming rates have been identified in the Arctic Ocean in the last 40 years. The study demonstrates the linkages of sea ice dynamics to ice drifting and accelerated melting. It occurs due to persistent low pressure and high air-ocean temperatures, supplemented by the coupled ocean-atmospheric forcing (http://news.uga.edu/releases/article/study-2015-melting-greenland-ice-faster-arctic-warming-0616/). The accelerated decline is recorded in the Arctic sea ice extent and sea ice concentration over the past four decades.

The ocean-atmosphere coupled mechanism plays a vital role in the global climate change. Sea ice variability and trends were computed using satellite and model reanalysis measurements for the whole Arctic and each of its nine regions: (i) Seas of Okhotsk and Japan, (ii) the Bering Sea, (iii) Hudson Bay, (iv) the Baffin Bay/Labrador Sea, (v) Gulf of St. Lawrence, (vi) Greenland Sea, (vii) Kara and Barents Seas, (viii) the Arctic Ocean and (ix) Canadian Archipelago. Overall, Arctic sea ice declined in all seasons and on a yearly average basis, although the highest and lowest negative trends were recorded in summer and winter/spring, respectively. The study reveals that the Arctic Ocean, Kara and Barents Seas, the Greenland Sea, and the Baffin Bay region are majorly responsible for the total negative sea ice extent trend in the Arctic (Dr. Avinash Kumar, personal communication). The study demonstrated the interannual and seasonal variabilities of Arctic sea ice and interactions among the atmosphere, ice and ocean (Tedesco et al. 2016).

1.10 ASSESSMENT OF SPATIO-TEMPORAL VARIABILITY OF SNOWMELT ACROSS SVALBARD

Indian researchers have monitored snowmelt over the Svalbard region as significant changes in the interannual variation of Arctic snow and sea ice are connected to the global climate changes using active microwave sensors. These sensors are frequently used to detect surface melting because of their sensitivity to the presence of liquid water in snow/ice. Data of QuikScat, OSCAT, ASCAT, and OSCAT-2 are used to map the annual melt duration and summer melt onset for the Svalbard archipelago. It provides one of the most extended and continuous radar backscatter records to estimate snowmelt onset and melt duration on Svalbard spanning from 2000 to 2017. A single threshold-based model was used to detect snowmelt timing; the threshold was calculated using meteorological data from the human-crewed weather stations. The results capture the timing and extent of melt events caused by warm air temperature and precipitation because of the influx of moist, mild air from the Norwegian and Barents seas. The highest melt duration and earlier melt onset occurred in southernmost and western Svalbard in response to the influence of the warm west Spitsbergen current. Compared to previous studies, we found considerable interannual variability and regional differences. Though the record is short, there is an indication of an increasing trend in total days of melt duration and earlier summer melt onset date possibly linked to the general warming trend (Dr A.J. Luis, personal communication). Climate indices such as Interdecadal Pacific Oscillation and Pacific Decadal Oscillation are well correlated with onset melt and duration across Svalbard. With the reported year-after-year decrease in sea ice cover over the Arctic Ocean, the trend towards longer snowmelt duration inferred from this study is expected to enhance the Arctic amplification (McCarthy 2011).

1.11 ASSESSMENT OF MASS BALANCE OF THE ARCTIC GLACIERS

Prof. A.L. Ramanathan (personal communication) studied the changes in the area from 1993 to 2018 and mass balance of Vestre Broggerbreen glacier, Ny-Ålesund, Arctic from 2011 to 2017. The glaciated area had decreased from 3.96 km^2 in 1993 to 3.57 km^2 in 2018. Its range varied between 0.011 and 0.02 km^2, resulting into a total area loss of 0.39 km^2 (~10% at 0.016 km^2 a-**1**). A comparatively rapid decrease in the glaciated area was found during 1998–2010 (0.02 km^2 a-1), whereas less retreat rate was found in 1993–1998 (0.011 km^2 a-1) and 2010–2018 (0.012 km^2 a-1 13). The Vestre Broggerbreen glacier's mass balance was negative throughout the entire study period (2011–2018). Mass balance ranged between −0.08 (2013–14) and −1.22 m w.e. (2015–2016) with a cumulative mass balance of −4.31 m w.e. (0.016 km^2 a-1). A strong relationship between mass balance and summer temperature was found with $R^2 = 0.97$ at $P < 0.05$ (Rajmund 2007).

1.12 SCIENTIFIC EXPLORATION OF KONGSFJORDEN

Kongsfjorden, an icy archipelago with a length of about 40 km and a width ranging from 5 to 10 km, is a glacial-fjord in the Arctic (Svalbard) which lies in the N-W coast of Spitsbergen, the main island of Svalbard. It is a site where warmer waters of the Atlantic meet the colder waters of the Arctic. An open fjord without a sill is primarily under the influence of the adjacent shelf processes. The Transformed Atlantic Water (TWA) from the west Spitsbergen current and the glacier-melt freshwater at the inner fjord create intense temperature and salinity gradients along the fjord's length. Southerly winds will result in down-welling at the coast. Such winds also hinder the exchange processes that take place between the shelf and the fjord, while the northerly winds will move the TWA water below the upper layer towards the coast. During summer, the meltwater not only stratifies the upper water column but significantly alters the turbidity.

It also impacts the seasonal changes in the biomass of phytoplankton. Thus, any altered interaction between the Atlantic water and the (turbid) meltwaters from tidal glaciers on a seasonal to interannual timescale is likely to affect the fjord's aquatic ecosystem. The long-term changes in the fjord hydrography and sedimentation will affect the benthic ecosystem.

Against the above backdrop of the fjord system's climate sensitivity, India has evolved a multi-institutional programme of long-term monitoring of the Kongsfjorden. It was initiated by the deployment of an ocean-atmosphere mooring system along regular repeat transects. It was designed to measure seasonal physical, chemical and biological parameters to establish a long-term comprehensive data set on physical, chemical, biological and atmospheric measurements. The influence of interaction between the warm Atlantic water and the cold glacial-melt fresh water and their effects on the biological productivity and phytoplankton species composition and diversity within the fjord are equally essential to be addressed.

1.13 DEPLOYMENT OF UNDERWATER MOORED OBSERVATORY IN THE KONGSFJORDEN FJORD

The Kongsfjorden is a natural laboratory. It is ideal for studying Arctic climate variability. Scientists predict that the melting of the Arctic glaciers will trigger patterns of weather and ocean circulations. Such changes could affect the climate of other parts of the world. One of the significant limitations in the logistics has been to reach the location and collect data, especially during the severe Arctic winter. The IndARC observatory is an attempt to overcome this lacuna. Data collected by IndARC would be used for climate modelling studies to understand the Arctic processes that influence Indian monsoons. The IndARC, the country's first underwater moored observatory deployed in the Kongsfjorden fjord, halfway between Norway and the North Pole, represents a significant milestone in India's scientific endeavours in the Arctic region. The engineers and scientists from the MoES-National Centre for Polar and Ocean Research (NCPOR), MoES-National Institute of Ocean Technology (NIOT) and MoES-Indian National Centre for Ocean Information Services (INCOIS) developed the IndARC. It was deployed from *RV Lance*, a research vessel belonging to the Norwegian Polar Institute. The observatory is moored and anchored at a depth of 192 m. It has an array of 10 state-of-the-art oceanographic sensors strategically positioned at various depths in the water. The sensors were programmed to collect real-time data on seawater temperature, salinity, ocean currents and other vital parameters of the fjord (https://ncpor.res.in/).

The correlation between less and more ice in the Arctic is very close to how the monsoon behaves. Just as we know that the *El Nino effect* (hot ocean temperatures in the Equatorial Pacific) is having a global impact on weather patterns, including the Indian monsoon, we learn that the Arctic ice also has a significant effect. The Arctic precipitation and temperatures from June to October hint at the monsoon likely to occur in the coming year. The oscillation in the air creates the western disturbance as it moves over ice and snow in the Arctic. If there is less oscillation, the air will have less moisture, leading to less rainfall in the monsoons.

1.14 EXPLORING TELECONNECTION BETWEEN ARCTIC CLIMATE AND TROPICAL INDIAN MONSOON

The climate change over the Arctic region and North Atlantic shows a mechanistic link with the Indian Summer Monsoon (ISM) during the Holocene. The marine and continental archives of ISM precipitation suggest significant shifts during the Holocene aligned with the Arctic climate over multi-time scales. The ISM strengthened during the Greenlandian (11.7–8.3 kyr BP), showing variable but overall decreasing precipitation during the Northgrippian (8.3–4.2 kyr BP). Synchronicity exists in palaeoclimatic records. It could be due to possible age errors and resolution and proxy response to the changing climate. During the Meghalayan age (4.2 kyr to recent), the Indian subcontinent witnessed a protracted dry event beginning at ~4.2 kyr BP and ended at ~3.4 kyr BP. Other significant events of the Meghalayan age include the Medieval Climate Anomaly (MCA). The Current Warm Period (CWP) showing a strong ISM, interrupted by the Little Ice Age (LIA) – a cold phase with low precipitation in the Indian subcontinent (Prof. A.K. Gupta, personal communication). The millennial-scale variability in the ISM is associated with the Heinrich and Bond events. The cooling in the Arctic sea, ice expansion in the North Atlantic and weakening of the Atlantic overturning meridional oscillations due to high freshwater flux and ice rafting in the North Atlantic caused weak ISM precipitation over the south and southeast Asia (http://www.rivm.nl/en/Documents_and_publications/Common_and_Present/Newsmessages/2016/Documentary_Sea_Blind_on_Dutch_Television).

In conclusion, we may submit that India is striving to obtain deep insight into the climate changes occurring over the Arctic region as its impacts are expected to influence Indian climate. Sustained monitoring and observational network shall be an added advantage to strengthen our understanding of Arctic climate and its teleconnection with Indian monsoons.

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Bio-Optical Characteristics in Relation to Phytoplankton Composition and Productivity in a Twin Arctic Fjord Ecosystem during Summer

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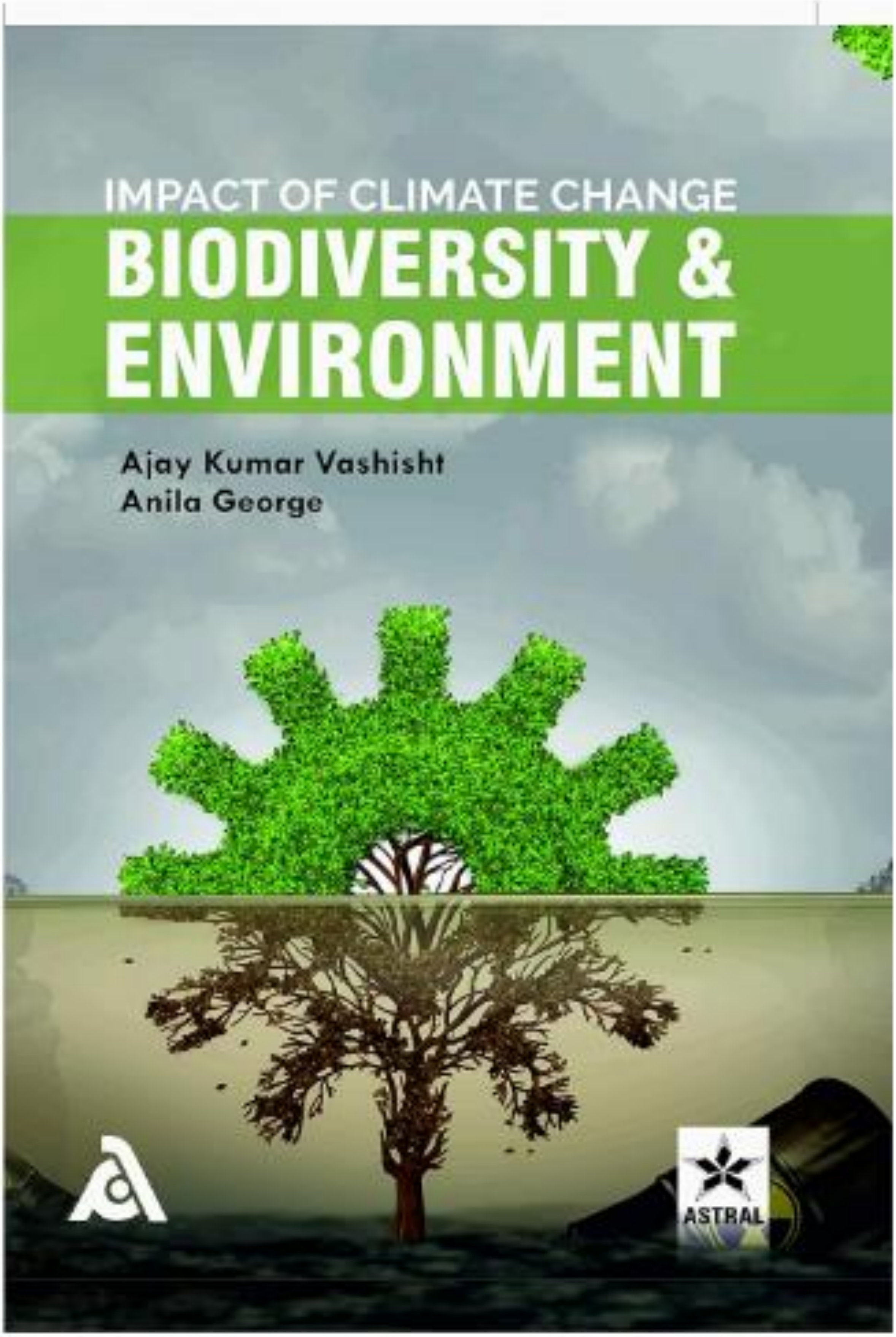
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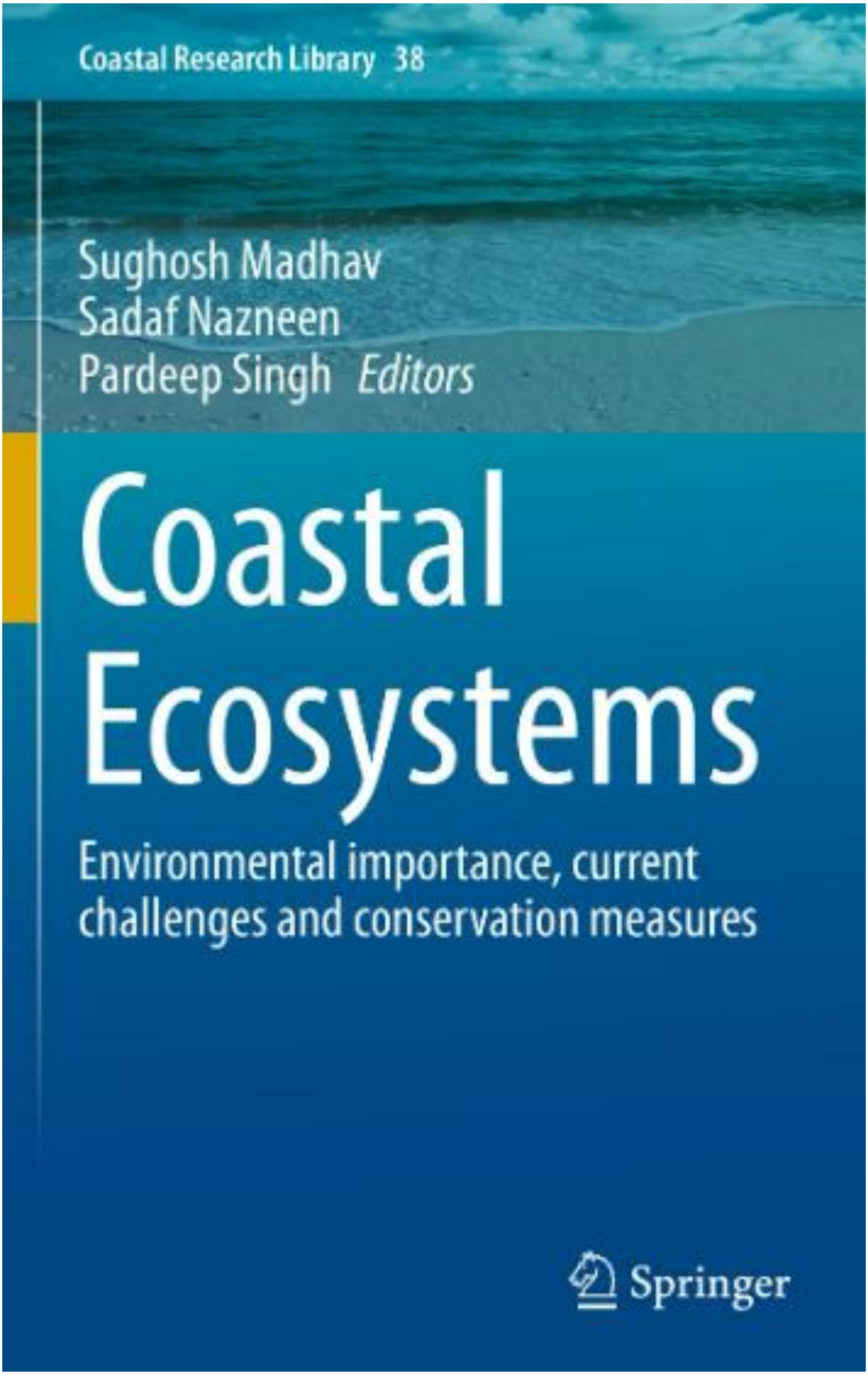
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Maritime Climate Change: Physical Drivers and Impact, *Series Editor: Neloy Khare*

Climate Change in the Arctic

An Indian Perspective

edited by

Neloy Khare

CRC Press
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Climate Change in the Arctic

Maritime Climate Change: Physical Drivers and Impact

Series Editor:
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As global climate change continues to unfold, the two-way links between the tropical oceans and the poles will play key determining factors in these sensitive regions' climatic evolution. Now is the time to take a detailed look at how the tropical oceans and the poles are coupled climatically. The signatures of environmental and climatic conditions are well preserved in many natural archives available over land and ocean. Many efforts have been made to unravel such mysteries of climate through many natural geological archives from tropics to the polar region. This series makes an effort to cover in pertinent time various depositional regimes, different proxies – planktic, benthic, pollens and spores, invertebrates, geochemistry, sedimentology, etc., and emerged teleconnections between the poles and tropics at regional and global scales, besides sea-level changes and neo-tectonism. This book series will review theories and methods, analyse case studies, identify and describe the evolving spatial-temporal variations in climate, and provide a better process-level understanding of these patterns. It will discuss significantly, generalisable insights that improve our understanding of climatic evolution across time – including the future. It aims to serve all professionals, students and researchers, scientists alike in academia, industry, government and beyond.

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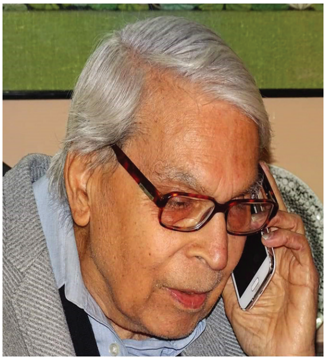

Late Prof Shashi Bhushan Bhatia

(18.03.1980–01.05.2021)

Prof Shashi Bhushan Bhatia was born on 18 March 1930 at Lucknow. Prof Bhatia post graduated in 1950 from the Lucknow University, obtained Ph.D. degree from the London University and D.I.C. from the Imperial College of London. He joined the Lucknow University as a Lecturer in 1953. In 1958, he was selected in the Geological Survey of India. Subsequently in 1959, Prof Bhatia was appointed as a Reader in the newly created Department of Geology in the Panjab University, Chandigarh, where he superannuated as a Professor and then continued as an Emeritus Professor.

Prof Bhatia's contributions to the Indian geology cover a vast time span. Foraminifera was his original field of specialisation. He is credited with the first discovery of the Permian foraminifera in India. Later he made important contributions to the study of Cretaceous and Paleogene ostracods. His research on the Cretaceous sediments aided in determining the time of extinction of the dinosaurs and initiation of the Deccan Volcanicity. Another important input to the Cretaceous was the report of bryozoa in the Neelkanth Formation – considered at that time a part of the Tal Group. The most important contributions made by Prof S. B. Bhatia, however, are to the Palaeogene sediments of the Himalaya. He studied fauna of the Subathu, Dagshai and Siwalik sequences. His findings precisely fixed the lower age limit of the Kakara sediments at 56.5 Ma, which signifies the time of collision of the Indian and Asian Plates. His research on the Subathu and the Dagshai formations makes significant contributions to the biostratigraphy, event stratigraphy and environment of deposition of that time. He put India on the world map of Chara studies.

Prof Bhatia had around 250 publications in reputed journals. He guided a dozen students for Ph.D. degree. He was a highly decorated scientist. In 1958, he was appointed as Indian Correspondent of the Journal of Micropaleontology. He was a Fellow of the prestigious Indian National Science Academy and recipient of L. Rama Rao award. Oil and Natural Gas Corporation decorated him with a silver plaque. He was an excellent teacher with exceptional skills of communication. He was a perfectionist and demanded the best from his students.

Prof Shashi Bhushan Bhatia breathed his last peacefully on 1 May 2021. His death is a great loss to Indian geology.

Contents

Foreword

Undertaking research in the Polar Regions is complex and challenging. The sustained vitality of polar research is intrinsically linked to the specialised logistics and infrastructural support available, which allows scientists to work in a challenging environment. It necessitates strong international cooperation and sharing of resources and infrastructural facilities. Ny-Ålesund at Svalbard in the Arctic has emerged as a vibrant symbol of international partnership. The Norwegian Government has ably guided many non-Arctic countries to research new areas of Arctic Science.

Having achieved a long and resilient experience in Antarctica, India forayed into Arctic Science over a decade back and recently joined the Arctic Council as an Observer. In collaboration with Norway, India has established its research base ‘Himadri’ at Ny-Ålesund, the well-known ‘Science village’ in the Arctic. With more than a decade’s effort, many exciting findings and results have emerged, especially in the science of climate change as evident in the Arctic region. With quality scientific output in a short period, India has made its presence strongly felt in Arctic Science and has contributed significantly to the knowledge base of Arctic research. Indian scientists have attempted to unravel the past and understand the present in order to elucidate the future trends on climate change patterns.

The multi-sectoral climate issues associated with Arctic change transcend national boundaries. The stakeholders including governments, indigenous communities, civil society, policymakers and industry need to be equally concerned. For any adaptation and mitigation efforts, informed decisions on the Arctic must be evidence-based and not geopolitically driven. Scientists, therefore, have a cardinal role to play in providing insightful data that can be translated to enable policy paradigm and sound advisory mechanism on climate change and its impact on the globe.

The Indian efforts made in Arctic climate science must be synthesised so that a comprehensive picture could emerge. The present book *Climate Change in the Arctic: An Indian Perspective* is an illustrious effort in this direction, covering a wide range of topics addressing various aspects of climate change in the Arctic. As changes in the Arctic region will have a profound effect on human life on Earth, there is a need for our polity and people including the industry leaders to have up-to-date and robust information on the science of Arctic climate change. This book amply provides a clear picture of the ongoing global climatic changes, their impacts on the Arctic and how the changing Arctic will influence the rest of the world. The message conveyed is clear: we must collectively work to reduce our carbon footprint to save one of the last frontiers on planet Earth, the Arctic.

Arbinda Mitra
Scientific Secretary
Date: June 2021
Place: New Delhi

Preface

The Polar Regions are an essential focus of research as unique systems, but they also play a pivotal role in global Earth systems. Situated at the northernmost part of *Earth*, the Arctic is a spectacular *polar region*. It is a unique area among Earth's ecosystems. The unique characteristics and cultures of the Arctic indigenous peoples are an adaptive mechanism to cope with the cold and extreme conditions. Historically, the Arctic regions' scientific activity is intimately linked with the post-World War II and the subsequent Cold War era's geopolitical circumstances. It has always been a pristine environment owing to least human interventions. For many years, the Arctic region was designated as a North 'dead land' that was not perceived as a place for living or economic activities. However, the situation during the past few decades has changed significantly. Now the Arctic is connected to global natural and anthropogenic chemicals via winds, ice movement and marine currents. Global warming has made the Arctic region more accessible and desirable. It is a complex region that is experiencing unprecedented changes. Based on long-term monitoring, it has been found that the Arctic is warming up much faster than expected, essentially due to Arctic amplification of the worldwide warming scenario. The Arctic holds the world's largest remaining oil and gas reserves, an enormous untapped mineral wealth.

A reduction in Arctic summer ice cover has become more intense in recent years, culminating in an area of a record low of 3.4 million square kilometres in 2012. Ice melting opens a place for new research and economic activities. It allows for exploring the possible amount of natural resources in the Arctic region.

The Arctic's responses to global change are too sensitive. It may be capable of initiating dramatic climatic changes through alterations induced in the oceanic *thermohaline circulation* by its cold, southward-moving currents or through its effects on the global *albedo* resulting from changes in its total ice cover.

Many scientific disciplines and engineering applications have significantly advanced based on the knowledge gained from polar research. Many of the discoveries that took place over Polar Regions have provided a critical understanding of direct benefit to humanity and served the society. It makes sense that access to the polar areas is fundamentally vital from its scientific viewpoints. Evidence continues to accumulate that the scientific value of the Arctic warrants significant investment for polar research. Sustained efforts must be on to continue and indeed flourish over the next several decades.

The Arctic Ocean is primarily surrounded by land and has difficult, terrain and adjacent shorelines. The ice and extreme weather conditions make it further challenging to reach. The logistics constraints make it difficult to conduct research on land and coastal areas; thus, such observations tend to be sparse.

Atmospheric processes in the Arctic are distinctive and scientifically significant. Among many, the transport and disposition of solar radiation, the formation and persistence of clouds, and variability in the atmospheric pressure fields exhibit large-scale patterns that influence the global climate.

A more detailed understanding and representation of these global climate models' processes are essential to improving future climate predictions. It requires intensive observations of the Arctic atmosphere over the oceans with specialised (ice breaker) vessel support.

Similarly, sea ice provides the interface between atmosphere and water, and it is one of the essential components of the system. Inadequate spatiotemporal observations limit our ability to describe the variability, change, and extremes of the polar region environment. Records of past environmental conditions, retrieved from paleo-archives such as ice cores or sediments, provide clues to nature's response to climate change force. Still, these too are incomplete, especially in terms of spatial coverage.

The Arctic Basin plays a pivotal role in the global carbon balance. Nonetheless, the mechanism by which this carbon is transported from the Arctic continental shelf to the deep basin is yet to be adequately understood.

The apparent changes are occurring in the intricate balance between Pacific's and Atlantic's waters. These may bring out a subtle change in the thermohaline profile features because the heat and salt balance prevents melting of surface ice.

The tectonics of ocean gateways, which allow passage of warm and cold currents between oceans, is useful for understanding climate changes in the Arctic region. India takes the honour to have a separate ministry dealing with the Earth System Sciences under which the entire gamut of polar science and logistics falls. Having acute concern on the global climate change issues and the significance both poles carry in a deeper understanding of the climate change system holistically, India opted to adopt a bipolar scientific approach by venturing into Arctic Science. The rich scientific and logistics experience gained through a glorified and meaningful journey of launching more than 40 annual scientific expeditions to the icy continent 'Antarctica' was an ambitious plan to launch unique scientific expeditions to the Arctic region addressing diversified climate-related issues apart from many other scientific objectives to be accomplished through Arctic Science. As a humble beginning, India deputed an exploratory team to visit the Arctic and establish tie-ups with the Norwegian colleagues as the site identified for India was the Norwegian territorial region. Having fruitful, supportive and healthy linkages with the Norway, India was initially allowed to use Norway's International Research Facilities at Ny-Ålesund, Svalbard. And a full-fledged Indian Arctic Research base namely 'Himadri' was finally set up in 2008 at Ny-Ålesund amidst the research bases of other participating countries. During this period, Indian researchers visited the Arctic a number of times in a year and conducted their exceptional dedicated experimentation to obtain observational data. Many significant studies have been undertaken by Indian Climate Scientists focusing on the Arctic Climate changes and their global relevance including Indian tropical climates, specialising in the Indian Summer Monsoon (ISM).

This book titled *Climate Change in the Arctic: An Indian Perspective* highlights some of the most exciting Arctic research conducted by Indian scientists ever since India entered the Arctic Science foray. Indian polar researchers have contributed to a wide range of disciplines, in a bid to get an insight into the essential information about Earth's systems and how they operate. Nevertheless, the research conducted by Indian scientists addressing various facets of the climate change occurring over the

Arctic region has exclusively been collated in 15 chapters to put forth Arctic climate changes through an Indian perspective.

Accordingly, **Khare** introduces the theme in the first chapter highlighting the overall climate change assessment over the Arctic through the Indian Polar Programme. Under Arctic Atmosphere Weather and Climate Change theme, **Maheskumar and Sunitha Devi** discuss in detail the Arctic weather and climate patterns, **Gwal et al.** investigate GPS-derived total electron content (TEC) and Scintillation Index for the Arctic and Antarctic Stations, and **Sonbawne et al.** monitor the atmospheric aerosols to help assess their sources and effects on Arctic climate.

To get an insight into the signatures of climate change through sediments, **Singh et al.** concentrate on the sedimentary parameters of the Arctic region in space and time to reconstruct past climatic conditions. On the contrary, **Choudhary et al.** have identified biogenic silica as an indicator of paleo productivity in lacustrine sediments of Svalbard, Arctic. They provide a comprehensive review of the studies that dealt with the biogenic silica over the Arctic region. **Tiwari and Megan Da Lima Leitao** touch upon the critical role of persistent organic pollutants and mercury in the Arctic environment. Also, they discuss about the indirect impact of these pollutants on climate change. Besides, **Gopikrishna et al.** studied the fjord sediments for their contamination and Implications for the Arctic Climate changes.

The impact of climate change on Arctic life has been assessed by **Hatha and Krishnan** who reported non-polar isolates in the Arctic fjords and Tundra and pointed out a warming trend in the Arctic environment. Simultaneously, **Jasmine Purushothaman et al.** concentrate on the Mesozooplankton community structure in Kongsfjorden, the Arctic, and assess impacts of climate changes through space and time. On the contrary, **Aswathy Shaji and Anu Gopinath** characterise the humic acids isolated from diverse Arctic environments.

The most critical aspect of the great potential Arctic microbes possess for pharmaceutical purposes lies in the biotechnological processes which have various characteristics. Such aspects have been detailed by **Dubey and Babel**. Interestingly, bio-optical characteristics in relation to phytoplankton composition and productivity in the Arctic fjord ecosystem have been highlighted by **Tripathy**.

In the Polar Regions, the present-day Circum-Arctic region comprises a variety of tectonic settings due to varied geophysical conditions: from active seafloor spreading in the North Atlantic and Eurasian Basin, and subduction in the North Pacific, to long-lived stable continental platforms in North America and Asia. A detailed account on the recent advances in seismo-geophysical studies conducted so far for the Arctic region in different tectonic environs has been provided by **Mishra et al.** in a bid to understand the efficacies of various geophysical and seismological tools.

On the contrary, **Luis and Roy** have addressed the impact of climate change on sea ice. They have studied the decadal Arctic Sea-Ice Variability to observe the pattern and its implication to climate change.

As Arctic Science advances, more and more challenging scientific questions will require sustained and continuous observations and measurements in the Arctic regions. It will help us understand the evolution of northern climates. Prediction of future changes can be based only on a full understanding of the Arctic and Antarctic systems.

This book collates recent scientific findings and sights related to the ongoing climate change in and around the Arctic region from the Indian perspective. This book will help satisfy the curiosity; usually, young minds carry. These youngsters and budding researchers will get an insight into the ongoing climate changes taking place over the Arctic region.

Neloy Khare
Date: June 2021
Place: New Delhi

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Immense supports and help received from all contributing authors are graciously acknowledged; without their valuable inputs on various facets of climate change over the Arctic region, the book would not have been possible. Various learned experts who have reviewed different chapters are sincerely acknowledged for their timely, important, and critical reviews.

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Neloy Khare
Date: June 2021
Place: New Delhi

Editor

Dr Neloy Khare, presently Adviser/Scientist G to the Government of India at MoES, has a unique understanding not only of administration but also of quality science and research in his areas of expertise covering a large spectrum of geographically distinct locations like Antarctic, Arctic, Southern Ocean, Bay of Bengal, Arabian Sea, Indian Ocean, etc. Dr Khare has almost 30 years of experience in the field of paleoclimate research using palaeobiology and palaeontology/teaching/science management/administration/coordination for scientific programmes (including Indian Polar Programme). Dr Khare has completed his doctorate (Ph.D.) in tropical marine region and Doctor of Science (D.Sc.) in southern high-latitude marine regions.

Dr Khare has been conferred Honorary Professor and Adjunct Professor by many Indian universities. He has an awe-inspiring list of publications to his credit (125 research articles in national and international scientific journals; three special issues in national scientific journals as Guest Editor; edited a special issue of *Polar Sciences* as its Managing Editor). The Government of India and many professional bodies have bestowed him with many prestigious awards for his humble scientific contributions to past climate changes/oceanography/polar science and southern oceanography. The most coveted award is the Rajiv Gandhi National Award – 2013 conferred by the Honourable President of India. Others include ISCA Young Scientist Award, Boys Cast Fellowship, CIES French Fellowship, Krishnan Gold Medal, Best Scientist Award, Eminent Scientist Award, ISCA Platinum Jubilee Lecture, and IGU Fellowship. Dr Khare has made tremendous efforts to popularise ocean science and polar science across the country by delivering many invited lectures, giving radio talks, and publishing popular science articles. Many books authored/edited on thematic topics and published by reputed international publishers are testimony to his commitment to popularise science among the masses.

Dr Khare has sailed in the Arctic Ocean as a part of ‘Science PUB’ in 2008 during the International Polar Year campaign for scientific exploration and became the first Indian to sail in the Arctic Ocean.

Contributors

Priyanka Babel
Department of Biotechnology
Mohanlal Sukhadia University
Udaipur, Rajasthan

Purushottam Bhawre
Department of Physics
Govt. Sanjay Gandhi P.G. College
Ganjbasoda, India

Kailash Chandra
Protozoology Section
Zoological Survey of India
Kolkata, India

Shabnam Choudhary
National Centre for Polar and Ocean Research
Goa, India

Suryanshu Choudhary
Department of Physics
Rabindranath Tagore University
Raisen, India

Tara Megan Da Lima Leitao
National Centre for Polar and Ocean Research
Goa, India

P.C.S. Devara
Centre of Excellence in Ocean-Atmospheric Science and Technology and
Environmental Science and Health
Amity University Haryana (AUH)
Gurugram, India

Chetan Anand Dubey
Centre of Advanced Study in Geology
University of Lucknow
Lucknow, India

Rajesh Kumar Dubey
UGC-Human Resource Development Centre
JNV University Jodhpur
Rajasthan, India

Gopikrishna VG
School of Environmental Sciences
Mahatma Gandhi University
Kerala, India

Anu Gopinath
Department of Aquatic Environment Management
Kerala University of Fisheries and Ocean Studies
Kochi, India

A.K. Gwal
Department of Physics
Rabindranath Tagore University
Raisen, India

Kannan VM
School of Environmental Sciences
Mahatma Gandhi University
Kerala, India

Neloy Khare
Ministry of Earth Sciences
Govt. of India
New Delhi, India

Krishnan KP
National Centre for Polar and Ocean Research
Goa, India

Alvarinho Luis
National Centre for Polar and Ocean Research
Goa, India

R.S. Maheskumar
Ministry of Earth Sciences
Govt. of India
New Delhi, India

G. Meena
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

O.P. Mishra
National Centre for Seismology
New Delhi

A.A. Mohamed Hatha
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences
Cochin University of Science and Technology
Kochi, Kerala

Mahesh Mohan
School of Environmental Sciences
International Centre for Polar Studies
Mahatma Gandhi University
Kerala, India

G N Nayak
Marine Sciences, School of Earth, Ocean and Atmospheric Sciences
Goa University
Goa, India

G. Pandithurai
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

Haritha Prasad
Protozoology Section
Zoological Survey of India
Kolkata, India

Priya Singh
National Centre for Seismology
New Delhi

Jasmine Purushothaman
Protozoology Section
Zoological Survey of India
Kolkata, India

Rasik Ravindra
National Centre for Polar and Ocean Research (Formerly)
Goa, India

Neelakshi Roy
National Centre for Polar and Ocean Research
Goa, India

and

Centre of Excellence for Natural Resources Data Management System, Department of Remote Sensing and GIS
Kumaun University
Almora, India

P.D. Safai
Cloud-Aerosol Interaction and Precipitation Enhancement EXperiment
Indian Institute of Tropical Meteorology
Pune, India

S.K. Saha
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

Aswathy Shaji
School of Ocean Science and Technology
Kerala University of Fisheries and Ocean Studies
Kochi, India

Anoop Kumar Singh
Centre of Advanced Study in Geology
University of Lucknow
Lucknow, India

Dhruv Sen Singh
Centre of Advanced Study in Geology
University of Lucknow
Lucknow, India

S.M. Sonbawne
High Altitude Cloud Physics Laboratory
Indian Institute of Tropical Meteorology
Pune, India

Sunitha Devi S
India Meteorological Department
New Delhi, India

Anoop Kumar Tiwari
National Centre for Polar and Ocean Research
Goa, India

Sarat Chandra Tripathy
National Centre for Polar and Ocean Research
Goa, India

Abbreviation List

A.O.	Arctic Ocean
AAS	Atomic absorption spectrometry
ABL	Atmospheric boundary layer
AMDEs	Atmospheric mercury depletion events
AMAP	Arctic Monitoring and Assessment Programme
ANOVA	Analysis of variance
AQUA-GAPS	Global aquatic passive sampling
ASE	Accelerated solvent extraction
ATOS	Antarctic Tourism Opportunity Spectrum
BDL	Below the detection limit
BSTFA	N,O-Bis(trimethylsilyl)trifluoroacetamide
BTBPE	1,2-Bis(2,4,6-tribromophenoxy)ethane
BWP	Brake wear plastics
CA	California
CAA	Canadian Arctic Archipelago
CEC	Capillary electro-chromatography
CFCs	Chlorofluorocarbons
CG	Congeners in the gas phase
CUPs	Current-use pesticides
CVAFS	Cold vapour atomic fluorescence spectrometry
D.M.	Diabetes mellitus
DB_XLB	Type of GC column
DB-5	Type of GC column
DBA	Dibromoanisole
DCM	Dichloromethane
DDC-CO	Dechlorane plus
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DF	Detection frequency
DOC	Dissolved organic carbon
DPTE	2,3-Dibromopropyl-2,4,6-tribromophenyl ether
ECD	Electron capture detection
EDGARv4.tox2	Emission Database for Global Atmospheric Research v4.tox2
ENV	SPE Cartridge Bond Elut-ENV for extraction of polar residues
ESSO	Earth System Science Organisation
Et-FOSA	N-Ethyl perfluorooctane sulphonamide
Et-FOSEs	Ethyl perfluorooctane sulphonamido ethanols
ETHeBB	2-Ethyl-1-hexyl-2,3,4,5-tetrabromobenzoate
EVA	Ethylene-vinyl acetate copolymer
FLD	Fluorescence detection
FOSAs	Perfluorooctane sulphonamides
FTAs	Fluorotelomer acrylates

FTIR	Fourier transform infra-red spectrometry
FTOHs	Fluorotelomer alcohols
G.C.	Greenland Current
GC-MS or GC/MS	Gas chromatography-mass spectrometer
GEM	Gaseous elemental mercury
GFFs or GF/Fs	Glass fibre filters
GOM	Gaseous oxidized mercury
GRAHM	Global/Regional Atmospheric Heavy Metals
HBB	Hexabromobenzene 2,3-dibromopropyl-2,4,6-tribromophenyl ether
HCBs	Hexachlorobenzenes
HCH	Hexachlorocyclohexanes; Hexachlorocyclohexane
HDPE	High-density polypropylene
HFRs	Halogenated flame retardants
HNPs	Halogenated natural products
HP/H.P.	Hewlett Packard
HPLC	High-performance liquid chromatography
HS-SPME	Headspace solid-phase microextraction
HVS	High-volume samplers
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
ICP/OES	Inductively coupled plasma - optical emission spectrometry
ICP-AES	Inductively coupled plasma atomic emission spectrometry
L/minute	Litre per minute
LCCP	Long-chain chlorinated paraffins
LDPE	Low-density polyethylene
LOD	Loss on drying
LRAT	Long-range atmospheric transport
LVS	Low-volume sampler
MCCP	Medium-chain chlorinated paraffins
Me-FBSA	N-Methyl perfluorobutane sulphonamide
Me-FBSE	N-Methyl perfluorobutane sulphonamidoethanol
Me-FOSA	N-Methyl perfluorooctane sulphonamide
Me-FOSEs	Methyl perfluorooctane sulphonamido ethanols
MeHg	Methylmercury
MEKC	Micellar electrokinetic chromatography
merB, hgcA	Methylation genes and analogues
Mg/a1	Penetration of light/penetration depth unit
MMHG or MMHg	Monomethyl mercury
MoES	Ministry of Earth Sciences
MPs	Microplastics
MSD	Mass spectrometer detector
MSD GC-ECNI-MS	Mass spectrometer detector gas chromatography with electron capture negative ion mass spectrometry
NBFRs	New/novel brominated flame retardants

NCP	Northern Contaminants Programme
NCPOR	National Centre for Polar and Ocean Research
NEEM	North Greenland Eemian Ice Drilling
NIC	Nippon Instruments Corporation
NILU	Norwegian Institute for Air Research
NU	Nunavut
OBPs	Organo-brominated pesticides
OCPs	Organo-chlorinated pesticides
OCS	Oxidation of carbonyl sulphide
ODE	Ozone depletion events
–OH	Hydroxyl functional group
PAD-3	Type of polymer resin cartridge
PAHs	Polycyclic aromatic hydrocarbons
PBBz	Pentabromobenzene
PBDEs	Polybrominated diphenyl ethers
PBM	Particulate bromine mercury
PBT	Pentabromotoluene
PCBs	Polychlorinated biphenyls
PCDD/Fs	Polychlorinated dibenzo-p-dioxins and furans
PCI	Positive chemical ionization
PDM	Pic du Midi
PFAAs	Perfluoroalkyl acids
PFAS	Polyfluoroalkyl substance
PFBA	Perfluorobutyrate; Perfluorobutanoic acid
PFBS	Perfluorobutanesulphonic acid
PFCAs	Perfluorinated carboxylates
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanesulphonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulphonic acid
PFRs	Organophosphorus flame retardants
PFSAs	Perfluoroalkyl sulphonic acids
PFTE	Polytetrafluoroethylene
pH	Potential of hydrogen
PL	Pacific Mode Layer
PML	Polar mixed layer
POPs	Persistent organic pollutants
PPE	Polypropylene
PUFs	Polyurethane foams
QM-A	High-purity grade for particulate matter 10 sampling and analysis
RGM	Reactive gaseous mercury
SBSE	Stir bar sorptive extraction
SCCP	Short chain chlorinated paraffins
SFC	Supercritical fluid chromatography

SIM	Selected ion monitoring
SOAs	Secondary organic aerosols
SOM	Soil organic matter
SPE	Solid-phase extraction
SPSS	Statistical software
SVOCs	Semi-volatile organic compounds
TBA	Tribromoanisole
TBPH	Bis(2-ethyl-1-hexyl) tetrabromophthalate
TCMX	2,4,5,6-Tetrachloro-m-xylene
TGM	Total gaseous mercury
THg	Total mercury
TLC	Thin-layer chromatography
TMS	Trimethylsilyl
TWP	Tyre wear plastics
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
XAD	Adsorbent resin for dioxins and furans

1 Climate Change Assessment over the Arctic Region

Initiatives through Indian Polar Programme

Neloy Khare
Ministry of Earth Sciences

CONTENTS

The Arctic Ocean, surrounding the North Pole, which consists of a large ocean surrounded by land, is like no other ocean on earth because of its unique location and climate. It is the region above the Arctic Circle (at approximately 66° 34′N). The sun does not set on the *summer solstice* and does not rise on the *winter solstice* above the Arctic Circle.

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The industrial revolution produced an excess of carbon dioxide and other greenhouse gas emissions. The rising temperatures in the Polar regions result in the rapid melting of the glaciers. The glaciers are diminishing from the land, calving off into the sea (http://www.sciencemag.org/news/2013/08/scienceshot). The impact of changing climate over the Arctic region is reflected in the Arctic amplification and reflected by the Arctic Ocean's shrinking sea ice cover in summer. Decrease in the snow cover over land in the Arctic, especially in spring, and glaciers in Alaska, Greenland and northern Canada is retreating. The permafrost, also known as the frozen ground in the Arctic, is thawing due to warming. Scientists began gathering evidence of changes in Arctic climate since the 1980s, which have become much more pronounced. The Arctic is experiencing unprecedented extremes in sea ice, temperature and precipitation, which remained unreported in the historical records and emerged as an enigma of climate mystery. Indubitably global warming has severely impacted the Arctic's climate, with many strange climatic events such as witnessing a rainy season almost equal to India's and up to 10 months without snow.

Since the late 1970s, the sea ice in the Arctic has decreased dramatically. According to National Snow and Ice Data Center, the Arctic summer sea ice extent in September 2012 was a record low, shown (in white) compared to the median summer sea ice extent for 1979–2000 (shown in orange) (Figure 1.1).

Climate change is a reality and has exhibited dramatic patterns across the Arctic (The National Oceanic and Atmospheric Administration (NOAA) and its partners – Annual Arctic Report Card – 2019). Some salient findings of this report (https://arctic.noaa.gov/Report-Card/Report-Card-2019) are enumerated below:

- The average annual surface air temperature in the Arctic from October 2018 through August 2019 was the second warmest in the observational record. Satellite recorded the second-lowest Arctic sea ice extent in 2019.

FIGURE 1.1 The Arctic summer sea ice extent measured in 2012 (white outline) compared with the observed changes from 1979 to 2000 (orange outline). In 2013, the Arctic summer sea ice extent rebounded somewhat but was still the sixth smallest extent on record. (Source: National Snow and Ice Data Center)

- The Bering Sea saw record low winter sea ice in 2018 and 2019.
- Birds are being affected, including the breeding population of ivory gull in the Canadian Arctic falling 70% since the 1980s.
- Greenland's ice sheet also experienced rapid melting in 2019, beginning earlier than usual and reaching 95% of the surface.

Arctic's climate changes are significant because the Arctic acts as a barometer of global climate change. Such ongoing changes in the Arctic climate harm the food chain, including phytoplankton and many marine mammals. It includes seals, walrus, whales, and polar bears. Well-known feedback mechanism acting in the Arctic region may lead to further warming. The Arctic *amplified response* to global warming is the repercussion of global temperature rise. Consequently, Greenland's ice sheet is shrinking drastically at an alarming rate (http://news.uga.edu/releases/article/study-2015-melting-greenland-ice-faster-arctic-warming-0616/, Tedesco et al. 2016).

1.1 FEEDBACK MECHANISM AND ARCTIC AMPLIFICATION

Due to sea ice melting in summer, dark open water areas are exposed, absorbing more heat from the sun (Figure 1.2). More ice melts due to excess heat. The sea ice's loss is one of the Arctic amplification drivers (Figure 1.3) (Slivka 2012; Goldenberg 2012). Permafrost may also play a role in positive feedbacks. As the thawing of permafrost starts, plants and animals frozen in the ground begin to decay. Their decomposition releases carbon dioxide and methane back to the atmosphere. It can further induce warming. The shifting Arctic vegetation also affects the surface brightness and adds up to warming. More water vapour is held up due to more warming of the

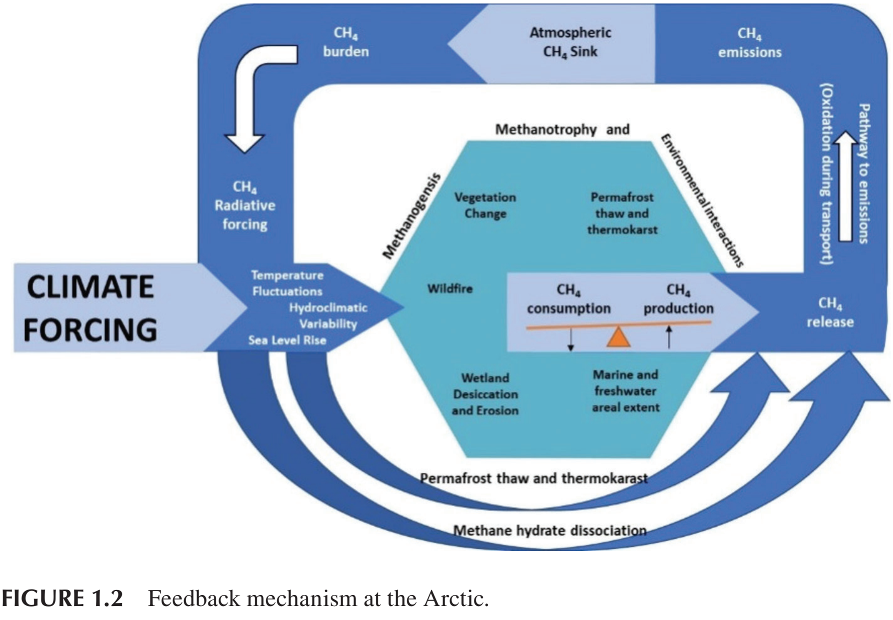

FIGURE 1.2 Feedback mechanism at the Arctic.

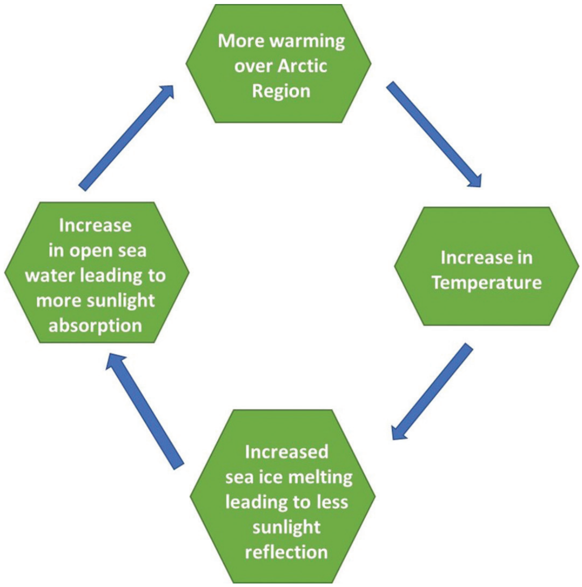

FIGURE 1.3 Arctic amplification.

Arctic atmosphere, which is an important greenhouse gas (Slivka 2012; Goldenberg 2012). In the Arctic, warming is causing further warming in the following manner.

There is no doubt that global warming tends to increase temperatures in the Arctic. It tends to melt ice, decreasing the area covered by sea ice and expanding the scope of darker exposed ocean, which tends to reduce sunlight reflection, as ice is far more reflective than the newly exposed Ocean. It tends to increase the sunlight that is absorbed by the sea. It tends to add to global warming, and the cycle repeats.

Other feedbacks from the loss of Arctic Ocean ice, ranging from a possible slowdown of the so-called "global ocean conveyor belt" to significant shifts in the northern hemisphere's jet stream, could also have severe climatic impacts.

The main consequences of global warming on the Arctic are the increase in temperatures (air and sea), *loss of sea ice* and melting of the *Greenland ice sheet* with a related *cold temperature anomaly*, observed since the 1970s (Foster 2012; Slivka 2012; Goldenberg 2012). Ongoing climate change over the Arctic region is also expected to impact ocean circulation changes, increased input of freshwater (Graeter 2018; Rabe et al. 2011) and ocean acidification (Qi et al. 2017), potential methane releases through the thawing of *permafrost* and methane clathrates (Schuur et al. 2015).

It has also been postulated that due to the potential climate teleconnections to mid-latitudes, these regions are expected to witness a greater frequency of extreme weather events (flooding, fires and drought) (Cohen et al. 2014). It will lead to ecological, biological and phenological changes. Other factors include physical migrations and extinctions (Grebmeier 2012), natural resource stresses, human health, displacement and security issues.

1.2 INDIA AND THE ARCTIC

India's engagement with the Arctic dates back to a century. It was in 1920 when British overseas Dominions signed the Treaty with other signatories like the US, Denmark, France, Italy, Japan, the Netherlands, Norway, Great Britain, Ireland and Sweden concerning Spitsbergen's 'Svalbard Treaty' in February 1920 in Paris.

India has been closely following the Arctic region's developments in the backdrop of the emerging opportunities and challenges due to the global warming-induced melting of the Arctic ice cap. Science, environment, commerce and strategy are the main concerns of India in the Arctic region.

India paved its way in the Arctic by launching a research programme in 2007 to thrust on climate change in the circumpolar north. The primary objectives of the Indian research in Arctic region are as follows:

1. To study the hypothesised teleconnections between the Arctic climate and the Indian monsoon by analysing records archived in the sediment and ice cores from the Arctic glaciers and the Arctic Ocean.
2. To characterise sea ice in the Arctic using satellite data to estimate the effect of global warming on the northern Polar region.
3. To research Arctic glaciers' dynamics and mass budget focusing on the impact of melting glaciers towards sea level changes.
4. To assess the Arctic flora and fauna vis-à-vis their response to anthropogenic activities. Besides, a bi-polar comparison is proposed to be undertaken in life forms.

India launched its first scientific expedition to the Arctic Ocean in 2007. A research base named "Himadri" was established at Ny-Ålesund, Svalbard, Norway, in July 2008 for researching disciplines like glaciology, atmospheric sciences and biological sciences. The area used for the Indian research base is the International Arctic Research Base at Svalbard. A Memorandum of Understanding (MOU) has also been signed with the Norwegian Polar Research Institute of Norway, for cooperation in science, as even with Kings Bay (a company of the Norwegian Government) Ny-Ålesund. It provides logistics and infrastructure facilities for undertaking Arctic research and maintaining the Indian research base 'Himadri' in the Arctic region.

Several scientists from various national institutions have participated in our Arctic programme. India became a member of the Council of the International Arctic Science Committee (IASC) in 2012. India's claim for Observer Status received attention in 2012 with widespread support from all member countries. In recognition of India's commitment and sustained interest in Arctic science, during the Eighth Biennial meeting of the Arctic Council held in Kiruna, Norway on 1 May 2013, under Sweden's Chairmanship, India was provided Observer Status to the Arctic Council.

1.3 BLACK CARBON

In contrast to most atmospheric aerosols, black carbon (BC) aerosols are good candidates for absorbing solar radiation. Due to such absorption, a warming effect on the planet is perceived. On the contrary, other aerosols such as sulphate aerosols provide the cooling effect due to scattering. BC aerosols play a critical role in affecting the climate system by changing and heating the clouds (semi-direct effect) or acting as cloud condensation nuclei (indirect effect). BC aerosols have emerged as third among the most extensive human-generated causes. CO_2 and CH_4, having a present-day radiative forcing of ~0.40 W/m^2 which is ~25% more of the pre-industrial period (Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2014).

Despite its importance, only a few modelling studies have addressed BC aerosols' effectiveness in warming the planet relative to CO_2 forcing (e.g. Roberts and Jones 2004; Cook and Highwood 2004; Hansen et al. 2005; Stjern et al. 2017; Smith et al. 2018). The results indicate that the BC aerosols are less effective in warming the earth than CO_2 (Yoshimori and Broccoli 2008). The concept of 'efficacy' to measure forcing agents' effectiveness was introduced by Hansen et al. (2005). The efficacy of BC aerosols emitted by burning of fossil fuel and biomass was 0.930 and 0.80, respectively, when effective radiative forcing (ERF) definition is used to estimate the radiative forcing (Hansen et al. 2005). This cloud enhancement in the lower troposphere dramatically reduces the direct warming effect of the BC aerosols. Stjern et al. (2017) found that multi-model median efficacy of the BC aerosols is less than one (0.80).

The decrease in efficacy with BC aerosols' altitude has been found in some recent studies (Ban-Weiss et al. 2012; Samset and Myhre 2015). Ban-Weiss et al. (2012) showed that near-surface BC aerosols cause warming. On the contrary, when BC aerosols are at heights, the varying climate response from BC aerosols at different sizes arises primarily due to various fast climate adjustments. These are defined as the climate response before any change in the average surface temperature globally (Bala et al. 2010; Ban-Weiss et al. 2012). BC warms the surface through diabatic heating. At heights in increased longwave radiation without heating the body, the absorbed solar radiation is lost to space. We note that the efficacy decreases with the size of BC aerosols. BC aerosols' efficiency to exert more significant radiative forcing due to the direct aerosol effect strengthens with altitude (Samset and Myhre 2011, 2015).

Because of the above, it may be postulated that the in-modulating Arctic Climate BC aerosols play an influential role in further strengthening the feedback mechanism, leading to Arctic amplification, and therefore a detailed investigation on this aspect must be made.

The consequences of the impact of rapid changes in the Arctic region go beyond the coastal states. To respond to such challenges warrants the active participation of all those actors who have a stake in global commons' governance. It requires a legitimate and credible mechanism. The interplay between science and policy can significantly contribute to addressing the complex issues facing the Arctic. India, which has significant expertise in polar research matters due to its long experience of launching annual scientific expeditions to the Antarctic and association with the Antarctic Treaty System, can play a constructive role in securing an influential position in Arctic affairs. As a permanent observer in the Arctic Council, India is committed to contributing to evolve and strengthen the effective cooperative partnerships that can contribute to a safe, stable and secure Arctic.

The warming of the Arctic region has recently gained worldwide attention due to its projected impacts on the global climate system. The effect of anthropogenic BC aerosol on snow is of enduring interest due to its role in aerosol radiative forcing (ARF) and further consequences for the Arctic and global climate changes. Having demonstrated its sincere pursuit of Arctic science ever since the Indian research base is set up at Ny-Ålesund (Svalbard), India has been continuously generating data on BC aerosol over the Arctic region. MoES-Indian Institute of Tropical Meteorology (IITM), Pune (India), participated in the Arctic expedition to study BC over the Himadri research base, Ny-Ålesund. Similarly, CSIR-National Physical Laboratory, New Delhi (India), participated in the Arctic expedition to measure the concentration of carbon monoxide (CO) over the Arctic region to compare it with the CO concentration in the Antarctic area. We discuss here briefly some of the Indian contributions to the assessment of BC and CO in a bid to help understand Arctic climate change and associated amplification vis-à-vis its teleconnection with the tropical countries like India.

1.4 ASSESSMENT OF BLACK CARBON AEROSOLS AND SOLAR RADIATION OVER HIMADRI, NY-ÅLESUND

India ventured into assessing the BC and measuring solar spectral at 'Indian Arctic Station, Himadri', Ny-Ålesund, during 2011–2014. The contribution from long-range transport of pollutants from far-away places is found to dominate the local sources such as emissions from shipping and power plants to the annual cycle with maximum BC mass concentration during winter/early-spring season and minimum during the summer season. Moreover, higher BC concentrations were observed during 2012 as compared to other years during the study period. The aerosol optical depth's (AOD) spectral variations observed during the summer months indicate an immense contribution of fine-mode aerosol particles to the BC mass concentration, particularly during 2012. Further, the zenith skylight spectra in the spectral range of 200–1100 nm indicate maximum particle scattered intensity around 500 nm (Dr. S.M. Sonbawne, personal communication). These results play a vital role in the earth-atmosphere radiation balance and hence exhibit profound influence on regional and global climate changes (Stohl et al. 2013).

Raju et al. (2011) attempted to study the BC radiative forcing over the Indian Arctic Station, Himadri, during the Arctic summer of 2012 by using an aethalometer. Measurements of BC aerosols were carried out continuously over the Indian Arctic Station, Himadri, during the Arctic summer (23 July to 19 August) of 2012. The monthly mean BC mass concentration during July and August was 0.093 ± 0.046 and 0.069 ± 0.050 μg/m^3, respectively. BC mass concentration showed maximum loading during 0800–1600 LT. Transport from distant sources (as observed from air mass back trajectories) apart from some local anthropogenic activities (emissions from shipping and power plants) could be the possible sources for the observed BC concentration at Himadri. Using the OPAC and SBDART models, optical properties and ARF in the spectral range of 0.2–4 μm for composite aerosol and without-BC aerosol at the top of the atmosphere, surface and atmosphere were computed. The presence of BC resulted in positive radiative forcing in the atmosphere leading to a warming effect (+2.1 W/m^2), whereas cooling was observed at the top of the atmosphere (−0.4 W/m^2) and surface (−2.5 W/m^2). BC formed about 57% of atmospheric ARF.

1.5 PRODUCTION OF CARBON MONOXIDE FROM ICE PACKS

Carbon monoxide is the most critical atmospheric gas which is produced due to the combustion of fossil fuel. It is also produced in large amounts by industries and motor vehicles. Carbon monoxide is a poisonous gas that has a short composition in the atmosphere. The hydroxyl radical (OH) gets combined with it chemically and converts it into non-poisonous material. It helps in monitoring the quantity of the hydroxyl compound. Hydroxyl being an oxidiser controls the composition of many greenhouse gases of the atmosphere. Recent studies show that carbon monoxide is continuously produced and liberated in large amounts in glacier areas. Indian scientists also conducted experiments related to carbon monoxide at Indian Research Centre, Maitri, situated in Antarctic Islands. With the help of various experiments, they know about the regular production cycle of carbon monoxide because of regular consideration of solar actinic rays. Consequently, scientists realised that carbon monoxide production is due to a photochemical reaction in Antarctic glaciers (Dr B.C. Arya, personal communication).

It is considered that some organic materials, like formaldehyde (HCHO), that are entrapped in ice crystals are decomposed through photochemical reactions and produced CO. Carbon monoxide, oxygen, nitrogen oxide analyser, solar photometer, portable climate centre, pyrometer, etc. are the main instruments on which experiments are generally conducted in Polar regions.

Indian scientists performed various experiments to produce carbon monoxide from snowpacks and came to know about the regular alterability in carbon monoxide production in Ny-Ålesund in 2008, especially in March and August. Despite all, Indian scientists also measured the concentration of BC, the size, distribution and composition of aerosols, and the amount of water vapour in the atmospheric air of Ny-Ålesund. In the summer of 2008, ozone analyser was used to measure surface ozone concentration (Dr B.C. Arya, personal communication).

Lucknow University, Lucknow, Birbal Sahni Institute of Paleosciences, Lucknow, Jawahar Lal Nehru University, New Delhi, Indian Institute of Technology, Kharagpur, Wadia Institute of Himalayan Geology, Dehradun, and MoES-National Centre for Polar and Ocean Research, Goa, among many others, have participated in the research and contributed to the understanding of climate change in the Arctic regions and its global impacts. Some of the significant Indian initiatives to address climate change issues impacting Arctic regions are detailed below.

1.6 CLIMATE CHANGE AND ARCTIC GLACIERS

Many changes of glaciers of the Arctic have been noticed in previous years. Indian scientists have also shown much interest to get information related to these changes in glaciers. They have studied West Craig, Borger, and Mindralavan Glaciers in this reference.

1.7 GEOMORPHOLOGY AND SEDIMENTOLOGY OF DIVERSIFIED MORPHOLOGICAL ZONES OF GLACIATED TERRAIN OF THE NY-ÅLESUND

Diversified surface processes of the Ny-Ålesund region carve the landscape and exhibit distinguished Arctic's landforms. Many studies are done on climate change using various proxies. Yet, meagre attention has been paid to geomorphological and sedimentological parameters. Sediment characteristics, AMS^{14}C dates and geomorphic features have been used to reconstruct paleoclimate. Based on the landforms and sediments, this region has been classified into five morphological zones: glacial (moraines GL), proglacial (lacustrine deposits LD), outwash plain (sand deposits OWP), fluvial deposits (FD) and coastal cliff (CC). The glacial moraines (GL) suggest devoid of any sedimentary structures and coarse-grained, matrix-supported boulders, and it is composed of unconsolidated, unstratified, massive.

In contrast, OWP, LD, FD and CC are semi-consolidated, stratified, fine-grained layers of sand, silt, and clay with gravels and faint sedimentary structures. CC's and LD's sediments are very poorly sorted, very positively skewed and very leptokurtic, and is comprised of medium to fine sand, silt and clay. The sediment characteristics of various morphological zones' geomorphic features explain that this region was carved and dominated by glaciers (Prof. D.S. Singh, personal communication).

The poorly sorted sediments of all the geomorphological zones explain the depositional environment's fluctuating energy, especially under warm climate at interglacial stages during 44, 27, 12, 10.5 ka BP. It may be inferred that the prevailing environment was not consistent and persistent for an extended period (Schuur et al. 2015).

1.8 QUARTZ GRAIN MICROTEXTURE AND MAGNETIC SUSCEPTIBILITY ASSESSMENT OF THE NY-ÅLESUND REGION

The quartz grain microtexture reveals predominant glacial activities in the top 40 cm of the section, while the middle 40–55 cm part represents some aeolian activities along with glacial signatures. The bottommost part, in addition to glacial markers, exhibits some aqueous evidence as well. The lithology shows medium-grained sand in the upper leg and coarse-grained sand with occasional shell pieces in the lower leg. Angular gravels (2–12 mm) are present throughout with increasing size from top to bottom. Based on the above observations and ^{14}C AMS dates, it can be summarised that after the Last Glacial Maximum (LGM), the pre-Holocene period shows rapid glacial retreat, followed by a warmer period during the early Holocene. Mid- and late Holocene is marked by a predominantly glacial environment characterised by meltwater streams originating from the glaciers and flowing into the fjord. Magnetic susceptibility studies have also been attempted. Four alternate stages of colder and warmer phases have been established (Dr R. Kar, personal communication). Though some similarities among the different climatic phases are discernible between the quartz grain microtexture and magnetic susceptibility studies, they are not entirely compatible, probably due to their different responses to the climatic variations (http://www.sciencemag.org/news/2013/08/scienceshot-arctic-warming-twice-fast-rest-world).

Indubitably, the sea ice is frozen ocean water that grows and melts in the ocean. On the contrary, icebergs, glaciers and ice shelves float in the sea, having originated on the land. Sea ice is typically covered with snow, and Arctic sea ice keeps the Polar regions cool. It also helps modulate and control the global climate. Having a bright surface, 80% of the sunlight that strikes sea ice gets reflected into space. As sea ice melts in the summer, it exposes the dark ocean surface. Therefore, instead of reflecting 80% of the sunlight, the ocean absorbs 90% of the sunlight. Thus, the oceans heat up, and Arctic temperatures rise further.

A slight rise in temperature at the poles leads to still more significant warming over time, thus making the Polar regions the most sensitive areas to a subtle change in earth's climates. Accordingly, both the thickness and extent of the Arctic's summer sea ice have shown a dramatic decline over the past 30 years, consistent with observations of a warming Arctic. The loss of sea ice can also accelerate global warming trends and change climate patterns.

Sea ice extent is a measurement of ocean area where there is at least some sea ice. Usually, scientists define a minimum concentration threshold to mark the ice edge; the most common cut-off is 15%.

The Arctic sea ice extent is focused more closely than other aspects of sea ice because satellites measure the volume more accurately than other measurements, such as thickness. The Arctic's sea ice minimum is considered when the Arctic's sea ice exhibits the lowest areal extent. It occurs at the end of the summer melting season. The Arctic sea ice maximum is regarded as the day of the year when Arctic sea ice reaches its most considerable areal extent. It occurs at the end of the winter cold season.

1.9 REMOTE SENSING OBSERVATIONS AND MODEL REANALYSIS

Applications of remote sensing techniques and modelling have been applied to assess and quantify the Arctic sea ice loss in July–September, with particular attention to September on a daily, monthly, annual and decadal basis.

Coincidently, the 12 lowest extents in the satellite era occurred in the last 12 years. It is attributed to the impacts of land-ocean warming and the northward heat advection into the Arctic Ocean over the past 40 years (1979–2018); actual warming rates have been identified in the Arctic Ocean in the last 40 years. The study demonstrates the linkages of sea ice dynamics to ice drifting and accelerated melting. It occurs due to persistent low pressure and high air-ocean temperatures, supplemented by the coupled ocean-atmospheric forcing (http://news.uga.edu/releases/article/study-2015-melting-greenland-ice-faster-arctic-warming-0616/). The accelerated decline is recorded in the Arctic sea ice extent and sea ice concentration over the past four decades.

The ocean-atmosphere coupled mechanism plays a vital role in the global climate change. Sea ice variability and trends were computed using satellite and model reanalysis measurements for the whole Arctic and each of its nine regions: (i) Seas of Okhotsk and Japan, (ii) the Bering Sea, (iii) Hudson Bay, (iv) the Baffin Bay/Labrador Sea, (v) Gulf of St. Lawrence, (vi) Greenland Sea, (vii) Kara and Barents Seas, (viii) the Arctic Ocean and (ix) Canadian Archipelago. Overall, Arctic sea ice declined in all seasons and on a yearly average basis, although the highest and lowest negative trends were recorded in summer and winter/spring, respectively. The study reveals that the Arctic Ocean, Kara and Barents Seas, the Greenland Sea, and the Baffin Bay region are majorly responsible for the total negative sea ice extent trend in the Arctic (Dr. Avinash Kumar, personal communication). The study demonstrated the interannual and seasonal variabilities of Arctic sea ice and interactions among the atmosphere, ice and ocean (Tedesco et al. 2016).

1.10 ASSESSMENT OF SPATIO-TEMPORAL VARIABILITY OF SNOWMELT ACROSS SVALBARD

Indian researchers have monitored snowmelt over the Svalbard region as significant changes in the interannual variation of Arctic snow and sea ice are connected to the global climate changes using active microwave sensors. These sensors are frequently used to detect surface melting because of their sensitivity to the presence of liquid water in snow/ice. Data of QuikScat, OSCAT, ASCAT, and OSCAT-2 are used to map the annual melt duration and summer melt onset for the Svalbard archipelago. It provides one of the most extended and continuous radar backscatter records to estimate snowmelt onset and melt duration on Svalbard spanning from 2000 to 2017. A single threshold-based model was used to detect snowmelt timing; the threshold was calculated using meteorological data from the human-crewed weather stations. The results capture the timing and extent of melt events caused by warm air temperature and precipitation because of the influx of moist, mild air from the Norwegian and Barents seas. The highest melt duration and earlier melt onset occurred in southernmost and western Svalbard in response to the influence of the warm west Spitsbergen current. Compared to previous studies, we found considerable interannual variability and regional differences. Though the record is short, there is an indication of an increasing trend in total days of melt duration and earlier summer melt onset date possibly linked to the general warming trend (Dr A.J. Luis, personal communication). Climate indices such as Interdecadal Pacific Oscillation and Pacific Decadal Oscillation are well correlated with onset melt and duration across Svalbard. With the reported year-after-year decrease in sea ice cover over the Arctic Ocean, the trend towards longer snowmelt duration inferred from this study is expected to enhance the Arctic amplification (McCarthy 2011).

1.11 ASSESSMENT OF MASS BALANCE OF THE ARCTIC GLACIERS

Prof. A.L. Ramanathan (personal communication) studied the changes in the area from 1993 to 2018 and mass balance of Vestre Broggerbreen glacier, Ny-Ålesund, Arctic from 2011 to 2017. The glaciated area had decreased from 3.96 km^2 in 1993 to 3.57 km^2 in 2018. Its range varied between 0.011 and 0.02 km^2, resulting into a total area loss of 0.39 km^2 (~10% at 0.016 km^2 a-**1**). A comparatively rapid decrease in the glaciated area was found during 1998–2010 (0.02 km^2 a-1), whereas less retreat rate was found in 1993–1998 (0.011 km^2 a-1) and 2010–2018 (0.012 km^2 a-1 13). The Vestre Broggerbreen glacier's mass balance was negative throughout the entire study period (2011–2018). Mass balance ranged between −0.08 (2013–14) and −1.22 m w.e. (2015–2016) with a cumulative mass balance of −4.31 m w.e. (0.016 km^2 a-1). A strong relationship between mass balance and summer temperature was found with $R^2 = 0.97$ at $P < 0.05$ (Rajmund 2007).

1.12 SCIENTIFIC EXPLORATION OF KONGSFJORDEN

Kongsfjorden, an icy archipelago with a length of about 40 km and a width ranging from 5 to 10 km, is a glacial-fjord in the Arctic (Svalbard) which lies in the N-W coast of Spitsbergen, the main island of Svalbard. It is a site where warmer waters of the Atlantic meet the colder waters of the Arctic. An open fjord without a sill is primarily under the influence of the adjacent shelf processes. The Transformed Atlantic Water (TWA) from the west Spitsbergen current and the glacier-melt freshwater at the inner fjord create intense temperature and salinity gradients along the fjord's length. Southerly winds will result in down-welling at the coast. Such winds also hinder the exchange processes that take place between the shelf and the fjord, while the northerly winds will move the TWA water below the upper layer towards the coast. During summer, the meltwater not only stratifies the upper water column but significantly alters the turbidity.

It also impacts the seasonal changes in the biomass of phytoplankton. Thus, any altered interaction between the Atlantic water and the (turbid) meltwaters from tidal glaciers on a seasonal to interannual timescale is likely to affect the fjord's aquatic ecosystem. The long-term changes in the fjord hydrography and sedimentation will affect the benthic ecosystem.

Against the above backdrop of the fjord system's climate sensitivity, India has evolved a multi-institutional programme of long-term monitoring of the Kongsfjorden. It was initiated by the deployment of an ocean-atmosphere mooring system along regular repeat transects. It was designed to measure seasonal physical, chemical and biological parameters to establish a long-term comprehensive data set on physical, chemical, biological and atmospheric measurements. The influence of interaction between the warm Atlantic water and the cold glacial-melt fresh water and their effects on the biological productivity and phytoplankton species composition and diversity within the fjord are equally essential to be addressed.

1.13 DEPLOYMENT OF UNDERWATER MOORED OBSERVATORY IN THE KONGSFJORDEN FJORD

The Kongsfjorden is a natural laboratory. It is ideal for studying Arctic climate variability. Scientists predict that the melting of the Arctic glaciers will trigger patterns of weather and ocean circulations. Such changes could affect the climate of other parts of the world. One of the significant limitations in the logistics has been to reach the location and collect data, especially during the severe Arctic winter. The IndARC observatory is an attempt to overcome this lacuna. Data collected by IndARC would be used for climate modelling studies to understand the Arctic processes that influence Indian monsoons. The IndARC, the country's first underwater moored observatory deployed in the Kongsfjorden fjord, halfway between Norway and the North Pole, represents a significant milestone in India's scientific endeavours in the Arctic region. The engineers and scientists from the MoES-National Centre for Polar and Ocean Research (NCPOR), MoES-National Institute of Ocean Technology (NIOT) and MoES-Indian National Centre for Ocean Information Services (INCOIS) developed the IndARC. It was deployed from *RV Lance*, a research vessel belonging to the Norwegian Polar Institute. The observatory is moored and anchored at a depth of 192 m. It has an array of 10 state-of-the-art oceanographic sensors strategically positioned at various depths in the water. The sensors were programmed to collect real-time data on seawater temperature, salinity, ocean currents and other vital parameters of the fjord (https://ncpor.res.in/).

The correlation between less and more ice in the Arctic is very close to how the monsoon behaves. Just as we know that the *El Nino effect* (hot ocean temperatures in the Equatorial Pacific) is having a global impact on weather patterns, including the Indian monsoon, we learn that the Arctic ice also has a significant effect. The Arctic precipitation and temperatures from June to October hint at the monsoon likely to occur in the coming year. The oscillation in the air creates the western disturbance as it moves over ice and snow in the Arctic. If there is less oscillation, the air will have less moisture, leading to less rainfall in the monsoons.

1.14 EXPLORING TELECONNECTION BETWEEN ARCTIC CLIMATE AND TROPICAL INDIAN MONSOON

The climate change over the Arctic region and North Atlantic shows a mechanistic link with the Indian Summer Monsoon (ISM) during the Holocene. The marine and continental archives of ISM precipitation suggest significant shifts during the Holocene aligned with the Arctic climate over multi-time scales. The ISM strengthened during the Greenlandian (11.7–8.3 kyr BP), showing variable but overall decreasing precipitation during the Northgrippian (8.3–4.2 kyr BP). Synchronicity exists in palaeoclimatic records. It could be due to possible age errors and resolution and proxy response to the changing climate. During the Meghalayan age (4.2 kyr to recent), the Indian subcontinent witnessed a protracted dry event beginning at ~4.2 kyr BP and ended at ~3.4 kyr BP. Other significant events of the Meghalayan age include the Medieval Climate Anomaly (MCA). The Current Warm Period (CWP) showing a strong ISM, interrupted by the Little Ice Age (LIA) – a cold phase with low precipitation in the Indian subcontinent (Prof. A.K. Gupta, personal communication). The millennial-scale variability in the ISM is associated with the Heinrich and Bond events. The cooling in the Arctic sea, ice expansion in the North Atlantic and weakening of the Atlantic overturning meridional oscillations due to high freshwater flux and ice rafting in the North Atlantic caused weak ISM precipitation over the south and southeast Asia (http://www.rivm.nl/en/Documents_and_publications/Common_and_Present/Newsmessages/2016/Documentary_Sea_Blind_on_Dutch_Television).

In conclusion, we may submit that India is striving to obtain deep insight into the climate changes occurring over the Arctic region as its impacts are expected to influence Indian climate. Sustained monitoring and observational network shall be an added advantage to strengthen our understanding of Arctic climate and its teleconnection with Indian monsoons.

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Bio-Optical Characteristics in Relation to Phytoplankton Composition and Productivity in a Twin Arctic Fjord Ecosystem during Summer

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Edited by

Majeti Narasimha Vara Prasad
School of Life Sciences
University of Hyderabad (an Institution of Eminence)
Hyderabad, Telangana, India

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Contents

List of Contributors

Nadeesh M. Adassooriya
Department of Food Science & Technology,
Wayamba University of Sri Lanka,
Makandura, Sri Lanka

Madhoolika Agrawal
Department of Botany, Institute of Science,
Banaras Hindu University, Varanasi,
Uttar Pradesh, India

S.B. Agrawal
Department of Botany, Institute of Science,
Banaras Hindu University, Varanasi,
Uttar Pradesh, India

Jitendra Ahirwal
Restoration Ecology Laboratory, Department
of Environmental Science and Engineering,
Indian Institute of Technology (Indian School
of Mines), Dhanbad, Jharkhand, India

J.R.B. Alfred
Nature Environment & Wildlife Society
(NEWS), Kolkata, West Bengal, India

H.A.D.B. Amarasiri
Department of Pharmacy, The Open
University of Sri Lanka, Nugegoda, Sri Lanka

Luís P. Azevedo
Materials Engineering Department, Federal
University of Ouro Preto, Ouro Preto, Minas
Gerais, Brazil

Bruno Barbosa
MEtRICS, Departamento de Ciências e
Tecnologia da Biomassa, Faculdade de
Ciências e Tecnologia, FCT, Universidade
Nova de Lisboa, Caparica, Portugal;
Universidade Feevale, Novo Hamburgo –
RS, Brazil

S.P. Biswas
Department of Life Sciences, Dibrugarh
University, Dibrugarh, Assam, India

E. Bocharnikova
Department of Functional Ecology,
Institute Basic Biological Problems,
Pushchino, Russia

Cláudia Cseko Nolasco de Carvalho
Department of Biology, State University of
Alagoas, Santana do Ipanema, Alagoas, Brazil

Udo Censkowsky
Bluesensus – Sustainability & Seafood
Consulting, Weilheim, Germany

S.B. Chaphekar
Homi Bhabha State University, Mumbai,
Maharashtra, India

Smita Chaudhry
Institute of Environmental Studies,
Kurukshetra University, Kurukshetra,
Haryana, India

Biswajit Roy Chowdhury
Nature Environment & Wildlife Society (NEWS), Kolkata, West Bengal, India

Ronan Courtney
Department of Biological Science, Faculty of Science & Engineering, Bernal Institute, University of Limerick, Limerick, Ireland

Sijagurumayum Geetanjali Devi
Department of Forestry and Environmental Science, Manipur University, Imphal, Manipur, India

Ajanta Dey
Nature Environment & Wildlife Society (NEWS), Kolkata, West Bengal, India

Bhupinder Dhir
School of Sciences, Indira Gandhi National Open University, New Delhi, India

Denise C.R. Espinosa
Polytechnic School of University of São Paulo, Chemical Engineering Department, São Paulo, Brazil

Mihail Eva
Department of Geography, Faculty of Geography and Geology, "Alexandru Ioan Cuza" University, Iasi, Romania

Ana Luísa Fernando
MEtRICS, Departamento de Ciências e Tecnologia da Biomassa, Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa, Caparica, Portugal

Seemaa S. Ghate
Women Scientist 'B', Department of Science and Technology, New Delhi, India; Knowhow Foundation, Pune, Maharashtra, India

Anu Gopinath
Department of Aquatic Environment Management, Kerala University of Fisheries and Ocean Studies, Kochi, Kerala, India

Anna Grobelak
Faculty of Infrastructure and Environment, Institute of Environmental Engineering, Czestochowa University of Technology, Czestochowa, Poland

Marta Jaskulak
Faculty of Infrastructure and Environment, Institute of Environmental Engineering, Czestochowa University of Technology, Czestochowa, Poland; LGCgE, Laboratoire de Génie Civil et géo-Environnement University of Lille, IMT Lille Douai, Univ. Artois, Yncrea Hauts-de-France, Lille, France

Lander de Jesus Alves
Postgraduate Program in Biology and Biotechnology of Microorganisms, State University of Santa Cruz (UESC), Ilhéus, Bahia, Brazil

Anu Joy
Department of Chemistry and Research Centre, St Albert's College, Ernakulam, Kerala, India

Atya Kapley
Director's Research Cell, National Environmental Engineering Research Institute, (CSIR: NEERI), Nagpur, Maharashtra, India

Rupinder Kaur
Soil Ecosystems and Restoration Ecology Lab, Department of Botany, Panjab University, Chandigarh, India

M.L. Khan
Department of Botany, Dr. Harisingh Gour Vishwavidyalaya (A Central University), Sagar, Madhya Pradesh, India

Nazmun Ara Khanom
Department of Chemistry, Jorhat Institute of Science & Technology (JIST), Jorhat, Assam, India

Amit Kumar
Department of Geoinformatics, Central University of Jharkhand, Ranchi, Jharkhand, India

Rima Kumari
Department of Environmental Science and Engineering, Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand, India

Carlos A.F. Lagarinhos
Polytechnic School of University of São Paulo, Metallurgical and Materials Department, São Paulo, Brazil

Suvha Lama
Director's Research Cell, National Environmental Engineering Research Institute (CSIR: NEERI), Nagpur, Maharashtra, India

R.P. Madav
Terracon Ecotech Pvt. Ltd., Mumbai, Maharashtra, India

D.N. Magana-Arachchi
National Institute of Fundamental Studies, Kandy, Sri Lanka

Subodh Kumar Maiti
Restoration Ecology Laboratory, Department of Environmental Science and Engineering, Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand, India

Thaís de Marchi Soares
Department of Soil Science, University of Sao Paulo, Piracicaba, São Paulo, Brazil

V. Matichenkov
Department of Ecology and Physiology of Autotrophic Organisms, Institute Basic Biological Problems, Pushchino, Russia

Maibam Dhanaraj Meitei
Department of Forestry and Environmental Science, Manipur University, Imphal, Manipur, India

Florin-Constantin Mihai
CERNESIM Center, Department of Sciences, Interdisciplinary Research Institute, "Alexandru Ioan Cuza" University, Iasi, Romania

Chanchal Kumar Mitra
Department of Biochemistry, University of Hyderabad, Hyderabad, Telangana, India

Akash Nag
Department of Environmental Sciences, Central University of Jharkhand, Ranchi, Jharkhand, India

Fábio Carvalho Nunes
Academic Department, Federal Institute Baiano (IFBAIANO), Santa Inês, Bahia, Brazil

Rashmi Paliwal
Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana, India

Sara Pelaez Sanchez
Department of Biological Science, Faculty of Science & Engineering, Bernal Institute, University of Limerick, Limerick, Ireland

Marcin Pietrzykowski
Department of Forest Ecology and Silviculture, Faculty of Forestry, University of Agriculture in Krakow, Krakow, Poland

Majeti Narasimha Vara Prasad
School of Life Sciences, University of Hyderabad, Hyderabad, Telangana, India

Richa Rai
Plant Ecology and Climate Change Science Division, CSIR National Botanical Research Institute, Lucknow, Uttar Pradesh, India

Sanchayita Rajkhowa
Department of Chemistry, Jorhat Institute of Science & Technology (JIST), Jorhat, Assam, India

Purabi Saikia
Department of Environmental Sciences, Central University of Jharkhand, Ranchi, Jharkhand, India

Jyotirmoy Sarma
Department of Chemistry, Kaziranga University, Jorhat, Assam, India

Olaf Schmidt
School of Agriculture and Food Science, University College Dublin, Dublin, Ireland

Petra Schneider
Magdeburg-Stendal University of Applied Sciences, Magdeburg, Germany

L.R. Sendanayake
Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka

Fernando G. da Silva Araújo
Materials Engineering Department, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil

Anand Narain Singh
Soil Ecosystems and Restoration Ecology Lab, Department of Botany, Panjab University, Chandigarh, India

Gagan Preet Singh Sidhu
Centre for Applied Biology in Environment Sciences, Kurukshetra University, Kurukshetra, Haryana, India

José Rodrigues de Souza Filho
Academic Department, Federal Institute Baiano (IFBAIANO), Catu, Bahia, Brazil

Jorge A.S. Tenório
Polytechnic School of University of São Paulo, Chemical Engineering Department, São Paulo, Brazil

Niteshwori Thongam
Department of Forestry and Environmental Science, Manipur University, Imphal, Manipur, India

R.P. Wanigatunge
Department of Plant and Molecular Biology, Faculty of Science, University of Kelaniya, Kelaniya, Sri Lanka

Shailendra Yadav
Director's Research Cell, National Environmental Engineering Research Institute, (CSIR: NEERI), Nagpur, Maharashtra, India

Preface

There is a growing global concern about environment and sustainable development. The 2030 Agenda for Sustainable Development was launched in 2015 to end poverty and set the world on a path of peace, prosperity and opportunity for all on a healthy planet (UN Sustainable development goals 2015). The 17 Sustainable Development Goals (SDGs) demand nothing short of a transformation of the financial, economic and political systems that govern our societies today to guarantee the human rights of all. They require immense political will and ambitious action by all stakeholders. Global efforts to date have been insufficient to deliver the desired to current and future generations. Due to COVID-19, globally visible and an unprecedented health emergency, economic and social crisis, threatening lives and livelihoods jeopardizing the SDG's Agenda's promise to the current and future generations.

In this regard an integrated approach of management and restoration of ecosystems is a clear global concern. With increasing population explosion and exploitation of natural capital pressure on the planet earth is steeply increasing. In the last half century, the world human population has doubled, the consumption of natural resources has been multiplied by six, biodiversity has drastically decreased and the degradation of many ecosystems and global environmental modifications are glaring.

Odum H.T., used the term "ecological engineering" in 1960s, in several publications. Mitsch and Jøørgensen highlighted the necessity of ecological engineering in 1989.

Ecology and Ecosystems study is the only scientific field capable of providing the scientific bases necessary to implement ecosystem manipulations e.g. to mitigate the effect of global climatic changes. Such ecosystem manipulations could potentially have very negative impacts if not well designed.

Conversely, modern scientific ecology needs concrete examples of applied management Practitioners, stakeholders, and policy makers for ecosystem engineering are indeed good forcing processes to encompass the range of the studied ecological variables in terms of heterogeneity, limits and the occurring interactions between these variables.

In the same vein, the full development of ecological engineering requires stakeholders, scientists from engineering sciences, socio-economical sciences, and all environmental sciences to work together both to build a common general framework and to ground their work on concrete common projects.

Ecological engineering is also particularly relevant for developing countries. Indeed, the need for sustainable exploitation of ecosystems is very high in these countries where populations are still quickly growing and where individuals and institutions have often difficulties to develop practices based on high input rates (energy, water, mineral nutrients).

In this context this book assumes considerable significance. Thus, this book aimed at integrating multiple ecosystem services of the “Earth Ecosystem” resources (biotic and abiotic) keeping in view the UN 17 Sustainable Development Goals. **Phytobiome** and **microbiome** services that humans derive are focussed. Essentially Ecological and Ecosystem Engineering principles of the global ecosystem (Earth) for sustainable development will be dealt in this work

Goals of Ecological Engineering are

1) the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance
2) the development of new sustainable ecosystems that have both human and ecosystems, and ecological value.
3) Ecological restoration - the return of an ecosystem to a close approximation of its condition prior to disturbance

Terms that are synonyms, subdisciplines, or fields similar to the crux of this books are: Bioengineering, biomanipulation, biospherics, ecohydrology, ecological engineering ecosystem rehabilitation, ecotechnology, engineering ecology, habitat reconstruction, nature cure, nature engineering, reclamation ecology, restoration ecology, river and lake restoration, solar aquatics, sustainable development, agroecology, synthetic ecology and wetland restoration.

Ecological Engineering - the design of sustainable ecosystems that integrate human ecosystems with its natural environment for the benefit of both. An attempt has been made and designed for the benefit of Environmental Engineers, Pollution Engineers and Energy Engineers, Researchers working in Water, Energy footprints, Carbon foot print, Environmental Biotechnologists etc. Researchers and academicians, undergraduate and graduate students in the broad area of Environmental Sciences, Ago-forestry and agronomy, Land scape engineers etc.

65 Authors from 9 countries viz., Brazil, Germany, India, Ireland, Poland, Portugal, Romania, Russia and Sri Lanka participated and contributed to various topics listed below:

1) Ecological engineering and ecosystem services - theory and practice
2) Ecological and ecosystem engineering for economic and environmental revitalization
3) Environmental issues and priority areas for ecological engineering initiatives
4) The role of Soil meso and macrofauna indicators for restoration assessment success in rehabilitated mine site
5) Urban Environmental issues – solutions by ecological and ecosystem engineering
6) Mitigation of Urban Environmental issues by applying ecological and ecosystem engineering
7) Soil fertility restoration, theory and practice
8) Extracellular soil enzymes act as moderator to restore carbon in the soil habitats
9) Ecological engineering for solid waste reduction and resource recovery
10) Urban floods and mitigation by applying ecological and ecosystem engineering
11) Ecological engineering and restoration of mine ecosystems
12) Restoration of abandoned mines
13) Wetland and watershed Lake restoration
14) Restoration of Riverine Health: An Ecohydrological Approach - Flow Regimes and Aquatic Biodiversity
15) Ecosystem services of phoomdi islands of Loktak, a dying Ramsar site in north-east India
16) The application of reefs in shoreline protection

17) Mangroves, as shore engineers, are nature-based solutions for ensuring coastal protection
18) Forests degradation prevention through nature-based solution: an Indian perspective
19) Restoring Ecosystem Services of Degraded Forest Ecosystems in a Changing Climate
20) Forest degradation prevention
21) Use of plants for air quality improvement
22) Phylloremediation for Mitigating Air Pollution
23) Air quality improvement using green cover
24) Air quality improvement using phytodiversity and plant architecture
25) Information explosion in digital science and ecosystems
26) Nanotechnology in Ecological and Ecosystem Engineering

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Muneeb U. Rehman • Sabhiya Majid
Editors

Therapeutic Applications of Honey and its Phytochemicals

Volume II

Springer

Editors
Muneeb U. Rehman
Department of Clinical Pharmacy
King Saud University
Riyadh, Riyadh, Saudi Arabia

Department of Biochemistry
Govt. Medical College (GMC-Srinagar)
Srinagar, Jammu and Kashmir, India

Sabhiya Majid
Department of Biochemistry
Govt. Medical College (GMC-Srinagar)
Srinagar, Jammu and Kashmir, India

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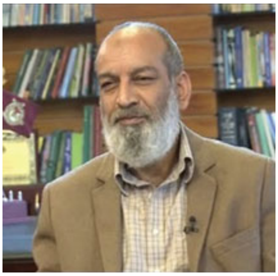
Dedicated to our Parents

Foreword



Honey is one of the nature's marvellous gifts to mankind finding mention in various valued ancient texts. This delicious edible substance produced by honey bees has been consumed by humans since times immemorial to supplement diet and cure various ailments. For its innumerable medicinal properties and health benefits, from ancient times honey has been used in traditional medicines to cure wounds, eye diseases, hiccups, constipation, piles, eczema, ulcers, etc. The various medicinal benefits of honey based on its antioxidant, anti-inflammatory, anti-cancerous, neuroprotective, anti-fibrotic and anti-diabetic properties are attributed to the presence of certain active ingredients in it. Flavonoids and polyphenols, the main bioactive compounds found in honey, are known potent antioxidants. Recent and modern studies have attributed the presence of these bioactive compounds to its therapeutic effects against illnesses related to nervous system, cardiovascular system, diabetes mellitus, gastrointestinal system and even the most dreaded cancers.

The book entitled *Therapeutic Applications of Honey and its Phytochemicals* (Volume II) is an in-depth compilation of recent research on this subject. The editors Dr. Muneeb U. Rehman and Prof. Sabhiya Majid have compiled the book splendidly shedding light on all the valuable research literature currently available on the topic. Volume II is based on prevention and treatment of various diseases by honey and its phytochemicals, providing finest details related to their possible mechanism of action. The main highlights of this volume are book chapters by collaborators from around the globe. Scientists from USA and Saudi Arabia have detailed the molecular mechanistic approach of anti-leukemic bioactive compounds in honey. Another chapter deals with the neuro-protective effect of honey and its mechanistic basis. A group from Saudi Arabia and UAE has discussed neuro-protection via NAD^+ pathway in various neuro-degenerative diseases. Collaborators from India and Saudi Arabia have discussed the molecular mechanisms underlying prevention and treatment of cancers by honey and its phytochemicals. Another group from India has elaborated upon the role of the phytochemicals from honey as MAP-kinase inhibitors. Besides these, the other major chapters included in this book are focussed on mechanistic basis of prevention and treatment of various diseases including fibrosis, diabetes, metabolic disorders, dermatitis, cardiovascular diseases, arthritis, wound healing and fatty liver disease by honey and its phytochemicals.

Therapeutic Applications of Honey and its Phytochemicals (Volume II) is an exhaustive and finest compilation of its kind. It specifically presents a holistic view of the available literature on honey and its medicinal value. The editors have incredibly provided solid foundation of the subject to meet the requirements of researchers, medical practitioners and entrepreneurs. For medical practitioners including those of alternative medicine, herbal therapists, and dieticians this book will be of immense clinical benefit. For academicians, scientists, teachers and students, this book will be a rich source of information from where they can satiate their quest for knowledge.

University of Kashmir
Srinagar, India

Khurshid Iqbal Andrabi

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About the Editors

Muneeb U. Rehman PhD is a faculty member at College of Pharmacy, King Saud University, Riyadh, Saudi Arabia. He holds a doctorate in Toxicology (specialization in cancer biology and natural product research) from Jamia Hamdard, New Delhi, India Dr. Rehman has more than 10 years of research and teaching experience in the field of toxicology, biochemistry, cancer biology, natural product research and pharmacogenomics. He is the recipient of several national and international fellowships and awards. He has published 90 research papers in peer-reviewed, international journals, and 25 book chapters. Dr. Rehman is an on the editorial boards and is a reviewer of several high-impact, international scientific journals. He is also a life member of various international societies and organizations. Currently, Dr. Rehman is engaged in studying the molecular mechanisms of cancer prevention by natural products and the role of pharmacogenomics and toxicogenomics in evaluating the effectiveness and safety of drugs.

Sabhiya Majid PhD is a Professor and Chairperson of the Department of Biochemistry, Govt. Medical College (GMC-Srinagar), J&K, India. She is also the Nodal Officer of the Multi-disciplinary Research Unit (ICMR-MRU) funded by Indian Council of Medical Research. Prof. Majid has received numerous grants from various Government of India funding agencies, and has implemented various research projects and infrastructure development schemes, including FIST–DST-GOI (Department of Science & Technology, Fund for Improvement of Science &Technology Infrastructure, Govt. of India. She is a member of several scientific associations and Boards of Undergraduate, Postgraduate and Research Studies. Prof. Majid has 25 years of experience in teaching, research and supervision of diagnostic laboratories at the Govt. Medical College Srinagar, including teaching MBBS, BDS, nursing and medical laboratory technology students. Her current research focuses on identifying non-invasive markers for cancer diagnosis.

Muneeb U. Rehman
Sabhiya Majid *Editors*

Therapeutic Applications of Honey and its Phytochemicals

Volume II

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Nuts and Nut Products in Human Health and Nutrition

Edited by Venketeshwer Rao, Leticia Rao, Md Ahiduzzaman and A. K. M. Aminul Islam

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Chiranjiv Pradhan, Nikhila Peter, Namitha Dileep, Selvi Subramanian, Muthulakshmi Chellamuthu, Manonmani Swaminathan, Modupeade C. Adetunji, Stephen A. Abiola Akinola, Nancy Nleya, Mulunda Mwanza, Jinu Madhi, Mohan Chandra Kalita, Venketeshwer Rao, Leticia Rao, Livio Torta, Patrizia Bella, Giulia Mirabile, Antonio Vella, Vincenzo Ferrantelli

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Saleena Mathew
School of Industrial Fisheries
Cochin University of Science and Technology
Kochi, Kerala, India

Manjusha Kalarikkathara Parameswaran
School of Industrial Fisheries
Cochin University of Science and Technology
Kochi, Kerala, India

Maya Raman
Department of Food Science and Technology, School of Ocean Science and Technology
Kerala University of Fisheries and Ocean Studies
Kochi, Kerala, India

Dhanya Pulikkottil Rajan
Department of Aquaculture
M.E.S Asmabi College
Kochi, Kerala, India

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About the Authors

Saleena Mathew has got over 35 years of research experience of which 30 years of teaching at postgraduate level. She was Director, School of Industrial Fisheries, Cochin University of Science and Technology, for one term of 3 years from 2005 to 2008 and retired from the University as Professor in 2016. For the last 27 years of service, she was engaged in teaching and research in the field of fish processing technology and fish biochemistry at the School of Industrial Fisheries, Cochin University of Science and Technology, and catered trained personnel for the seafood industry. She is a Recognized Guide of Cochin University of Science and Technology for the last 25 years and served as Expert Member and Chairperson of various scientific and academic bodies of Cochin University of Science and Technology and as Expert Member for various programs of other universities and research institutes. She was appointed as Associate Member of The World Academy of Sciences (TWAS), Italy, in 1998, and has visited Argentina, Italy, and other foreign countries as part of her research work. She has coordinated and conducted various symposia, workshops, and training programs at the School in the field of fish processing, quality assurance, and food safety. She has got more than 50 research publications in the specialized areas of biochemistry, fish preservation, and bioactive substances from fish and fish discards.

Maya Raman is presently working as Associate Professor (Meat and Fish Processing), Kerala University of Fisheries and Ocean Studies, Cochin. She graduated in Botany and received her M.Sc. (Industrial Fisheries) and Ph.D. degrees from the School of Industrial Fisheries, Cochin University of Science and Technology, India, in 2006. Her doctoral research was in fish biochemistry and fish processing technology. She also worked as Postdoc at Applied Nutrition and Food Chemistry, Centre for Chemistry and Chemical Engineering, Lund University, with the scholarship from Erasmus Mundus External Cooperation Windows Lot 15 Program. She also worked as Women Scientist at Indian Institute of Technology Madras with the Women Scientist Scheme (WOS-A) funded by the Department of Science and Technology, India. She was selected as Young Student Speaker IFCON 2003 by the Association of Food Scientists and Technologists, India. She also worked as Faculty at the Department of Food Science and Technology, MACFAST, as Certified Technologist (Export Inspection Authority, India) at Koluthara Exports Limited, and as Research Officer at NGIL, India. She has 17 peer-reviewed publications to her credit and has published a book and 8 book chapters. She has also presented 14 papers at national and international symposia/conferences. Her area of expertise is fish biochemistry (collagen), fish processing technology, nutrition and health (cancer), nanotechnology, bioactive marine compounds, dietary fibers (cereal, vegetable, marine algae) and colon cancer (in vitro and in vivo), molecular modelling and dynamics, gut simulation techniques, drug encapsulation, hydrogels, antimicrobial biodegradable food wraps, etc. She is also Life Member of the AFST(I), SOFT(I), and SASNET, and member of ACS. She also qualified the National Eligibility Test (NET) conducted by the ASRB in 2001. A patent on hydrogel from cyclic beta-glucan for cosmetics/food applications has also been filed in 2016.

Manjusha Kalarikkathara Parameswaran graduated in Zoology at the St. Teresa's College Ernakulam and attained her M.Sc. in Biochemistry from School of Biosciences, Mahatma Gandhi University, in 2002. She qualified the joint UGC-CSIR National Eligibility Test (NET) in 2002 and was awarded Junior Research Fellowship (2004–2009). She has also qualified the NET (Plant Biochemistry) conducted by the ASRB-ICAR in 2018. She was awarded Ph.D. in Marine Sciences (Biochemistry) for the studies pertaining to the bioactive potential of glycosaminoglycan's in cephalopods from the School of Industrial Fisheries, Cochin University of Science and Technology (CUSAT), India, in 2011. She has worked as Faculty in Biochemistry at Mar Athanasius College, Kothamangalam; St. Mary's College for Women, Thiruvalla; School of Aquatic Food Products and Technology, Kerala University of Fisheries and Ocean Studies (KUFOS); and the Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, CUSAT. She is a Lifetime Member of the Society of Marine Biologists (SOMB) and Annual Member of the Society of Fishery Technologists India (SOFT-I). She has published three papers and presented six articles in various national and international conferences. Her research interests are marine bioactives and biopolymer hydrogels.

Dhanya Pulikkottil Rajan is presently working as Assistant Professor at MES Asmabi College, Thrissur. She also worked as Faculty at School of Industrial Fisheries, Cochin University of Science and Technology (CUSAT) and St. Albert's College, Ernakulam. She is a postgraduate in Industrial Fisheries from CUSAT and holds doctoral degree in Marine Sciences. Her doctoral study investigated the effects of spice oleoresins in microbial decontamination and their potential application in quality stabilization of tuna (*Euthynnus affinis*) during storage. She has qualified the National Eligibility Test under the Indian Council of Agricultural Research in 2013 and is a Lifetime Member of the Society of Fisheries Technologists (India). She has 5 years of teaching and 4 years of research experience in the field of fish processing. She had worked as Certified Technologist at CAP Seafoods, Kerala, before pursuing research. Her research interests include biopreservation, enhancement of safety and sensory qualities, value addition, and microbial spoilage of seafood products by psychrotrophic and histamine-forming bacteria. She has presented/published 14 research papers in various international and national journals/conferences and published 1 book chapter.

Abbreviations

°C	Degree Celsius
µg	Microgram
µl	Microliter
µm	Micrometer
^{1}H-NMR	Proton Nuclear magnetic resonance
AAS	Atomic absorption spectrometer
ACN	Acetonitrile
AFB	Aflatoxin
AGE	Agarose gel electrophoresis
AMPs	Antimicrobial peptides
APHA	American Public Health Association
a_w	Water activity
AWWA	American Water Works Association
BHC	Benzene hexachloride
BOD	Biological oxygen demand
BoNT	Botulinum toxin
BSA	Bovine serum albumin
CBB	Coomassie brilliant blue
CE	Capillary electrophoresis
CHNS-O	Carbon-hydrogen-nitrogen-sulfur-oxygen
CLLE	Continuous liquid/liquid extraction
COD	Chemical oxygen demand
CP	Cold plasma
CS	Chondroitin sulfate
CTX	Ciguatoxin
DCM	Dichloromethane
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DGGE	Denaturing gradient gel electrophoresis
DO	Dissolved oxygen
DS	Double strength
DS	Dermatan sulfate

DSC	Differential scanning calorimeter
EC	Enzyme Commission
ECM	Extracellular matrix
EDTA	Ethylenediaminetetraacetic acid
ELISA	Enzyme-linked immunosorbent assay
ETP	Effluent treatment plant
FBD	Fluidized bed drying
FBS	Fetal bovine serum
FFA	Free fatty acid
FID	Flame ionization detector
FTIR	Fourier transform infrared
FTU	Formazin Turbidity Unit
GAG	Glycosaminoglycan
Gal	Galactose
GalN	Galactosamine
GalNAc	N-acetylgalactosamine
GC	Gas chromatography
GlcA	Glucuronic acid
GlcN	Glucosamine
GlcNAc	N-acetylglucosamine
GM Counter	Geiger Muller counter
H_2SO_4	Sulfuric acid
HA	Hyaluronic acid
HACCP	Hazard Analysis Critical Control Point
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
HHP	High hydrostatic pressure processing
HMWM	High-molecular-weight markers
HPD	Heat pump drying
HPLC	High-performance liquid chromatography
HPTLC	High-performance thin layer chromatography
HRMS	High-resolution mass spectrometry
i.d.	Internal diameter
ICP	Inductively coupled plasma spectrophotometer
ICP-AES	Inductively Coupled Plasma - Atomic Emission Spectroscopy
IdoA	Iduronic acid
IF	Infrared
IQF	Individually quick frozen
ISO	International Organization for Standardization
JTU	Jackson Turbidity Unit
KS	Keratan sulfate
MPN	Most probable number
MT	Metallothioneins
MTX	Maitotoxin
NMR	Nuclear magnetic resonance

NTU	Nephelometric Turbidity Unit
PCB	Polychlorinated biphenyl
PEF	Pulsed electric field processing
PITC	Phenylisothiocyanate
PL	Pulsed light
ppm	Parts per million
RF	Radio frequency
rpm	Revolutions per minute
SDS	Sodium dodecyl sulfate
SEM	Scanning electron microscope
SFE	Solid funnel extraction
SS	Single strength
TDS	Total dissolved solids
TEMED	Tetramethylethylenediamine
TOC	Total organic carbon
TSS	Total suspended solids
TTX	Tetrodotoxin
UV	Ultraviolet
WHO	World Health Organization
WPCF	Water Pollution Control Facilities
YTX	Yessotoxin

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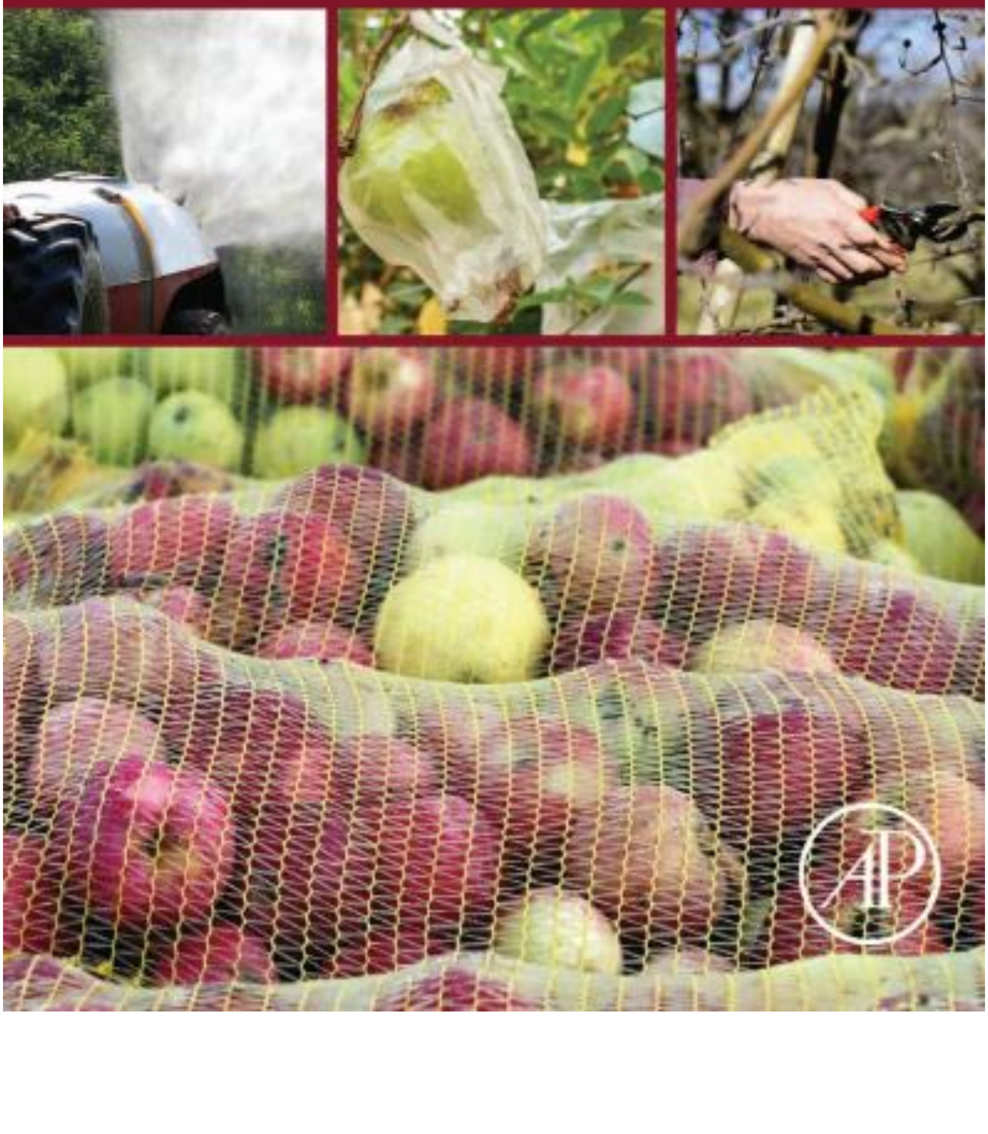

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Edited by

CHANDRAKASAN SIVAPERUMAN
Zoological Survey of India, Andaman & Nicobar Regional Centre, Government of India, Ministry of Environment & Forests, Port Blair, India

AYYAM VELMURUGAN
ICAR-Central Island Agricultural Research Institute, Port Blair, India

AWNINDRA KUMAR SINGH
ICAR-Central Island Agricultural Research Institute, Port Blair, India

IYYAPPAN JAISANKAR
ICAR-Central Island Agricultural Research Institute, Port Blair, India

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NUTRITION AND DIET RESEARCH PROGRESS

Food for Huntington's Disease

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