



Resolving the weakening of orographic rainfall over India using a regional climate model RegCM 4.5

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ABSTRACT

In this study, the weakening of the orographic rainfall for the period 2000–2011 during the Indian summer monsoon (JJA) is investigated using the regional climate model RegCM 4.5. Analysis reveals that when sulfate aerosol feedback is included in the model run, the simulated temperature shows a cooling of the continental upper troposphere by 0.3 °C. At the same time, the sulfate aerosol loading in the atmosphere had induced cooling of 0.2 °C of the lower troposphere over the Indian region. Consequently, the simulated zonal wind fields show a weakening at the upper and lower tropospheric levels, particularly where the semi-permanent systems that drive the monsoon circulations are located. It is suggested that the weakening of zonal winds has caused a suppression of the orographic rainfall along the west coast of India (Western Ghats), as evident from the observations. Concurrently, the simulations indicate a sulfate aerosol induced reduction in orographic monsoon rainfall over the southern Western Ghats, whereas their effect is insignificant in controlling the orographic rainfall in the northern Western Ghats. Moreover, our analysis indicates a decline in rainfall over the Himalayan foothills when the sulfate aerosol feedbacks are included, which corroborates well with the observations.

1. Introduction

Climate change and its impacts on the strength and intensity of Indian summer monsoon have evinced interest among researchers globally. Observations and modeling studies concur the weakening of Indian summer monsoon (Ashfaq et al., 2009; Turner and Annamalai, 2012; Annamalai et al., 2013) in which the rainfall in the recent decade 2001–2011 recorded a departure of –5.1% from the long-term mean (Guhathakurta et al., 2015). Such a weakening of the monsoon circulation is related to a significant decline in rainfall along the west coast of India (Western Ghats, WG), where the local orography determines the cloud formation and rainfall. Considered to be older than the Great Himalayas, the WG is a chain of mountains that run parallel 30–50 km inland along the western coast of peninsular India. This huge mountain mastiff acts as a barrier to the moisture laden south westerly winds during the Indian summer monsoon season. According to UNESCO (<https://whc.unesco.org>), the region is internationally recognized for its unique biological and ecological diversity, which is an abode to rich montane evergreen forests and grasslands that control the monsoon weather patterns. WG region receives maximum rainfall during the summer monsoon season due to its steep orography and the proximity

to the ocean (Annamalai and Sperber, 2016). Millions of people in peninsular India thrive in the water sourced from the rivers originating from the WG. The region has received attention recently when studies have indicated a reduction in orographic rainfall over the region (Rajendran and Kitoh, 2008; Rajendran et al., 2012; Krishnan et al., 2015), which is detrimental to the biodiversity and to the habitats depending on them that includes human population. Hence, the main objective of this study is to investigate the causes of the observed decreasing trend in the orographic rainfall over the region.

Climate model analysis showed that anthropogenic aerosols may have a role in the observed decrease in Indian summer monsoon rainfall (ISMR) during the late twentieth century (Ueda et al., 2006; Ganguly et al., 2012; Guo et al., 2015; Sanap et al., 2015). The Indian region in the recent decades has shown an increasing trend in the anthropogenic aerosol concentration (Moorthy et al., 2013), causing a significant shift in the hydrological cycle and rainfall activity (Lau et al., 2006; Bollasina et al., 2011). In a warming climate that is composed of a large number of anthropogenic aerosols, the related radiative effects have the potential to offset the incoming solar radiation (Rosenfeld et al., 2008). The consequent cooling of the surface leads to a decrease in surface evaporation and a decline in the monsoon precipitation. In the locations

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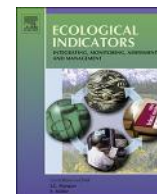
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Original Articles

Biochemical composition of particles shape particle-attached bacterial community structure in a high Arctic fjord

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ABSTRACT

Kongsfjorden, a high Arctic fjord was used as a model site to test the hypothesis that source and biochemical composition of particulate organic matter (POM) exert strong selective pressure on particle-attached bacterial community than their free-living counter parts. For this subsurface water samples were collected along the particle density gradient in Kongsfjorden. Microbial communities were size fractionated into free-living (FL, 0.2–3 µm) and particle-attached (PA, > 3 µm), and V3-V4 16S rRNA gene amplicon sequencing was used for evaluating bacterial community composition. Further, elemental (C/N), isotopic ($\delta^{13}\text{C}$) and biochemical composition (carbohydrates, proteins and lipids) of POM were also determined. Clear niche segregation among PA and FL communities was observed, except at a location close to Open Ocean. Higher alpha diversity was recorded in majority of the PA communities as compared to the FL. $\delta^{13}\text{C}$ (‰) and particulate-carbohydrate (P-CHO) content of POM strongly influence PA bacterial community composition, which was composed primarily of complex biopolymers/carbohydrates degrading bacterial taxa, in particular members of phyla *Verrucomicrobia* and *Bacteroidetes*. In addition, glacial meltwater influx and particulate organic carbon (POC) influence FL bacterial community structure. Thus, it appears that particles act as direct substrates for bacterial utilization and select particle-attached bacterial community with specific structure and function while dissolved organic carbon (DOC) plume around the particles select for some specialized free-living bacteria. Further, our results suggest that PA bacterial community can act as ecological indicator for the availability and turnover of complex polymeric substrates in high Arctic fjord environment.

1. Introduction

Particulate organic matter (POM) in an aquatic ecosystem is important for organic carbon flux and elemental cycling (Simon et al., 2014). Marine bacteria colonize POM and create a hotspot for bacterial growth and activity (Azam and Long, 2001). This plays a crucial role in POM degradation and resupply of energy to the planktonic food web via microbial loop (Azam et al., 1994). In global oceans, most of the POM is recycled via microbial loop and only a small fraction of POM sinks into the deeper layers (Simon et al., 2002). Conversely, in high latitude cold Oceans, such as the Arctic Ocean a large proportion of POM reaches seafloor, particularly on Arctic shelves and fjords (Smith et al., 2015). However, warming of coastal Arctic might enhance attenuation of sinking particulate organic carbon flux (Marsay et al., 2015). In the fore

mentioned process particle-associated bacterial activity as well as community composition is expected to play an important role (Kellogg and Deming, 2014). It is estimated that warming beyond 5 °C will force Arctic planktonic community metabolism to shift from autotrophic to heterotrophic (Holding et al., 2013). In addition, increased primary production due to sea ice decline (Post et al., 2013) and glacier as well as permafrost melting contributes high amount of autochthonous and allochthonous particles to the coastal Arctic region, respectively (Kuliński et al., 2014). These particles of diverse origin with differing physico-chemical properties, size and biochemical composition might impact bacterial colonization and subsequent carbon export and storage (Jiao et al., 2014). Thus, it is important to determine the role of particle quality in selecting particle-attached and free-living bacterial community to understand the mechanism regulating the fate and fluxes of

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A characteristic study of humic acids isolated from Arctic fjord sediments

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Abstract Humic substances are ubiquitous natural materials found in sediments as a product of biochemical transformation reactions representing a significant proportion of organic carbon cycle on earth. This study involves the analysis of humic substances with special emphasis on humic acids (HAs) in sediments collected from the Kongsfjorden System of Arctic region in June, 2017. The characterization of the isolated HAs were done using various spectroscopic techniques viz. UV-visible, Fluorescence, FTIR and NMR. Isolated HAs were also undergone for elemental analysis along with other characterization. The UV spectral analysis results with a lower E_4/E_6 ratio suggesting the presence of HAs with high degree of aromaticity and condensation. Indications for the presence of hydroxyl, methyl, methylene, carbonyl, carboxyl, phenol, alcohol and amide groups were obtained from the FTIR spectrums of HAs. NMR spectral characteristics also confirm the presence of OH group as well as the presence of CH protons adjacent to $C=X$, where X can be any electronegative element. This also confirms the presence of carbonyl group which is also evident in the FTIR spectral studies. Presence of aliphatic regions slightly more dominated with long chain and/or alicyclic moieties rather than methyl groups was also inferred from the results of NMR.

Keywords Kongsfjorden, sediments, humic acids

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1 Introduction

The understanding of the role of aquatic systems in global biogeochemical cycles needs a critical knowledge on the source, fate and reactivity of organic matters. In determining the relative contribution of autochthonous and allochthonous sources of organic matter due to the overlapping of elemental and isotopic compositions of various end member sources, the bulk organic matter techniques are the effective ones. The limitations in using

elemental composition and biochemical compositions for source characterization of sedimentary organic matter makes molecular biomarker approach as an invaluable tool for explaining environmental processes in a quantitative way.

The primarily deposited organic debris embedded in sediments can be classified broadly as humic substances and non humic substances. The humic group includes all those organic molecules which are chemically similar to living matter, whereas the non humic group comprises of compounds that arise during diagenesis from organic debris that is not a part of plants and animals.

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Biochemical composition of sedimentary organic matter in the coral reefs of Lakshadweep Archipelago, Indian Ocean

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ABSTRACT

Surface sediments were collected from the shore and lagoons of Kavaratti, Kadamat Agatti and Pitti islands of Lakshadweep Archipelago during May 2015 and analysed for biochemical composition and quality of organic matter. The biochemical composition of sedimentary organic matter from the entire study area was characterised by the dominance of carbohydrates (CHO) followed by proteins (PRT) and finally lipids (LPD). PRT:CHO ratios were less than 1 and indicated the presence of aged organic matter in the islands. The poor nutritional quality of sediments to support benthic fauna was evident from the values of LPD:CHO ratios. The refractory nature of sediments and less availability of food to benthic source was supported by BPC:TOC ratios. Based on estimated ratios and biopolymeric carbon values, the trophic status of the study area was categorised as oligotrophic.

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Coral reef sediments; organic matter; biochemical composition; Lakshadweep

Introduction

Marine shelf sediments are the major sites for mineralisation and nutrient regeneration of organic matter derived from pelagic primary production and terrestrial input [1]. A fraction of 25–50% of the organic matter derived from coastal primary production is deposited to the sediments [2]. It plays a pivotal role in the chemistry of oceans and provides a significant reservoir in the global carbon cycle [3]. Quantity and the composition of organic matter in sediments are strongly influenced by heterotrophic microorganisms [4,5]. Organic matter in sediments is derived from a variety of sources such as autochthonous, allochthonous and anthropogenic sources [6]. Biogeochemical processes associated with organic matter remineralization in sediments depend greatly on its quality. Hence quantity and quality of organic matter in surface sediments are recognised as major factors affecting benthic fauna dynamics and metabolism [7–9]. Organic matter in marine sediments is composed of labile and refractory compounds, whose relative importance changes as a function of a complex array of processes, including degradation, heterotrophic utilisation, transformation, accumulation and export [10]. The assessment of the quantity and quality of organic matter, whether labile or refractory, is a prerequisite for explaining diagenetic processes [7]. The biochemical composition has been commonly utilised to achieve vital



RESEARCH ARTICLE



Spatial variation of phosphorus fractionation in the coral reef sediments of Lakshadweep Archipelago, Indian Ocean

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ABSTRACT

Surface sediments were collected from the shore and lagoons of Kavaratti, Kadamat and Agatti islands of Lakshadweep Archipelago during May 2015 and analysed for the spatial distribution of the micronutrient element, phosphorus. Phosphorus was separated by sequential extraction procedure into five fractions – exchangeable (Ex-P), iron bound, (Fe-P), calcium bound (Ca-P), organic and residual fractions (OP) and total phosphorus (TP). The average relative contribution of each P species to TP was: $OP > Ca - P > Ex - P > Fe - P$. The high concentration of organic and residual phosphorus (87–96%) compared to inorganic phosphorus is particularly evident at stations characterised by higher total phosphorus concentrations. Among the three forms of IP in the sediments, Ca-P was dominant at all stations. The OC/OP ratio ranged from 3 to 163 in the sediments, suggesting that the organic matter in sediments had been subjected to degradation. Hence, the major contribution towards organic and residual phosphorus form is from the residual fraction comprising biologically resistant or non-available phosphorus form composed of refractory materials. The concentration of phosphorus reported in the present study is higher than that of the earlier studies in Lakshadweep, indicating a terrestrial and anthropogenic influence on the sediment.

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Introduction

Coral reefs occupy a unique niche in marine ecosystems [1]. They are one of the most productive ecosystems [2] and are used as environmental indicators because of their apparent sensitivity to physical and chemical changes in the marine environment [3]. Although coral reefs are oligotrophic in nature, production of organic matter and nutrient turnover attribute is high. In order to unravel the high biological productivity of the reef ecosystem, the role of phosphate as a growth-limiting nutrient is of great concern [4]. P is also critical to the global climate and environmental changes because of the relationship between atmospheric carbon dioxide and marine photosynthetic productivity [5–7]. Numerous studies have indicated that estuaries and adjacent seas are important sinks for P, which can be captured in large quantities in these ecosystems



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Baseline

Spatial variation of trace element concentration and contamination assessment in the coral reef sediments of Lakshadweep Archipelago, Indian Ocean

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ABSTRACT

Surface sediments were collected from the shore and lagoons of Kavaratti, Kadmat and Agatti islands of Lakshadweep Archipelago and analysed for trace element concentration. The sediment contamination was assessed on the basis of geochemical, biological hazard and ecological risk indices. Except Cd and Pb, all the other trace elements selected for the study were below the contamination level. Compared to Kadmat, Kavaratti and Agatti were more polluted and the pollution was pronounced in lagoons than shore. Population pressure, untreated sewage, diesel based power generation, shipping and tourism activities contribute to sediment contamination. Statistical analysis revealed the association of trace elements with sedimentary characteristics due to anthropogenic sources.

Trace elements are the most toxic, abundant and persistent pollutants that can accumulate in marine habitats and increases the concentration through biomagnification (Chakraborty et al., 2010). These are transported to the marine environment through natural and anthropogenic processes as dissolved species in water or in association with suspended sediments. Trace elements have the potential to affect sediment nutrient cycling, cell growth and regeneration as well as reproductive cycles and photosynthetic potential of marine organisms (Bricker, 1993). The geochemical investigation of sediment provides information about trace elements in the aquatic systems (Boamponsem et al., 2010).

Lakshadweep is an archipelago of coral islands scattered in the Arabian Sea off the West Coast of India. It consists of 36 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 km² with lagoons occupying about 4200 km². Lakshadweep has a total population of 64,429 with a population density of 2013 persons/km², which is one of the highest in India (LAPCC, 2012). The islands are flat and scarcely rise more than two meters and are vulnerable to storms and sea erosion. They are made up of coral sand and boulders which have been compacted into sandstone. The lagoons have sandy bottoms with scattered coral boulders and pinnacles followed by extensive sea grass beds at the landward side (James et al., 1986). According to Pillai (1986) 105 species of corals under 37 genera were recorded from

Lakshadweep.

The livelihood of the islanders of Lakshadweep Archipelago is greatly dependent on coral reefs, as they provide food, income, employment, shelter and protection. The geochemical aspect of trace elements within the reef environment requires an attention as it can assess the pollution status of the ecosystem. Hence a baseline data regarding the trace element pollution is essential to assess the health of these coastal ecosystems. The present study is an attempt to assess the contamination and spatial distribution pattern of seven trace elements (Cr, Mn, Fe, Cu, Zn, Cd and Pb) in the shore and lagoon sediments of three inhabited islands, namely, Kavaratti, Kadmat and Agatti belonging to Lakshadweep Archipelago.

Kavaratti is the capital of Lakshadweep Archipelago. It is a popular tourist destination due to the presence of pristine white sand beaches and calm lagoons. Kavaratti having an area of 3.93 km² lies 360 km away from the Kerala coast at 10° 32' and 10° 35' N latitude and 72° 35' and 72° 40' E longitude. The maximum length and width of the island is 5.8 and 1.6 km respectively. It is the most populated island in Lakshadweep. It has a lagoon area of 8.96 km². This island ranked first among the islands with 86 species of corals and live coral coverage was recorded as 39% (Pillai and Jasmine, 1989). Kadmat is located at 11° 10' and 11° 16' N latitude and 72° 45' and 72° 48' E longitude, with an area of 3.20 km². The lagoon has a width of 1.5 km. It is the central

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Baseline

Spatial and Temporal Variations of Arsenic Distribution in a Tropical Estuary Along the West Coast of India

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ABSTRACT

Arsenic (As) contamination was studied and reported for the first time in the sediments of the Cochin estuary. Surface sediment samples were collected from twenty-seven stations encompassing the entire estuary constituting south, central and north estuary. The total As concentration varied from 0.01 mg/kg to 9.28 mg/kg and undetected to 23.37 mg/kg during the pre and post-monsoon. The degree of contamination assessed in terms of geochemical indices such as contamination factor (CF), geoaccumulation index (I_{geo}) and enrichment factor (EF) unraveled the As contamination to be meager. The application of risk index factor and sediment quality guidelines showed that the As concentration in the estuary is below the background concentration. Pearson correlation analysis of As with iron and TOC exhibited significant weak and poor correlations with these variables.

Heavy metals pose severe threat to aquatic niches owing to their persistence nature, toxicity, non-biodegradability and bioaccumulation (Xu et al., 2017). Sediments are considered as the utmost repositories of these metals (Sany et al., 2013). Under favorable conditions these metals can be released into the water column and consequently, cause deleterious effects on aquaculture (Morina et al., 2016). Metals such as copper, zinc, iron, manganese, and nickel are essential for the function of biological systems, but enrichment of such metals can be toxic for aquatic and benthic organisms (Haghnazari et al., 2018). However certain metals such as cadmium, mercury, arsenic (As) and lead are non-essential and elevated concentrations of these metals are toxic to water and human ecosystem (Luoma, 2017).

As is a group V element whose toxicity had been globally debated and As has gained much importance in aquatic ecosystems (Mirlean et al., 2003; Pérez-López et al., 2011). In aquatic environments, As exists in both organic and inorganic forms. The inorganic forms consist of arsenite {As (III)} and arsenate {As (V)} compounds and environmental exposure to As occurs through these forms (Hughes, 2002). The natural source of As is the weathering of primary and secondary minerals (Datta et al., 2007) and the most abundant As ore mineral is arsenopyrite (FeAsS) (Tomkins et al., 2006). However, anthropogenic activities such as mining, smelting, pesticides, waste incineration, feed additives, combustion of coals, refining of fossil fuels, etc. have amplified the concentration of As in aquatic realms (Hatje et al., 2010). Studies on As contamination have been held in various parts of Indian estuaries.

Literature relating to As revealed that As concentrations are prominent in the northeastern, northwestern, southwestern and north-central parts of Bangladesh (Ahmed et al., 2004), identifying these geographical places as hot spots. Nair et al. (2003) found As concentrations in riverine sediments of Zuari (5.07 mg/kg–10.20 mg/kg) and Mandovi (5.84 mg/kg–9.72 mg/kg) situated on the west coast of India. The As values were found to vary from 2.4 mg/kg to 11.46 mg/kg in the Hugli River estuary and Sundarbans mangrove wetland ecosystem (Sarkar et al., 2004; Antizar-Ladislao et al., 2015). Chakraborty (2012) observed a notable As concentration of 31.6 mg/kg to 347.4 mg/kg in Godavari River estuary and Krishna Kumar et al. (2010) detected As concentrations ranging from 6.71 mg/kg to 15.6 mg/kg in the coral reef skeleton of Gulf of Mannar. A similar study conducted in coastal beach rock of the Gulf of Mannar identified As concentration to vary from 2.75 mg/kg to 20.72 mg/kg (Dajkumar Sahayam et al., 2010).

Cochin estuary, the largest estuarine system in the southwest coast of India is gaining importance owing to its increase in nutrient content, trace metal concentrations and organic matter (Martin et al., 2008; Martin et al., 2010, 2012; Mathew et al., 2019). Several studies about the toxicity of metals have been addressed in this estuary (Ouseph, 1992; Balachandran et al., 2005; Balachandran et al., 2006; Martin et al., 2012; Mohan et al., 2014). Hitherto studies relating to long-term monitoring of metals revealed three-fold enrichment of iron, copper, and lead; tenfold enrichment of cadmium; and twenty fivefold enrichment of zinc, thus making the estuary a cesspool of contaminants with

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Spectroscopic Investigation on the Catalytic Efficacy of Biofabricated Gold Nanoparticles using Marine Macroalgae

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Abstract

The present article reports a green and cost effective route for the synthesis of gold nanoparticles (AuNPs) using aqueous extract of marine macroalgae *Padina Tetrastomatica*. The biosynthesized AuNPs were characterized using UV-Visible spectroscopy, XRD, TEM, SAED, EDAX and FTIR techniques. The prepared AuNPs were found to be more or less spherical with an average size of 11.43nm. They were crystalline in nature, and showed a surface plasmon resonance peak at 532 nm. The biosynthesized AuNPs were used as nanocatalyst in the reduction of anthropogenic organic pollutant, 4-nitrophenol to beneficial 4-aminophenol using NaBH₄, which followed a pseudo-first-order kinetics.

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Keywords: Biosynthesis, gold nanoparticles, *Padina Tetrastomatica*, UV-Visible Spectroscopy, nanocatalyst, Nitrophenols.

1. Introduction

Nitrophenols (NP) are one of the most hazardous and toxic organic pollutants in waste water produced from

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A novel green synthesis of gold nanoparticles using seaweed *Lobophora variegata* and its potential application in the reduction of nitrophenols

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ABSTRACT

Developing a facile and green approach to synthesize gold nanoparticles (AuNPs) with high catalytic activities for the reduction of toxic nitrophenols to beneficial aminophenols is of tremendous environmental and industrial relevance. The present study reports an environmentally benign synthesis of AuNPs using aqueous extract of seaweed *Lobophora variegata* as a potential bioreductant. The signatory pinkish red color and a surface Plasmon resonance peak at 530 nm in the UV-Visible spectrum confirmed the formation of AuNPs. TEM images revealed that the biosynthesized AuNPs were spherical in shape with an average size of 11.69 ± 2.38 nm. The high crystallinity of the biogenic AuNPs is confirmed from the clear lattice fringes in the High resolution TEM images, bright circular rings in SAED pattern and Bragg's reflections of (111), (200), and (220) in XRD pattern. FTIR spectra revealed the role of bioactive metabolites in stabilizing the nanoparticles. The report emphasizes the spectroscopic investigation on the efficacy of the biosynthesized AuNPs as excellent catalyst in the reduction of anthropogenic organic pollutants, 4-nitrophenol (4NP), 3-nitrophenol (3NP), and 2-nitrophenol (2NP) to the corresponding aminophenols using NaBH_4 , which followed a pseudo-first-order kinetics with rate constants in the order $k_{2\text{NP}} > k_{4\text{NP}} > k_{3\text{NP}}$.

KEYWORDS

Green synthesis; gold nanoparticles; *Lobophora variegata*; nanocatalyst; Nitrophenols

1. Introduction

Nitrophenols (NP) are anthropogenic organic pollutants in wastewater produced from industrial plants for the manufacture of pesticides, insecticides, herbicides, explosives, and synthetic dyes (Higson 1992). Because of the carcinogenic and mutagenic properties, these are very harmful to human beings and aquatic organisms. They are enrolled as a toxin by the United States Environment Protection Agency (Arora, Srivastava, and Singh 2014; Pandey and Mishra 2014). Conversely, its reduction product aminophenols (AP) have a wide range of applications such as precursors for the manufacture of several analgesic and antipyretic drugs, as photographic developer, as anticorrosion agent in paints, and in dye industries (Vaidya, Kulkarni, and Chaudhari 2003; Nemanashi and Meijboom 2013). One of the prominent methods to convert toxic nitrophenols to beneficial aminophenols is to carry out their reduction using NaBH_4 . However, this reaction is insignificantly slow in the absence of a catalyst. In recent times, nanocatalysis has emerged as a rapidly developing area of research in which metal nanoparticles are used as catalysts for wide range of chemical reactions. Small size, high surface area to volume fraction, and size relative activity have made metal nanoparticle an efficient catalyst. The potential catalytic ability of noble metal nanoparticles in the reduction of NP have been reported recently (Sen, Maity, and Islam 2013; Zhao et al. 2015).

Among noble metal nanoparticles, gold nanoparticles (AuNPs) are of specific interest owing to their remarkable surface plasmon resonance (SPR) in the visible region with extensive applications in various fields such as drug delivery, catalysis, optoelectronics, surface-enhanced Raman scattering, biological labeling, bio-imaging, and antimicrobial (Jain et al. 2008; Kumar et al. 2011). Various physical and chemical methods are available for the synthesis of AuNPs. However, they are often costly and involve the utilization of hazardous chemicals that are potentially harmful to the environment (Menon, Rajeshkumar, and Venkat Kumar 2017; Khandanlou et al. 2018). So, there is a growing interest associated with the development of cost-effective, non-toxic, and environment friendly methods for the synthesis of AuNPs.

Nowadays, bio-inspired methods have aroused much interest due to its simplicity, environment benign nature, and cost-effectiveness. Biological resources like microbes and plant extracts were used for this purpose. Among these methods, the plant-mediated synthesis achieved fabulous attractiveness due to its eco-friendliness and simplicity. Moreover, it does not require the complicated process of maintaining cell culture as in microbe assisted synthesis. There are numerous reports available for the biosynthesis of AuNPs using several terrestrial plants (Narayanan and Sakthivel 2008; Iravani 2011; Philip et al. 2011). However,

Isolation Characterization and High-Performance Thin-Layer Chromatographic Quantification of Active Xanthonoid Mangiferin from *Canscora perfoliata*

Mundengara Deepak*, Cheruthazhakkat Sulaiman, Indira Balachandran, and Kitharathu P. Subhash Chandran

Key Words:

Canscora perfoliata
Xanthonoid
Mangiferin

Summary

Canscora perfoliata Lam., an important, traditionally used medicinal plant, belongs to the Gentianaceae family. Many pharmacological activities are reported for this plant; however, the major chemical constituents are not yet explored. The present study using chromatographic techniques led to the isolation of an active xanthonoid mangiferin from the whole plant. The structural identification was carried out by spectroscopic methods, such as ultraviolet (UV), Fourier transform infrared (FTIR), mass (MS) and nuclear magnetic resonance (NMR) spectroscopy. A modified high-performance thin-layer chromatographic (HPTLC) method was developed for the quantification of mangiferin in hydroalcoholic extract. The method was validated as per the International Conference on Harmonization (ICH) guidelines. Separation was achieved on silica gel 60 F₂₅₄ HPTLC plates using ethyl acetate–methanol–formic acid–acetic acid–water (10:1:1:1:1, V/V). Detection and quantification were performed by densitometric scanning at 254 nm. Linearity for the compound was observed between 100–500 ng per spot ($r^2 = 0.9979$). The limit of detection and limit of quantification were 30 and 50 ng for mangiferin. The relative standard deviation for instrumental precision, intra-day precision, and inter-day precision were less than 1%. The percentage of average recovery was 97.7, indicating good reproducibility. The linear regression analysis data showed good linearity, repeatability, accuracy and specificity. The amount of mangiferin obtained from the extract was $1.4 \pm 0.1\%$ (w/w). This method can be used for routine quality control analysis and for the identification of the plant.

1 Introduction

Canscora perfoliata is an important, traditionally used medicinal plant belonging to the Gentianaceae family. *Canscora grandiflora*, *Canscora macrocalyx*, *Canscora ventricosa*, *Exacum*

alatum are the official synonyms of this plant. Distribution of the plant is mainly in Western Ghats, India. The plant is being used by tribal people to treat poisonous bites. The pharmacological importance of the plant has been explored well. The ethanolic extract of the whole plant showed significant pharmacological activities, including hepatoprotective activity in CCl₄ induced hepatotoxic rats [1], hypoglycemic and hypolipidemic activity in alloxan-induced diabetic rats. In acute toxicity study, the ethanolic extract of the whole plant was non-toxic up to 2000 mg kg⁻¹ in rats [2]. It also showed antihyperlipidemic activity in Triton X-100-induced hyperlipidemia in male Wistar albino rats [3], immunomodulatory activity in Swiss albino mice [4], and significant anti-inflammatory activity in carrageenan-induced paw edema in Wistar albino rats [5].

From a literature survey, it was found that reports on the phytochemical constituents of the plant are not yet available. In the present study, an attempt for the isolation of the major compounds from the hydroalcoholic extract has been done using sophisticated techniques. Characterization of the isolated compound was done by multiple chromatographic and spectroscopic analyses, such as thin-layer chromatography (TLC), ultraviolet–visible (UV–vis), Fourier transform infrared (FTIR), nuclear magnetic resonance (NMR) spectral analysis, and mass spectroscopy (MS) studies. Further, we have developed a modified, simple, accurate, and cost-effective HPTLC method for the quantification of major isolated compound. Marker compounds are being used for standardization and characterization of medicinal plants [6]. The developed method was validated as per the International Conference on Harmonization (ICH) guidelines [7].

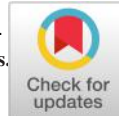
2 Experimental

2.1 Material Collection

Fresh materials of plant were collected from Palakkad district Kerala. The materials were authenticated by the Plant Systematic and Genetic Resources Division, Centre for Medicinal Plants Research, Arya Vaidya Sala, Kottakkal. Plant materials were shade-dried and powdered.

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Effect of Different Feeding Levels of Plant-ingredient-based Feed on Fillet Fatty Acid Profile, Carcass Trait, and Sensory Characteristics of Indian Major Carps in Earthen Pond Polyculture

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Abstract

The objective of the present study was to evaluate the effect of plant-ingredient-based feeds on fillet fatty acid profiles, proximate composition, carcass traits, and sensory characteristics of three Indian major carps (IMCs), *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*, when fed at different levels of their body weight. An experimental feed was prepared with only plant ingredients. The IMCs were fed twice daily at 1.0, 1.5, 2.0, and 2.5% of their body weight for 150 d in 0.06-ha earthen pond polyculture systems. The maximum growth and best feed utilization was achieved with feeding at 2% of fish biomass in the ponds. Fillet yield and lipid recovery increased significantly ($P < 0.05$), with increasing feeding level up to 2% of body weight and plateaued thereafter. In fillets, eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3) concentration increased with increasing feeding levels. Carcass traits, sensory characteristics, and consumer acceptance of IMC fillets were not influenced by feeding plant-ingredient-based feeds at different feeding rates.

KEYWORDS

carp polyculture, fatty acids, feeding level, plant ingredients, sensory evaluation

Over the last decades aquaculture has shown tremendous growth to meet the growing demand of fish consumption worldwide. Emphasis is being given on the strategies for lowering the production cost from aquaculture through better utilization of feeds by fish. Feed constitutes about 40–60% of the input cost in aquaculture (De Silva and Hasan 2007) and to develop less-expensive and sustainable formulations, fishmeal (FM) and fish oil (FO) have been replaced by plant ingredients. Blends of plant protein sources as the FM replacement in fish feeds have been successful to a large extent in several aquaculture species (Gatlin

et al. 2007; Tacon and Metian 2008; Hardy 2010). Similarly, replacement of FO by vegetable oils also did not reduce the performance of some fish species (Zakęś et al. 2010; Ljubojević et al. 2015). Results of our earlier study in this line indicated that complete replacement of FM and FO by plant protein sources and vegetable oils are possible in Indian major carp (IMC) diets without affecting the growth, production, and fatty acid (FA) profiles of fillets when grown in earthen pond aquaculture systems. In commercial fish farming, restricted feeding of appropriate rations without growth suppression is preferred for economic and environmental benefits as well as for better product quality (Van Ham et al. 2003). Studies have also been

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Effect of extended period of boiling on allergic protein of flower tail shrimp *Metapenaeus dobsoni*

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ABSTRACT

Consumption of shellfishes is a major cause of allergic reaction and IgE mediated hypersensitivity is an increasing health issue in sensitive individuals. Thermal stability of allergen of the flower tail shrimp *Metapenaeus dobsoni* was evaluated during extended period of boiling for immunoreactivity. Shrimp extracts boiled for 5 to 25 min showed increased IgE reactivity of 0.251 to 0.268 nm at absorbance of 490 nm in comparison to raw extract. Tropomyosin of 37 KDa was observed to withstand longer periods of boiling and found to retain IgE binding activity. Thermal treatment by means of boiling for longer duration increased the recognition of this major allergen in individuals with shrimp sensitivity. Hence, tropomyosin subjected to longer period of boiling could be used in facilitating shrimp allergy diagnosis and for detection of allergen in processed food products.

Keywords: Boiling, IgE reactivity, Immunoblotting, Tropomyosin

Introduction

Seafoods are rich in many essential nutrients and can play a major role in the nutrition and health of human beings. Although consumers' preference of seafood is increasing, the major seafood groups such as fish and shellfish frequently cause allergic reactions in sensitive persons. Among shellfishes, shrimps are predominant in causing allergic reactions and IgE mediated shellfish allergy is a prevalent health issue in both children and adults (Tsabouri *et al.*, 2012). Allergic reactions are usually associated with gastrointestinal and dermatological symptoms. It is also manifested with severe life threatening reactions like anaphylaxis and shellfish allergy is a long lasting one which can persist throughout life (Steensma, 2003; Lopata and Lehrer, 2009). The allergic symptoms can even develop in sensitive individuals due to inhalation of cooking vapours and direct handling contact with shellfish in addition to ingestion (Jeebhay and Lopata, 2012). It is reported that shellfish allergy patients have similarity with peanut allergy and show clinical reactivity throughout life associated with increased risk of wheezing and hyper reactivity (Lopata *et al.*, 2010). Allergic responses in sensitive persons are mediated through immunoglobulin, IgE.

Myofibrillar protein, tropomyosin is reported as a major allergen in shellfishes having two identical subunits

with molecular weight of 35 to 38 KDa (Shanti *et al.*, 1993; Leung *et al.*, 1998). It is present in both muscle and non-muscle cells. It is an important muscle protein having major role in muscle contraction and is a pan allergen of invertebrates (Goetz and Whisman, 2000). Presence of this protein in very low concentration can elicit reactions in sensitive persons. Alpha helical and coiled structure of tropomyosin is highly conserved in nature and can cause IgE cross reactivity with patients allergic to crustaceans and house dust mites (Reese *et al.*, 1999). The cross reactive nature of tropomyosin is reported to be due to highly conserved amino acid sequences (Lehrer *et al.*, 2003). Although there is a number of IgE binding epitopes reported for tropomyosin, it can vary from one allergic person to another (Shanti *et al.*, 1993; Motoyama *et al.*, 2007). The allergenic protein structure in quaternary form can give stability enhancement through increasing IgE reactivity and by efficient antibody cross linking. Several other allergenic components other than tropomyosin have also been reported in shellfishes.

Avoidance of specific diet causing allergy is the main advice to people suffering from allergic reactions. Strict avoidance of specific diet can become difficult in situations with unintentional cross contact with different food materials and can result in allergic reactions in highly sensitive people. Accurate identification of allergic protein is highly essential for specific allergic testing



Identification of allergic proteins of Flower tail shrimp (*Metapenaeus dobsonii*)

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Abstract Allergy to seafood mainly fish and shellfish has been reported. Tropomyosin is recognized as a major allergen in many crustaceans especially shrimps. A study was carried out to identify the IgE reactive proteins of allergic nature in Flower tail shrimp (*Metapenaeus dobsonii*), a frequently consumed shrimp in India mainly in dried form. Protein profiling and identification of IgE reactive proteins in raw and cooked extracts of Flower tail shrimp was carried out by SDS-PAGE and immunoblotting using sera of 13 patients having allergic reactions on consumption of shrimp and positive to skin prick test. The IgE binding ability was determined by ELISA and it was found higher in the case of cooked extracts ranging from 0.244 to 0.440 at 490 nm. The SDS-PAGE of raw extract revealed many protein bands between 205 and 6.5 KDa, while in the case of cooked extracts bands of 36, 20, 29 and 70 KDa were prominent. Heat resistant protein of 37 KDa, tropomyosin was showing a clear immune reaction both in the case of raw and cooked extracts was identified as the major allergen by all the patient sera. The minor proteins of raw extract identified by immune reaction are 50, 75 and 100 KDa. The identified allergen can be used for the diagnosis and management of shrimp allergy.

Keywords Food allergen · Flower tail shrimp · Immunoblotting · Tropomyosin

Introduction

In many of the developing countries, food allergy is considered as a major food safety concern. Food allergy is mainly associated with hypersensitive reaction mediated through immune system to the dietary intake of proteins (Sicherer and Sampson 2010). Eight kinds of food including soy, wheat, peanut, tree nuts, fish, shellfish, egg and milk have been identified as source of allergens and 90% of food allergies are due to these eight foods. In case of seafood, prawns and shrimps are the major contributors about 20–22% by volume of the world seafood market (FAO 2014). Shellfishes mainly crustaceans and molluscs are frequent elicitor of food hyper sensitive reactions which is mainly mediated through immunoglobulin E and these immune mediated reactions comprise acute urticaria, atopic dermatitis, asthma, gastrointestinal disorders including diarrhea, vomiting and life-threatening anaphylaxis (Sicherer 2011). Higher prevalence of shrimp allergic reactions is noticed in case of developing countries and coastal areas (Lopata et al. 2010). A large variety of shellfish species are reported as causative of allergy (Burney et al., 2010). In addition to ingestion of foods containing shrimp, inhalation or skin contact while cooking or working can also leads to development of immune reactions. Shrimp allergy is considered as a Type I allergy as the initial encounter with an allergen sensitizes the individual to future exposures.

Tropomyosin, a myofibrillar protein having molecular weight ranging from 34 to 38 KD is reported as a major allergen in many crustacean species (Lehrer et al. 2003;

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RESEARCH

Open Access

Polyphenol composition and antioxidant potential of mint leaves



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Abstract

Soluble and insoluble/bound phenolic compounds and an aqueous infusion of two mint species (Medina and Hasawi), were tested for their total phenolic content, 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonate (ABTS) and 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity, iron (III) reduction, iron (II) chelating and oxygen radical absorbance capacity (ORAC). Furthermore, the potency of the mint extracts in the inhibition of radical-induced DNA scission, human low-density lipoprotein (LDL) cholesterol oxidation, formation of thiobarbituric acid reactive substances (TBARS) in a cooked ground meat system and LPS (lipopolysaccharide)-stimulated cyclooxygenase-2 (COX-2) expression in J774A.1 mouse macrophage cells were monitored. Results showed that the soluble phenolics had a higher phenolic content and antioxidant activity than the insoluble-bound extracts and aqueous infusions in most of the assays. Both varieties exhibited notable antioxidant activities and inhibition of LDL cholesterol oxidation, DNA scission and COX-2 gene expression at transcriptional level. However, Medina mint was a more potent antioxidant than the Hasawi mint. High performance liquid chromatography with online tandem electrospray ionization mass spectrometry (HPLC/ESI-MS/MS) analysis of the extracts revealed that rosmarinic acid was the major phenolic compound present in both mint samples.

Keywords: Mint, Phenolic compounds, Antioxidant activity, Rosmarinic acid, HPLC/ESI-MS/MS

Introduction

Spices and herbs are known to serve as powerful antioxidants. Members of the Lamiaceae family such as mint, basil, rosemary, sage, savory, oregano, and thyme, are particularly well known for their use in food and traditional medicine (Park 2011). Extracts of rosemary and sage are routinely used to control oxidation of food lipids (Zheng and Wang 2001; Shahidi and Zhong 2010). These products are now commercially available in the decaffeinated form. Aqueous infusions obtained from mint leaves have long been used to treat anorexia, hypertension, and many spasmolytic and gastrointestinal problems (Mimica-Dukic and Bozin 2008). In addition, mint has been shown in clinical trials to treat headaches through analgesic properties, reduce painful muscle spasms in patients undergoing endoscopy of the upper and lower gastrointestinal (GI) tract, and reduce abdominal pain and dyspepsia (McKay and Blumberg 2006). In vitro-based studies have also demonstrated the potential

anti-depressant effects of mint extracts (Lopez et al. 2010). Many of these medicinal effects of mint are closely associated with the high content of phenolic compounds; the phenolics from mint tea and mint extracts have been shown to exhibit antimicrobial and antiviral activities (Mimica-Dukic and Bozin 2008). Additionally, mint extract has been shown to increase cellular superoxide dismutase activity, a natural protective mechanism against oxidative damage (Mimica-Dukic et al. 1996).

Phenolics belong to an important class of compounds responsible for the antioxidant activity of mint. Previous studies have found the total polyphenolic content of peppermint leaves to be approximately 19–23% with total flavonoids of 12% (McKay and Blumberg 2006). Mata et al. (2007) reported that the main active components in mint were eriocitrin, rosmarinic acid, luteolin 7-O-rutinoside, hesperidin, and small quantities of picrosides, gardenin B and apigenin. Another study determined the major polyphenols in mint as rosmarinic acid, caffeic acid, ferulic acid and eugenol (Tahira et al. 2011).

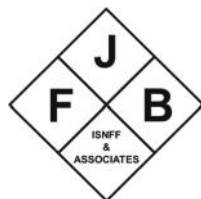
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Phenolic content, antioxidant and anti-inflammatory activities of seeds and leaves of date palm (*Phoenix dactylifera* L.)

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Abstract

The total phenolic content of date palm (*Phoenix dactylifera* L.) seeds (samples 1 and 2) and leaves were determined and for the first time their antioxidant activity in a food system investigated. The anti-inflammatory activity and potency of samples in the inhibition of radical-induced DNA scission and human low-density lipoprotein (LDL) cholesterol oxidation was also evaluated. The total soluble phenolic content of the date palm leaves was 106.96 mg gallic acid equivalents (GAE)/g sample and ranged from 68.73 to 82.62 mg GAE/g of date seeds. Extracts showed good radical scavenging activity in the different *in vitro* tests conducted in this work and were found to be effective in inhibiting the oxidation of cooked ground meat. Soluble phenolic extract from date seeds of sample 1 was most effective in inhibiting DNA strand scission by 74.15%, while soluble phenolics from palm leaves showed the highest inhibition of LDL cholesterol oxidation (87.82%). Both samples significantly inhibited mRNA level of COX-2 at concentrations as low as 5 µg/mL, with the most potent inhibitory effect being for date palm leaf extracts at 50 µg/mL. A number of phenolic compounds including proanthocyanidin dimers, catechin, epicatechin, 5-O-caffeoylshikimic acid isomers, ferulic acid, rutin and isorhamnetin hexoside, among others, were detected in date palm seeds and leaves.

Keywords: Date seeds; Leaves; Antioxidant activity; Phenolic profile; DNA breakdown inhibition; LDL oxidation inhibition.

1. Introduction

Phoenix dactylifera L. (Date palm) belonging to the family Arecaceae is considered as one of the oldest cultivated fruit trees. It is believed to be indigenous to the countries of the Middle East since at least 6,000 BC (Copley et al., 2001). Saudi Arabia is one of the main homelands of the date palm tree, where it is grown on about 90% of the cultivated land (Shaheen, 1990). The date palm (*Phoenix dactylifera*) is dioecious, medium-sized tree with pinnate leaves carrying about 150 leaflets having spines on the petiole. It consists of small yellowish flowers attached directly to the spikelets which develop into fruits. The fruits are known as dates. They

are oval-cylindrical in shape and have single seed and their color ranges from bright red to bright yellow when unripe, depending on the variety (Vyawahare et al., 2009).

Date palm fruits serve as an important component of the diet in most of the arid and semiarid regions of the world (Biglari et al., 2008). The various parts of the plant are widely used in traditional medicine for the treatment of a number of disorders, including memory disturbances, fever, inflammation, paralysis, loss of consciousness, and nervous disorders (Anonymous, 1985; Nadkarni, 1976). Many pharmacological studies conducted on date palm fruits have shown that they possess antiulcer (Al-Qarawi et al., 2005), anticancer (Ishurda and John, 2005), anti-diarrhetic (Abdul-



Carbon nanodots synthesized from chitosan and its application as a corrosion inhibitor in boat-building carbon steel BIS2062

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Abstract

Carbon quantum dots are fluorescent nanoparticles with various unique properties such as environmental friendliness, high conductivity, low toxicity and high stability. This study aimed to synthesize carbon nanodots (CDs) from chitosan and apply them as a corrosion inhibitor in BIS 2062 carbon steel. CDs were synthesized from chitosan, and their morphological characteristics studied using atomic force microscopy (AFM) and transmission electron micrograph (TEM). The AFM and TEM results showed that the CD had a spherical shape and 2D structure. The FTIR spectroscopy results indicated that the CDs were rich in C=O and C–O functional groups. The UV–Vis spectroscopic analysis showed absorption peaks at 288 and 222 nm. Moreover, the zeta potential was positive. The BIS 2062 carbon steel, which is used for boat building, was coated with CDs, and its electrochemical characteristics were studied through linear sweep voltammetry (LSV) and electrochemical impedance spectroscopy (EIS). The LSV and EIS results showed that steel coupons coated with 0.05% CD had excellent corrosion resistance. Cyclic voltammetric evaluation using glassy carbon electrode revealed that the oxidation and reduction potential of iron oxide were significantly suppressed due to the coating of CDs. The results highlighted the use of CDs as a corrosion inhibitor and a potential alternative to graphene-based materials.

Keywords Carbon nanodots · Marine corrosion · Corrosion inhibition · 2D material

Introduction

Quantum dots are nanosized semiconductor crystals that are generally inorganic in nature. There exist many concerns regarding the safety and toxicity of inorganic quantum dots because they are mainly fabricated using toxic heavy metals. The newly developed carbon nanodots (CDs) can overcome this disadvantage because they are completely organic in nature. Xu et al. (2004) found out CDs during the purification of a single-walled carbon nanotube. Scientists have begun to exhibit increased interest in CDs because of their

unique properties such as high conductivity, low toxicity, biocompatibility and water solubility (Zhu et al. 2015). CDs have been synthesized from different natural carbon sources such as orange juice Sahu et al. (2012), citric acid (Dong et al. 2013), bananas (De and Karak 2013), folic acid, cinnamon and red chillies (Vasimalai et al. 2018). CDs have been synthesized through arc discharge (Xu et al. 2004), the ultrasonic or microwave technique (Zhu et al. 2009), laser ablation (Li et al. 2010), electrochemical synthesis, and hydrothermal carbonisation (Dong et al. 2013). CDs synthesized from natural sources may get contaminated with inorganic nutrients and toxic metals. CDs synthesized from spices do not exhibit cytotoxicity and hence can be used for developing cancer treatment methods or drug delivery management strategies (Vasimalai, et al. 2018; Tabak et al. 1999). CDs exhibit properties similar to those of semiconductor inorganic quantum dots (Mohapatra et al. 2016).

To synthesize pure CDs, the precursor must be made of pure organic molecules. Chitosan is one of the best choices for synthesizing CDs, because its pure form can be obtained from chitin through deacetylation. Moreover,

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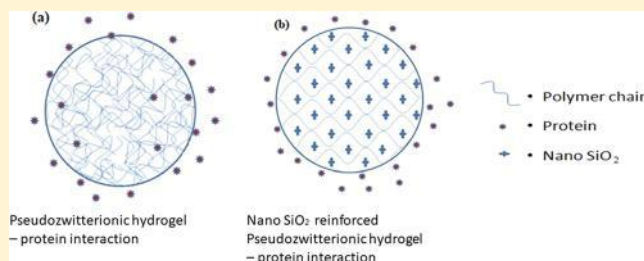
Biofouling Control Using Nano Silicon Dioxide Reinforced Mixed-Charged Zwitterionic Hydrogel in Aquaculture Cage Nets

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Supporting Information

ABSTRACT: Biofouling in aquaculture cages negatively affects the farm productivity, and it requires huge sums of money and labor for its management. A superhydrophilic pseudozwitterionic hydrogel, *N*-isopropylacrylamide (NIPA) + [2-(methacryloyloxy)ethyl]trimethylammonium (TMA) + 3-sulfopropyl methacrylate (SA) copolymer, is considered as a potential antifouling agent. The present study aimed to synthesize a nano silicon oxide reinforced NIPA–TMA–SA mixed-charged zwitterionic hydrogel over polyaniline-coated polyethylene aquaculture cage nets through the in situ microwave reaction and to test its biofouling resistance. The study highlighted the formation of stable coating over polyethylene, four different treatments, and their effective inhibition of fouling compared with the untreated one. Six month's immersions of treated nettings in the estuarine environments demonstrated that the biofouling inhibition by nano silicon oxide reinforced zwitterionic hydrogel-coated polyethylene was unable to satisfy the industrial standards but made the samples free from hard-shelled fouling organisms compared with untreated controls. More research is needed to improve the quality of the coatings. The mixed-charged zwitterionic hydrogel with nano silicon oxide showed medium hydrophilic nature. Fourier transform infrared, scanning electron microscopy, and spectroscopic evaluation showed the successful formation of hydrogel over the aquaculture cage net. Nano silicon oxide reinforced in the matrix through hydrogen and coordination bonding between NH_2 and carbonyl of the polymeric chain, respectively.



1. INTRODUCTION

Fish production through aquaculture farming is considered as an alternative cheap protein source for growing populations in the world. Biofouling is a major problem, and the submerged aquaculture cage nets are highly susceptible to biofouling, eventually ending with increased economic burdens.¹ Frequent replacement of cage nets or manual/mechanical cleaning needs to be undertaken to get rid of the biofouling.² Copper oxide-coated aquaculture cage nets are extensively used to combat biofouling, and the major disadvantages are that they are less effective against foulers and increase the weight of the cages and the fear of excessive copper leaching into the environment, thereby resulting in pollution.³ The biocide coating must be light in weight, more toxic to the foulers, and adhered strongly over the net. The aquaculture cage nets are generally fabricated using polyethylene (PE), which is nonpolar in nature. Surface modification of polyethylene needs to be done with a suitable polar molecule to incorporate biocides. Polyaniline (PANI), a conductive polymer, is in situ synthesized over the polyethylene cage nettings and effectively employed as a platform to incorporate biocides.⁴ The biocide may be either a nano metal oxide or an organic hydrophilic hydrogel.^{4,5}

Hydrogel-based materials against biofouling have been investigated extensively since hydrogels are not having surface energy difference with surrounding waters and require only minimum thermodynamic driving force for irreversible bind-

ing. Cowie et al.⁶ developed a colorless poly(hydroxyl-ethylmethacrylate) hydrogel for inhibiting fouling on optical windows of submerged sensors. Rasmussen et al.⁷ tested the settlement of barnacles on different nonsolid hydrogels. The materials exhibit lower settlement with difference in different gels. Ekblad et al.⁸ investigated the protein-resistant poly(ethylene glycol) (PEG) hydrogel against biofouling. PEG has poor stability as PEG macromolecular chains can rapidly autoxidize and degrade during storage and handling at room temperature, especially by transition metal ions, which exist in most biological solution.⁹ Significant effort has been invested in the search for alternative antifouling materials with stability higher than that of PEG. Zwitterionic polymers are just perfect alternatives for PEG. Zwitterionic polymers refer to a family of materials that have the same number of cations and anions along their polymer chains. Zwitterionic polymers are superhydrophilic due to the presence of abundant ions and formation of subsequent strong hydration layers. Zwitterionic polymers are usually synthesized using sulfur, carboxy, or phosphor betaines.^{10–14} These betaine pendent structures resist the attachment of proteins or microorganisms. Zwitterion-based hydrogels and films may partially lose their

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The diversity of finfish population in Poonthura estuary, south-west coast of India, Kerala

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Abstract Quantitative measures of diversity are the ideal tools to reveal the community differences that are due to changes in the relative taxon abundance. The present study is an attempt to investigate the measures of finfish diversity of the Poonthura estuary, located in Thiruvananthapuram district of Kerala, India. Samples were collected using gill nets from three stations. Bio-diversity indices such as Margalef's richness (d), Pielou's evenness (J'), Shannon diversity (H') $\log_e(2)$, Simpson diversity ($1-\lambda$), Simpson dominance (λ), average taxonomic distinctness ($\Delta+$), and variation in taxonomic distinctness ($\lambda+$) were worked out for monthly and seasonal data (pre-monsoon, monsoon, and post-monsoon). The ranges of species richness, evenness, Shannon diversity, and Simpson diversity and dominance were 2.30 to 4.51, 0.79 to 0.92, 2.52 to 3.42, 0.76 to 0.91, and 0.11 to 0.23 respectively. Considering the lacuna in information on this estuary, the results of the present study provide reference points for the measures of fish diversity for future studies. Non-metric multidimensional scaling (NMDS) plotted to understand the seasonal and monthly variation of diversity. The clusters showed 40% similarity in the monthly samples, with the post-monsoon season showing the highest number of species. Various physicochemical parameters influenced the temporal fluctuations in diversity including seasons, river runoff, sewage

discharge, and intrusion of saline water. Moreover, higher values of chlorophyll a is an indicator of eutrophication. Proper management inputs are necessary to sustain the resources along with pollution abatement measures for improving the livelihood support from this estuary.

Keywords Backwater · Physicochemical parameters · Diversity indices · Monsoon

Introduction

Estuaries are highly complex ecosystems having economic, social, and environmental significance. They are one of the finest nurseries and breeding grounds for a number of commercially as well as ecologically important species of fishes, prawns, crabs, and molluscs of high-nutritive (Bond 1979) pharmaceutical values (Shukla and Pandey 2005). Coastal states of India are rich in estuaries, backwaters, coastal creeks, and large brackish water areas. These water bodies contribute a substantial part of fish production in India (Nair et al. 1983).

The Poonthura estuary is one of the most polluted estuaries in the Thiruvananthapuram city (Mini Chandran and Natarajan 2014). The high-population density of the city is a driving factor for degradation of coastal waters due to pollution from a variety of sources. The major reason for pollution is the absence of adequate facilities for the disposal of sewage in the adjacent human settlement. The production of coir fiber by retting in several parts of the estuary leads to a large-scale

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Full length article

Antimicrobial properties and phenoloxidase activation of the lectin isolated from kadal shrimp (*Metapenaeus dobsoni*)Abdul Salam Rubeena^a, Elumalai Preetham^{a,b,*}^a School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, Panangad, Kerala, India^b Department of Processing Technology (Biochemistry), Kerala University of Fisheries and Ocean Studies, Panangad, Kerala, India

ARTICLE INFO

Keywords:

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 Antiviral activity

ABSTRACT

The present study reveals purification and characterization of the lectin from the haemolymph of *Metapenaeus dobsoni*. The *Md-Lec* was purified by affinity chromatography with mannose coupled sepharose CL-4B column and it exhibits single band with a molecular weight of 68 kDa in SDS-PAGE. Furthermore, the molecular mass was confirmed by MALDI-TOF and functional groups present were analysed by FTIR. The surface morphology of purified *Md-Lec* displays the homogeneous nature of protein. The X-ray diffraction (XRD) analysis expresses three peaks at 10.771°, 21.625° and 31.752° which indicate the crystalline nature of the protein and the retention time of 3.068 min evident from HPLC reveals the purity of the sample. Functional analysis of purified *Md-Lec* exhibits yeast agglutination activity against *Saccharomyces cerevisiae* and has the ability to agglutinate the human erythrocytes, which was observed by light microscopy. It also exhibited phenoloxidase activation, encapsulation and phagocytic activities. In addition, purified *Md-Lec* showed the broad spectrum of bacterial agglutination activity against Gram negative *Vibrio parahaemolyticus* and *Aeromonas hydrophila*, important fish pathogens. Antiviral potential and anticancer activity of purified *Md-Lec* against CyHV-2 virus and MDA-MB-231 breast cancer cell lines were also evaluated in this study.

1. Introduction

Lectins are glycoproteins which can bind to carbohydrates like mannose, galactose, lactose, N-acetyl glucosamine, N-acetyl galactosamine, fucose, and rhamnose with significant specificity [1]. They possess at least one carbohydrate recognition domain (CRD) that specifically and reversibly binds to different sugar moieties present on the surfaces of pathogens, and lectins are present in almost all organisms including plants, animals, viruses, bacteria, cyanobacteria and yeasts [2–5].

Lectins are involved in many biological functions including cell adhesion, phagocytosis, complement activation and innate immunity [6]. Based on their structure, binding specificities and calcium dependency, lectins are classified into different families like C-type lectins, F-type lectins, galectins, intelectins, rhamnose binding lectins, I-type lectins, Lily-type lectins etc. [7]. C-type lectin (CTL), one of major marine lectins, is characterized by Ca²⁺-dependent binding to mono and oligosaccharides, and they are classified in several groups; collectins, proteoglycan core proteins, selectins directly or indirectly involved in immune function [8]. Role of different types of lectins, their therapeutic applications and the tissue distribution of lectins in the fishes is

described by our group [9].

In invertebrates like shrimp, based on structural differences, expression patterns and functions, there are seven groups of lectins: C-type, L-type, P-type, M-type, fibrinogen-like domain lectins, galectins, and calnexin/calreticulin [10]. The shrimp lectins take part in innate immune mechanisms by activating prophenoloxidase, encapsulation, melanization and promotion of phagocytosis [11–15].

Metapenaeus dobsoni is distributed along the Indian coast, off Sri Lanka, Malaysia, Indonesia to Philippines and New Guinea. In India it is common along the South west coast- Kerala, Goa, Karnataka and the south east coast-Orissa, Visakhapatnam, Tamil Nadu and Union territory of Puducherry [16]. Presently little information is available about the immune system and immune response in kadal shrimp. Therefore, the present study addressed to characterize the immune response in kadal shrimp, with focus on isolation and characterization of a lectin from haemolymph and substantiate its functional roles in agglutination, antimicrobial and anticancer properties.

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Effect of alkoxy glycerol on growth performance, immune response and disease resistance in Nile Tilapia (*Oreochromis niloticus*)

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ARTICLE INFO

Keywords:

Shark liver oil
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ABSTRACT

Fish oil and their compounds derived from the same have immense applications in the improvement of health, brain development, enhancing immunity etc. This study aimed at the supplementation of such a compound alkoxy glycerol derived from shark liver oil in fish diet and thereby analyzing growth as well as immune parameters of *Oreochromis niloticus*. 400 fishes were distributed into 11 glass tanks, and then fishes were weighed before starting the experiment. (Average weight was found to be 5.3 ± 0.10 g). Feed was prepared using alkoxy glycerol in the doses like 5, 10, 15 g kg⁻¹. Fishes were fed with the prepared diet for 30 days and growth parameters like specific growth rate (SGR), weight gain (WG), final weight (FW), and feed conversion ratio (FCR) were measured. On the 30th day, fishes were challenged with 0.1 ml of normal saline solution containing 10^7 CFU ml⁻¹ of *Aeromonas hydrophila* and disease resistance was monitored. After 30 days of post challenge observation, immunological and lipid peroxidation assays like alternative complement (ACH50), phagocytosis (PI), respiratory burst activities (RB), and serum lysozyme (SL) were performed.

1. Introduction

The fish reserve in our wet land depletes fast since we rely more on overfishing [Thanigaivel et al., 2015; Van Doan et al., 2016]. This condition has to be changed and our area for fishing should change from saline source to fresh water aquaculture. In the year 2017, the importance of aquaculture as an alternative to open sea fishing has been discussed. The benefits to rearing Nile Tilapia (*O. niloticus*) for food are numerous. They are relatively hardy and can tolerate a range of conditions. The global production of tilapia was estimated to be 6.69 million metric tonnes in 2016 [Ellis, 1990].

Since the demand for this fishes has risen, unprotected and bulk production of *O. niloticus* has increased worldwide. This leads to immense infection in their fingerlings [Ellis, 2001]. Along with bacterial infection, poor water quality leads to the accumulation of ammonia and nitrite level in water. This scenario will adversely affect the growth of fish [Hoseinifar et al., 2018; Abbas et al., 2012]. The pathogen *Streptococcus agalactiae* has been reported as one of the major causes that contribute to tremendous economic loss for this industry [Akrami et al., 2013]. Not only bacteria, some viral pathogens, including

betanodavirus, iridovirus, and herpes-like virus also have reportedly caused severe disease in tilapia species [Aliko et al., 2018]. Observations of extensive mortality of raised tilapia and wild fish in Israel and Ecuador have been reported [Balfry and Higgs, 2001; Balfry et al., 2006]. The physical and chemical quality of an aquatic environment is essential to understand the pathogenesis in fish and to develop effective preventive practices and adequate treatments [Blazer, 1992; Brohult et al., 1986; Soto and Revan, 2012; Yano, 1992]. Nile tilapia is prone to infections by *Streptococcus* sp. [Burgos-Aceves et al., 2018]. Rather than giving antibiotic or chemotherapeutic medicines, functional low cost feed additives can be used to tackle the problem of infection [Cabral, 2005; Chen et al., 2012; Zuo et al., 2012].

Additives such as inulin and ascorbic acid when used to check their in vivo activities in Nile tilapia had reported increased lysozyme activity in fishes and results suggested that vitamin C could be a potential, less expensive, and promising dietary supplementation than inulin. Along with other herbal and natural feed additives, lipids can also be used for feed enrichment. Together with carbohydrates and proteins, lipids are the main constituents of plant and animal cells. This category includes fatty acids, neutral fats, waxes, lipoproteins, glycolipids and

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Intensifying the Anticancer Potential of Cationic Peptide Derived from Serine Threonine Protein Kinase of Teleost by Tagging with Oligo Tryptophan

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Abstract

Serine threonine protein kinase plays an important role in the cell growth, cell cycle regulation and development which shows a significant role in signal transduction pathway. In this study, a cationic peptide IE13 was derived from serine threonine protein kinase of a teleost fish and it was modified as IW13 by replacing the C-terminal residue with tryptophan. The anti-cancer potential of IE13 and IW13 was tested against three different types of cell lines HeLa (Human Cervical carcinoma cells), A549 (Human lung cancer cells) and MCF 7 (Human breast cancer cells) at different concentrations (300, 100, 30 and 10 μ M) in semi logarithmic range. The results showed that the peptide IW13 showed EC₅₀ of 92 μ M for MCF 7, 102 μ M for A549 and 85 μ M for HeLa whereas, IE13 showed less growth inhibition on the tested cell lines. The flow cytometry study was conducted to demonstrate the cell cycle inhibition by the cationic peptide IW13 against HeLa cell line. Cytotoxicity studies of the cationic peptide showed no cytotoxicity against normal cell line (RAW 264.7). Tailoring of these properties was likely to be a key in safe and successful transfer of this peptide from laboratory experiments into clinical practice for pharmaceutical formulations.

Keywords Serine threonine protein kinase · Cationic antimicrobial peptide · Cytotoxicity · Anticancer · HeLa · A549 · MCF 7

Abbreviations

STPK	Serine threonine protein kinase	PS	Phosphatidyl serine
HeLa	Human cervical carcinoma cells	Trp	Tryptophan
A549	Adenocarcinoma human alveolar basal epithelial cells	Cs	<i>Channa striatus</i>
MCF 7	Human breast cancer cells (Michigan Cancer Foundation 7)	RAW 264.7	Murine macrophage cell line
CAPs	Cationic antimicrobial peptides	DMEM	Dulbecco's modified eagle's medium
		FCS	Foetal calf serum
		GIBCO	GIBCO cell culture media and reagents
		OD	Optical density
		PBS	Phosphate buffered saline

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Introduction

Chemotherapeutic agents that are targeted towards cancer cells usually affect the normal cells especially the rapidly proliferating cells such as bone marrow and hair follicle cells. Also, these conventional anticancer drugs develop resistance among cancer cells by cellular changes through multiple mechanisms (Gatti and Zunino 2005). Therefore, various novel anticancer therapeutic agents were proposed among which the cationic antimicrobial peptides (CAPs) had become an important area of study as functional therapeutics



Full length article

Antimicrobial and biochemical characterization of a C-type lectin isolated from pearl spot (*Etroplus suratensis*)

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ABSTRACT

The present study reveals purification and characterization of a C-type lectin from the serum of pearl spot, *Etroplus suratensis* (*Es-Lec*). The *Es-Lec* was purified by affinity chromatography with mannose coupled sepharose CL-4B column and it exhibits single band with a molecular weight of 75 kDa in SDS-PAGE. The surface morphology of purified *Es-Lec* displays the homogeneous nature of protein. A distinct peak with a retention time of 2.958 min was appeared in high performance liquid chromatography (HPLC), X-ray diffraction (XRD) analysis expresses a single peak at 31.8372° and MALDI-TOF peaks which shows the purity and crystalline nature of the protein respectively. Functional analysis of purified *Es-Lec* exhibits yeast agglutination activity against *Saccharomyces cerevisiae* and has the ability to agglutinate the human erythrocytes, which was observed by light microscopy and haemagglutination inhibition was also done. In addition, purified *Es-Lec* showed the broad spectrum of antibacterial activity against Gram negative *Vibrio parahaemolyticus* and *Aeromonas hydrophila*. Antibiofilm potential of purified *Es-Lec* against selected Gram-negative bacteria exhibited the disruption of biofilm architecture at the concentration of 50 µg ml⁻¹ and also it exhibited antiviral and anticancer activity.

1. Introduction

Lectins are glycoproteins characterized by their capability to attach carbohydrates like mannose, galactose, lactose, *N*-acetyl glucosamine, *N*-acetyl galactosamine, fucose, and rhamnose with significant specificity [1]. They possess at least one carbohydrate recognition domain (CRD) that specifically and reversibly binds to different sugar moieties present on the surfaces of pathogens, and lectins are present in almost all organisms including plants, animals, viruses, bacteria, cyanobacteria and yeasts [2–5].

Lectins are involved in many biological functions including cell adhesion, phagocytosis, complement activation and innate immunity [6]. In fish, lectins are reported in serum, gills, surface mucus, egg surfaces and other organs [7–10,19]. Based on their structure, binding specificities and calcium dependency, lectins are classified into different families like C-type lectins, F-type lectins, galectins, intelectins, rhamnose binding lectins, I-type lectins, Lily-type lectins etc. [11]. C-

type lectin (CTL), one of major lectins in fish, is characterized by Ca²⁺-dependent binding to mono and oligosaccharides, and they are classified in several groups; collectins, proteoglycan core proteins, selectins directly or indirectly involved in immune function [12]. Various types of CTLs of diverse carbohydrate specificities have been identified in various fish species including; rainbow trout (*Oncorhynchus mykiss*), catfish (*Silurus asotus*), common carp (*Cyprinus carpio*), Japanese eel (*Anguilla japonica*), fugu (*Takifugu rubripes*) and zebrafish (*Danio rerio*) [13–18]. Different types of lectins, their roles and the tissue distribution of lectins in the fishes is comprehensively reviewed by Preetham et al. [19].

In fish, mannose-binding proteins (MBP) or mannose-binding lectins (MBL), a CTL play an important role in innate immunity and disease resistance [20]. Although mannose binding lectin (MBL) have been reported in rainbow trout, channel catfish (*Ictalurus punctatus*), common carp, Nile tilapia (*Oreochromis niloticus*), rohu (*Labeo rohita*) etc. [13,17,21–23] their exact role in agglutination and antimicrobial

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REVIEW



The Role of Lectins in Finfish: A Review

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ABSTRACT

The immune system of vertebrates involves both innate and acquired immune responses. The innate immunity is more generalized with robust response whereas the other has a highly specific response to infectious pathogens. Because of the lack of specialized lymphatic organs, innate immunity is an important mode of defense in fishes. The less specific innate immune system acts mainly through complement pathway which depends on pattern-based recognition of “self” and “non-self” targets by host lectins and associated proteins. This ultimately results in the clearance of target cells. Lectins are glycoproteins which possess at least one carbohydrate recognition domain (CRD) that specifically and reversibly binds to a carbohydrate which is widely distributed in bacteria, fungi and viruses, and thus activates the innate immune system. Lectins are involved in many biological functions including cell adhesion, phagocytosis, complement activation and innate immunity. Fish lectins have also an important role in fertilization, embryogenesis and morphogenesis. Based on the structure, binding specificities and calcium dependency, lectins are classified into different families like C-type lectins, F-type lectins, galectins, intelectins, rhamnose binding lectins, I-type lectins, Lily-type lectins etc. Lectins such as ficolins, galectins, calnexin, pentraxin, F-type lectins, intelectins, mannose-binding proteins (MBPs) are known to play an important role in innate immunity and disease resistance. The skin forms an important immune structure in fish and the skin mucus is reported to have lectins, as well as stomach, intestine, liver, gills, eggs, skin, serum, and plasma of different families of fish. In addition to their important role in cellular recognition as pattern recognition receptors, the interaction of lectins with carbohydrates has been explored in various fields of research where saccharide specificity is essential. These proteins are invaluable tools for the study of simple or complex carbohydrates, in solution or on cell surface, as well as for cell characterization. The action of the innate immune system in recognition of a pathogen is initiated by pathogen recognition receptors (PRRs). This can detect and respond to the pathogen-associated molecular patterns (PAMPs). PRRs also detect death-associated molecular patterns (DAMPs) which are endogenous molecules released by damaged or stressed cells. Lectins belong to the humoral component of innate immune system and are involved in recognition of PAMPs effecting in agglutination and neutralization of potential microbial pathogens or activation of complement components. Taken together, various study reports suggest that fin fish lectins plays a major role in immune recognition of microbial pathogens and facilitate their clearance by phagocytosis. The present review discusses the occurrence and biological role of lectins in finfish.

KEYWORDS

Lectins; carbohydrate recognition domain; innate immune response; bacterial agglutination; pathogen-associated molecular patterns

Introduction

As phylum, fish have contributed to understand the evolution of the immune system, as the immune system of fish is physiologically similar to that of higher vertebrates, despite certain distinctions (Uribe et al.,

2011). Similar to mammals; the fish immune system is organized into innate and adaptive, both involved in cell-mediated defense and humoral factors (soluble substances). The innate parameters are crucial factors in disease resistance (Magnadóttir, et al., 2001; Magnadóttir, 2006; 2010). The adaptive response of



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Full length article

Effects of orange peels derived pectin on innate immune response, disease resistance and growth performance of Nile tilapia (*Oreochromis niloticus*) cultured under indoor biofloc system



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ABSTRACT

The present study investigates the effects of orange peels derived pectin (OPDP) on skin mucus and serum immune parameters, disease resistance and growth performance of *O. niloticus* cultured under indoor biofloc system. Six hundred Nile tilapia (average weight 9.09 ± 0.05 g) were distributed into 15 fiber tanks (300 L per tank) assigned to five treatments repeated in triplicate. Fish were fed experimental diets contain different levels OPDP as follows: 0 (control in clear water), 0 (control in biofloc system), 5, 10, and 20 g kg^{-1} OPDP for 8 weeks. At weeks 4 and 8 post feeding, skin mucus lysozyme (SMLA), peroxidase activities (SMPA), serum lysozyme (SL), serum peroxidase (SP), alternative complement (ACH50), phagocytosis (PI), and respiratory burst activities (RB) as well specific growth rate (SGR), weight gain (WG), final weight (FW), and feed conversion ratio (FCR) were measured. Also, resistance against *Streptococcus agalactiae* was assessed after 8 weeks post-feeding. Nile tilapia fed OPDP supplemented diets had significantly higher SMLA and SMPA compared to the controls ($P < 0.05$). The maximum values were observed in tilapia fed 10 g kg^{-1} OPDP followed by 5 and 20 g kg^{-1} OPDP. Nevertheless, no significant differences were observed between these two supplemented diets and between the control groups ($P > 0.05$). Regarding the serum immunological parameters, dietary inclusion of 10 g kg^{-1} OPDP showed significant higher SL and PI than other supplemented groups and control groups ($P < 0.05$). However, no significant differences were observed in SL and PI of fish fed 5 and 20 g kg^{-1} OPDP ($P > 0.05$). Dietary administration of OPDP significantly increased SP and ACH50 compared to the controls ($P < 0.05$), regardless of inclusion level. Additionally, non-significant change was found in RB of OPDP fed fish when compared with the controls ($P > 0.05$). The challenge test revealed that relative percent of survival (RPS) in OPDP treatments were 45.45%, 81.82%, 50%, respectively. The highest RPS was noticed in fish fed 10 g kg^{-1} OPDP. Furthermore, dietary administration of OPDP significantly improved SGR, WG, FW, and FCR ($P < 0.05$). Overall, the present findings suggested that OPDP can be taken into account as functional feed additives for *O. niloticus*.

1. Introduction

Aquaculture industry is one of the fastest growing food producing sectors [1]. This industry has been significantly contributed to provide high quality and affordable protein source worldwide [2]. Due to fast growth rate, Nile tilapia, *Oreochromis niloticus* has been considered as one of the most farmed fish globally in more than 100 countries, [3]. The global production of tilapia was estimated to be 6.69 million metric

tonnes in 2016 [4] and expected to reach 7.3 million metric tonnes by 2030 [5]. The increase in fish demand from markets pushed aquaculture industry toward intensified culture systems which per se increased the risk of infectious diseases such as *Streptococcosis* [6,7]. Besides, the “post-effect” in the form of drainage water, a rich source of organic matter, nitrogen and phosphorus, causes severe pollution and frequent harmful algal blooms in aquatic ecosystems; considered as the major obstacle in the sustainable development of this industry [8–10].

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Marine derived bioactive compounds for treatment of Alzheimer's disease

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1. ABSTRACT

Alzheimer's disease (AD) is mounting as social and economic encumbrance which are accompanied by deficits in cognition and memory. Over the past decades, Alzheimer's disease (AD) holds the frontline as one of the biggest healthcare issues in the world. AD is an age related neurodegenerative disorder marked by a decline in memory and an impairment of cognition. In spite of tedious scientific effort, AD is still devoid of pharmacotherapeutic strategies for treatment as well as prevention. Current treatment strategies using drugs are symbolic in nature as they treat disease manifestation though are found effective in treating cognition. Inclination of science towards naturopathic treatments aiming at preventing the disease is highly vocal. Application of marine-derived bioactive compounds, has been gaining attention as mode of therapies against AD. Inspired by the vastness and biodiversity richness of the marine environment, role of marine metabolites in developing

new therapies targeting brain with special emphasis to neurodegeneration is heading as an arable field. This review summarizes select-few examples highlighted as therapeutical applications for neurodegenerative disorders with special emphasis on AD.

2. INTRODUCTION

Aging is an implacable and unavoidable stage of entropy where one comes across diseases and disabilities- a collective consequence of genetic, environmental and lifestyle factors (1). Aging is considered as a main risk factor for a myriad of diseases including inflammatory and metabolic disorders, cancer and neurodegenerative diseases. The coequal hands in the hub of neurodegenerative diseases, Alzheimer's disease (AD), Parkinson's disease (PD), and Huntington's disease (HD) are often life threatening and regarded as social as well



Comparison of molecular characteristics of Type A humic acids derived from fish waste and sugarcane bagasse co-compost influenced by various alkaline extraction protocols

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ABSTRACT

An analytical investigation on different alkaline extraction methods to extract "Type A" humic acids (HAs) from fish waste and sugarcane bagasse co-compost using 0.1 M concentration of $\text{Na}_4\text{P}_2\text{O}_7$, NaOH and KOH was experimentally studied. The influence of each alkaline extraction method in producing heterogeneous characteristics of the humic acids (HAs) was critically compared to identify the variations in yield, elemental composition; spectroscopic properties and morphological features. Contrasting variations in the yield; elemental Carbon (C) and Oxygen (O) composition was identified in HAs extracted with 0.1 M $\text{Na}_4\text{P}_2\text{O}_7$ and NaOH. UV-vis and fluorescence spectroscopy exhibited slight differences in the absorption maxima (λ_{max}) and emission spectra (λ_{em}) values. FTIR analysis showed contrasting variations in the peak intensities of the functional moieties. Especially, high resolved IR spectra was observed in HAs extracted with $\text{Na}_4\text{P}_2\text{O}_7$ for C=C of amide I (1631 cm^{-1}) and C-O of polysaccharides (1085 cm^{-1}) whereas NaOH and KOH derived HAs exhibited prominent shoulder for alkyl C-H groups (2935 cm^{-1}). ICP-MS results showed drastic variations in the concentration of micro elements and heavy metals in HAs obtained from each method. ^1H NMR spectra showed intense signals in 3–4 ppm region for HAs extracted with NaOH. Stereo microscopic and photon correlation spectroscopic measurements revealed variations in the particle sizes of HAs. Tiny diffused amorphous structures of HAs extracted using $\text{Na}_4\text{P}_2\text{O}_7$ and large rock-like macromolecular structures of HAs isolated with KOH and NaOH was apparent from SEM analysis. The comparative findings of the study provide an insight towards understanding the sensitive variations observed in the molecular characteristics of humic acids influenced by the alkaline extraction protocols.

1. Introduction

Seafood processing sector generates large quantities of biological waste that are dumped in landfills; discarded in open sea waters that ultimately create health and environmental problems including organic matter contamination and sickening odours. The wastes generated from the fish markets and processing sites such as canneries, fresh and frozen fish processing plants could be transformed to valuable organic products rich in N and P through composting process [1]. As composting appears to be a viable solution for safe disposal of fish wastes; different bulking agents and amendments such as alder; fir; peat moss and vermiculite were used to transform fish wastes into useful agriculture

product [2]. Also sea food waste processing liquid effluents has high organic load and does not contain any toxic or carcinogenic agents compared to municipal and industrial effluents [3].

Different bulking agents such sawdust and wood shavings, alder and fir sawdust, sea weeds and pine barks were studied with fish wastes through composting pile and reactor methods [1,4]. However utilization of sugarcane bagasse residual wastes from sugar processing industries remained less utilized for composting marine fish processing wastes. Utilization of sugarcane bagasse (SCB) in composting offers numerous advantages such as maintenance of water content of the organic mixture by forming porous spaces in the composting mass to increase the availability of oxygen and reduces the loss of static

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Studies on Proximate Composition and Phytochemical Profiling of *Turbinaria ornata* and its Antiproliferative Effect on Y79 Cell Lines

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Abstract

Marine brown algae *Turbinaria ornata* (*T. ornata*) that grows along Tamilnadu coast (Gulf of Mannar) were collected to study the composition of major and minor nutrients, phytochemical constituents and to evaluate the cytotoxic effect. Proximate composition of this brown seaweed was investigated by the determination of moisture, ash, protein, lipid and carbohydrate. The mineral content was analyzed using Inductive Coupled Plasma- Mass Spectrometry (ICP-MS). In general, the results of proximate analysis showed that moisture content (83.62%) was most abundant followed by carbohydrate (43.7% dry weight), ash content (23.4%) protein (5.4% dry weight) and lipid (1.9% dry weight). This work presents the data on the mineral content such as manganese, sodium, magnesium, potassium, zinc etc. of the brown algae. The chemical components present in the methanolic extract of the sample were analyzed using Gas Chromatography–Mass Spectrometer (GC-MS). The presence of secondary metabolites illustrate that this brown seaweed *T. ornata* can be harnessed for their biomedical potentials. Apart from this, the methanolic extract extracted also showed cytotoxic activity against human retinoblastoma Y79 cell lines and the Inhibitory Concentration (IC₅₀) was found to be at 6.37 µg/mL. Further research should be explored for the beneficial application of *T. ornata* as a potent therapeutic tool against cancer.

Keywords *Turbinaria ornata* · ICP-MS · GC-MS · Phytochemical screening · Cytotoxicity

Introduction

The marine biospheres are considered as one of the richest sources of natural products originating from marine organisms such as seaweeds, invertebrates, coral reefs and marine bacteria. Seaweeds belong to a group of plants known as algae. Seaweeds are classified as Rhodophyta (red algae), Phaeophyta (brown algae), and Chlorophyta (green algae)

depending on their nutrient and chemical composition. Seaweeds have been utilized as food, animal feeds, fertilizers and as sources of traditional medicine in many Asian countries since ancient times. They are excellent dietary sources of vitamins, proteins, carbohydrates, phytochemicals, trace minerals and other bioactive compounds (Kumar et al. 2008; De Aragao et al. 2016). In order to fully exploit the nutritional value of macro and micro algae, several studies on the biochemical and nutritional composition of various algae collected from diverse parts of the world have been conducted (Rupérez 2002; McDermid and Stuercke 2003; Ortiz et al. 2006; Marsham et al. 2007; Chakraborty and Santra 2008; Matanjun et al. 2009; Śmieszek et al. 2017). The biochemical composition of marine seaweeds is consistently known to be intensively influenced by geographical location and local environmental and sampling conditions. Several studies have been carried out using the crude extracts from marine algae on proximate composition, phytochemical screening and antibacterial activities (Maftuch et al. 2016; El Shafay et al. 2016; Michalak et al. 2017). Due to the presence of potent pharmacologically bioactive substances with wide arrays of potential health benefits (Blunden 1993; Smit 2004) those

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OPINION

Jurassic invaders: flood-associated occurrence of arapaima and alligator gar in the rivers of Kerala

A. Biju Kumar, Smrithy Raj, C. P. Arjun, Unmesh Katwate and Rajeesh Raghavan

Climate change and invasive species are two of the greatest threats to global biodiversity, and their impacts are compounded when they interact with each other¹. For example, altered flow regime as a result of climate change is one of the major pathways by which alien species are introduced into new aquatic ecosystems², while storms and associated flooding increase their dispersal through escapes from aquaculture facilities³.

Freshwater ecosystems of Kerala are considered as a global hotspot for fish diversity (~200 species) and endemism (30%)^{4,5}, with some rivers (e.g. Periyar and Chalakudy) harbouring the only remaining global populations of several threatened species (including Alliance for Zero Extinction (AZE) species)⁶. Unfortunately, these irreplaceable sites are under considerable threat from a range of anthropogenic stressors, including hydropower dams, alien invasive species, overharvest and pollution^{5,7,8}. The unprecedented and catastrophic floods in August 2018 has become an additional and perhaps one of the most significant threats to the native freshwater fishes of Kerala, as evidenced by the increasing occurrence of 'fugitive fish'⁹ – escapees from aquaculture facilities. What makes this case of fugitive fish hazardous from a biodiversity perspective is the fact that majority comprise of mostly predatory exotic species, which are rapidly spreading, acclimatizing and flourishing in new environments across the globe¹⁰.

Two most notorious alien species which emerged during the 2018 floods, that have the potential to threaten Kerala's exceptionally rich native ichthyofauna are the arapaima, *Arapaima gigas* (Schinz, 1822) and alligator gar, *Atractosteus spatula* (Lacepède, 1803) (Figure 1). Popularly known as ' piscine living fossils', both arapaima and alligator gar are 'ancient fishes'^{11,12}, with their origin dating back to the Cretaceous or even earlier^{13,14}. Arapaima, endemic to the Amazon, is one of the 'megafishes' of the world, growing up to 4.5 m in length and 200 kg in body weight, while the alligator gar, native to USA and Mexico, reaches a body length and weight up to

3 m and 137 kg respectively¹⁵. Both these species are the focus of organized (and in some cases unregulated) food, recreational and ornamental fisheries in their range countries¹⁵. While much of the native arapaima populations are currently overfished and their international trade regulated (i.e. Schedule II of CITES)¹⁶, habitat loss due to river engineering structures and indiscriminate fisheries have resulted in significant decline in alligator gar populations in their native range¹⁷. Concomitant with the population decline in their range countries, is the increasing occurrence of aquaculture associated 'fugitives' of these two giant fishes from outside their natural range, mostly as a result of the unregulated ornamental fish trade^{18–20}.

As a result of its large body size, life history and feeding ecology, *A. gigas* demonstrates multiple impacts on the ecosystems where it is introduced. For example, in Bolivia, the introduction of *A. gigas* resulted in considerable decline of native species, subsequently affecting fisher livelihoods¹⁸. On the other hand, impacts of alligator gar introduction/invasion on native species are unknown because of the relatively few studies on this topic, mostly as a result of the recent spread of this species into non-native habitats. Nevertheless, considering its high-

ly predatory nature, adaptations to wider ecological niches and large body size, the 'precautionary principle' needs to be adopted and detailed research on impacts carried out²¹.

Both arapaima and alligator gar are illegally introduced into India as they do not figure in the indicative list of 92 ornamental fishes considered for import²². In addition, arapaima being listed in the Schedule II of CITES, has been specifically prohibited for import into the country²². In Kerala, the 'use of non-domestic fish and fish seeds for fish farming without subjecting them to quarantine proceedings and quality check' has been prohibited through the Kerala Inland Fisheries and Aquaculture Act, 2010, while the Kerala Fish Seed Bill, 2014 demands strict quarantine measures for introduction of any non-native fish into the state. Nevertheless, lack of mechanisms for implementing and enforcing these provisions facilitates the illegal farming of top predators like arapaima and alligator gar in Kerala. Their culture, exhibition and sale continue unabated through public aquarium shows, social media and e-commerce enterprises. Interview and promotion videos of ornamental fish farmers and farms available in the public domain (including several on YouTubeTM) reveal that the fingerlings of



Figure 1. a, *Arapaima* caught from the Kodungalloor backwaters after the 2018 floods. b, Alligator gar caught from the Kurumali River.

SHORT COMMUNICATION



WILEY

First record of the Javanese ricefish, *Oryzias javanicus* (Bleeker, 1854) (Beloniformes: Adrianichthyidae) in the natural waters of India

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1 | INTRODUCTION

The Javanese ricefish, *Oryzias javanicus* (Bleeker, 1854), (Beloniformes: Adrianichthyidae) has a natural distribution in the brackishwaters of South East Asia from Peninsular Thailand, Malaysia, Singapore, Western Borneo and Indonesia east to Sulawesi and Lombok (Fricke, Eschmeyer, & Laan, 2018), and in Bangladesh (Ahmed, Islam, Sanzida, Akter, & Nahar, 2017, Unpublished; based on sequences available in GenBank) (Figure 1). Together with *O. dancena*, they are two of the most adaptable ricefish species, and highlighted as new experimental models (Imai, Koyama, & Fujii, 2005; Kang, Tsai, Liu, Lee, & Hwang, 2010; Parenti, 2008; Yusof, Ismail, Koito, Kinoshita, & Inoue, 2012). Here, we record for the first time, the occurrence of *O. javanicus* from natural waters in the south-eastern coast of India, ~1,000 km away from its natural distribution range, and separated by the Bay of Bengal.

2 | MATERIALS AND METHODS

Live samples ($n = 15$) of *Oryzias* sp. were collected on 14th April 2018 from the Muttukadu lagoon (12°48'31.38"N, 80°14'42.51"E) (Figure 1) near the experimental station of ICAR-Central Institute of Brackishwater Aquaculture (CIBA), Chennai, India. The collection location was 250 m away from the mouth of the Muttukadu lagoon, which opens to the Bay of Bengal. Fish was encountered mainly in the shallow water zone near mangrove areas with slow water current

and muddy substratum. They were found to be swimming in small schools close to the water surface at a depth of <50 cm. At the time of collection, water salinity was around 33 ppt. The total length of male and female fish ranged from 32.5–36.8 mm and 30.2–34.5 mm respectively. For morphological identification, 10 samples were preserved in 10% formaldehyde mixed with seawater and five samples were preserved in 90% ethanol for molecular studies. Two samples (one male and one female) were deposited in the collections of the Zoological Survey of India (ZSI) with the accession number MBRC/ZSI/F1853. To validate the morphological identification, the partial sequences of cytochrome c oxidase subunit I (COI) gene was generated. The genomic DNA was extracted from ethanol preserved muscle tissue using a standard DNA proteinase K digestion/phenol-chloroform extraction procedure. A degenerated primer was designed by aligning COI sequence of *Oryzias* spp. available in NCBI GenBank. The fragments of COI gene (532 bp) were amplified using primer; COI_OJ_F: 5' AAGCCTGCTAATTCGAGCWG 3' and COI_OJ_R: 5' GGGTCGAAGAATGTGGTRTT 3'. PCR amplification was carried out in a reaction mixture containing 10 ng template DNA, 12.5 µl of Taq DNA polymerase master mix containing 1.5mM MgCl₂ (Ampliqon), 0.4 µM of each primer, and nuclease free water added up to 25 µl. The PCR amplification was carried out with the following conditions: 35 cycles of denaturation (93°C for 30 s), annealing (50°C for 30 s) and extension (72°C for 45 s) with an initial denaturation step of 93°C for 2 min and a final extension step at 72°C for 5 min. The purified PCR products were bi-directionally sequenced using corresponding primer sets. A neighbour-joining (NJ) phylogenetic tree and a maximum-likelihood (ML) tree were constructed

100 pressing questions on the future of global fish migration science, conservation, and policy

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The subterranean *Aenigmachanna gollum*, a new genus and species of snakehead (Teleostei: Channidae) from Kerala, South India

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Abstract

Aenigmachanna gollum, new genus and species, is described from Kerala, South India. It is the first subterranean species of the family Channidae. It has numerous derived and unique characters, separating it from both the Asian *Channa* Scopoli and the African *Parachanna* Teugels & Daget. Uniquely among channids, *A. gollum* has a very slender (maximum body depth only 11.1–11.3% SL), eel-like body (head length 20.8–21.6% SL), large mouth (jaw length 60.4–61.1 % HL), 43–44 anal-fin rays, 83–85 scales in a lateral series, an unusual colour pattern and it lacks pored lateral-line scales on the body and body buoyancy. In addition, it is distinguished by its DNA barcode sequence, which is 15.8–24.2% divergent from other species of the family Channidae. Morphological modifications usually associated with a subterranean life, such as reduction of eyes and enhancement of non-visual senses (taste, smell, mechanosensory systems) are absent in *A. gollum*. However, it shares with subterranean fishes a slight reduction of its pigmentation in comparison to epigeal channids.

Key words: Western Ghats-Sri Lanka biodiversity hotspot, relict lineages, laterite, aquifer

Introduction

The Western Ghats area of Peninsular India is part of a global biodiversity hotspot (Western Ghats-Sri Lanka), as evidenced by its high levels of endemism for different groups of animals and plants (Myers *et al.* 2000; Gunawardene *et al.* 2007; Mittermeier *et al.* 2011), but especially for teleostean freshwater fishes, amphibians and reptiles (Abell *et al.* 2008; Dahanukar *et al.* 2011; Mittermeier *et al.* 2011). Some of the unique diversity of these three groups in the Western Ghats is the result of more recent diversification, while this area of Asia is also well-known for its relict lineages, e.g., the teleostean fishes *Lepidopygopsis* (Dahanukar *et al.* 2013) and *Horabagrus* (Mo 1991), the anurans *Nasikabatrachus* (Biju & Bossuyt 2003) and *Astrobatrachus* (Vijayakumar *et al.* 2019), the caecilian *Indotyphlus* (San Mauro *et al.* 2014), the gekkonid *Hemidactylus anamallensis* (Bansa & Karanth 2013), and the colubroid ophidian *Xylophis* (Deepak *et al.* 2018).

Of particular interest among freshwater fishes are those relict lineages that are restricted to subterranean waters in the southern periphery of the Western Ghats. These include often blind and pigmentless, endemic representatives with obscure, potentially ancient evolutionary relationships, such as the catfish genera *Horaglanis* (Menon 1950) and *Kryptoglanis* (Vincent & Thomas, 2011), and three species of the swamp eel genus *Monopterus* (Eapen 1960; Bailey & Gans 1998; Gopi 2002).

Here, we describe the first subterranean representative of the family Channidae. The teleostean family Channidae comprises ca. 50 species in two genera (Praveenraj *et al.* 2019). *Parachanna* with three species is restricted to drainages in West- and Central Africa and the Nile basin, while the Asian genus *Channa* with 47 species is distributed from southeastern Iran in the Middle East through Afghanistan and Pakistan east to the Amur basin in southeastern Russia and south to the Sunda islands (Courtney & Williams 2004). Being popular food fishes, some of the larger Asian snakehead species have also been introduced outside of their native range and have become established as invasive neozoa threatening the local fish fauna owing to their considerable potential for further expansion (Courtney & Williams 2004).



REVIEWS

Mahseer (*Tor* spp.) fishes of the world: status, challenges and opportunities for conservation

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Prakash Nautiyal · Shannon D. Bower · Steven J. Cooke ·
Steve Lockett · Mark Everard · Unmesh Katwate · K. Ranjeet ·
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Abstract The mahseer fishes (*Tor* spp.) represent an iconic genus of large-bodied species of the Cyprinidae family. Across the 16 recognised species in the genus, individual fish can attain weights over 50 kg, resulting in some species being considered as premier sport fishes. *Tor* species also generally have high religious and cultural significance throughout South

and Southeast Asia. Despite their economic and cultural importance, the status of *Tor* fishes has been increasingly imperilled through their riverine habitats being impacted by anthropogenic activities, such as hydropower dam construction and exploitation. Moreover, conservation efforts have been constrained by knowledge on the genus being heavily skewed

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Demographics of *Lagocephalus inermis* in the Arabian Sea unveils complex conservation challenges

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The first assessment of the demographics of *Lagocephalus inermis*, a species associated with pufferfish bites and fishing down the food web in the Arabian Sea, south-west coast of India, was performed based on length structured population dynamics of 1601 individuals caught in commercial fisheries. Analysis revealed that the current level of exploitation is 90% of the predicted exploitation producing maximum relative yield per recruit (E_{max}), suggesting high levels of exploitation with potential for significant negative consequences for trophic cascades.

KEYWORDS

exploitation, fisheries management, population dynamics, pufferfish, tetraodontids

The Tetraodontidae comprise around 27 genera and 184 species of pufferfishes (Matsuura, 2014) distributed in tropical and subtropical waters, with their highest diversity in the Indo-West Pacific Ocean (Nelson *et al.*, 2016; Stump *et al.*, 2018). Pufferfishes are linked to a rich culinary history in east Asian cultures (Ishige, 2001) where they are used in both low-value preparations and extravagantly priced luxury commodities (NMFS, 1989). Exploitation for puffer food trade in the region has resulted in populations of highly-sought after species declining between 75 and 95% and subsequently listed on the IUCN Red List as of Conservation Concern (*i.e.*, threatened or near threatened; Stump *et al.*, 2018). However, in other parts of the world (*e.g.*, Arabian Sea and Mediterranean Sea), these fish have been reported to be a menace and are implicated in pufferfish bites, a phenomenon where large shoals of pufferfish destroy fishing nets and reduce the value of the target catch (Mohamed *et al.*, 2013; Nader *et al.*, 2012; Raphael *et al.*, 2017).

An apparent growing incidence of pufferfish bites in the Arabian sea, particularly off the south-west coast of India, have been attributed to an increased biomass of tetraodontids as a result of trophic cascading involving the removal of top predators, in particular *Rachycentron canadum* (L. 1766) and *Arius* spp. catfishes (Mohamed *et al.*, 2013). Pufferfish catches from this region have increased significantly since the year 2005 to reach c. 2000 t in 2011 (Mohamed *et al.*,

2013), with an average daily landing of close to 3 t at major fishing harbours (C. V. Anju, 2017, personal observation). The smooth-backed pufferfish *Lagocephalus inermis* (Temminck & Schlegel 1850) contributes the highest landings in the region (Mohamed *et al.*, 2013) and is the dominant species implicated in pufferfish bites (Raphael *et al.*, 2017). Found at depths from 20 to 200 m, *L. inermis* is a demersal, mid-level carnivore, preying on anchovies and squids (Mohamed *et al.*, 2013; Thomas *et al.*, 2009). Despite the increase in pufferfish-associated fisheries management issues, not much scientific information is available on the demographics of the members of the genus *Lagocephalus* Swainson 1839 from the Arabian Sea, a knowledge gap we address through this paper.

Samples of *L. inermis* ($n = 1601$) landed in fish trawls (operated at 40–50 m depth) at Munambam fishing harbour, India (10.18°N, 76.17°E) were measured (standard length, L_S , to the nearest mm) and weighed (M , to the nearest g) in fortnightly intervals from August 2017 to May 2018. June and July are closed seasons for trawl fisheries on the SW coast of India and therefore sampling was not possible in these 2 months. Data were collected randomly by selecting individuals for length and mass estimation without keeping any size bias.

Length-mass relationship (LWR) between L_S and total mass (M , g), $M = a L_S^b$ was determined following Pauly (1984) and



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Sub-lethal responses of mahseer (*Tor khudree*) to catch-and-release recreational angling

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ABSTRACT

Fishes exhibit a range of biological responses to the process of catch-and-release recreational angling. In the last decade, research has begun to consider how such fisheries interactions alter the behaviour (e.g., movement, feeding activity, reproduction) of fish upon release. In this study, we assessed reflex impairment and then affixed radio telemetry transmitters to 34 blue-finned mahseer (*Tor khudree*) angled on the Cauvery River, India, between February and May of 2015. We then tracked their movements over two time scales: continuously for 90 min post-release, and hourly over a 24 h period. When testing reflex impairment, mahseer were more likely to first lose orientation, followed by loss of tail grab response, then loss of regular operculum beats. Neither reflex impairment nor time taken for fish to swim away from the release site varied significantly with air exposure or handling time. Similarly, movement rates of mahseer were consistent amongst tagging periods. However, trends did indicate that larger fish subject to longer angling and handling times took longer to leave the release site, moved less during the initial release period, and moved less over a 24 h cycle. We recommend that anglers view impairment of multiple reflexes in blue-finned mahseer as an indication that caution in handling is warranted. We also recommend further study of size- and age-based differences in mahseer behaviour, including specific research on responses of trophy-sized mahseer to catch-and-release angling. Our work contributes to the understanding of sublethal behavioural consequences of catch-and-release while generating some of the first information to guide development of best practice guidelines for those catching and releasing blue-finned mahseer.

1. Introduction

Many anglers around the world practice catch-and-release (C&R), as an estimated two-thirds of ~47 billion fish caught during recreational fishing activities per year are released back into the water (Cooke and Cowx, 2004). Defined as ‘the act of returning a fish to the water after capture, presumably unharmed’ (Arlinghaus et al., 2007), the success of C&R as a conservation strategy is highly dependent on the degree of physiological disturbance (including injury) experienced by fishes during capture and handling. The level of physiological disturbance can range from mild physiological stress from which fish recover to severe physiological impairment which leads to post-release mortality (see reviews by Cooke and Suski, 2005; Arlinghaus et al., 2007). ‘Sub-lethal consequences’ refers to outcomes experienced by fishes that, while not

resulting in death, do result in physiological or behavioural changes over the short to long-term (Cooke et al., 2002). These consequences can include increased susceptibility to post-release predation (a lethal outcome) through alterations in movement, changes in migration, feeding, or parental care patterns, and changes in habitat associations (Thorstad et al., 2003; Hanson et al., 2007; Suski et al., 2007; Klefoth et al., 2008). There is growing recognition that behavioural outcomes for animals that interact with humans can be used as objective assessments of animal condition needed to understand consequences of human activities on wildlife (Sutherland, 1998; Caro, 1999). Behavioural outcomes can also be used to identify opportunities to improve welfare of animals (Swaigood, 2007).

Notwithstanding some inherent drawbacks to the approach, including challenges establishing control groups and accounting for

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Are well-intended Buddhist practices an under-appreciated threat to global aquatic biodiversity?

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Abstract

1. The inherently pro-conservation and humane Buddhist practice of 'live release', entailing the release into the wild of creatures destined for slaughter, poses potentially significant conservation consequences if inappropriate, invasive species are procured for release.
2. This article collates evidence, citing one legal case and other examples, about the risks of the live release of potentially invasive aquatic species that may result in serious, possibly irreversible, conservation threats to aquatic biodiversity and natural ecosystems, with ensuing adverse ecological and human consequences.
3. It is essential that practitioners are aware of these risks if their actions are not to work diametrically against the pro-conservation and humane intents of the practice.
4. Ensuring that live release occurs safely necessitates raising awareness, with guidance informed by science, to ensure that good intentions do not result in perverse, environmentally destructive outcomes.
5. We propose four simple principles to achieve this, for dissemination to the global adherents of these otherwise entirely laudable practices.

KEYWORDS

conservation, fish, humane, invasive species, live release, mercy release

1 | INTRODUCTION

Biotic homogenization – declining biological diversity resulting from environmental changes favouring a subset of species – is a pervasive global problem (McKinney & Lockwood, 1999), reaching substantial levels in some regions of the Palaearctic and Nearctic realms (Villéger, Blanchet, Beauchard, Oberdorff, & Brosse, 2011). Scott and Helfman (2001) observed that fish species are prone to biotic homogenization owing to the pressures of habitat destruction, favouring a few tolerant species, as well as purposeful introductions that may also lead to extinctions of native species. Across other taxonomic groups, potentially invasive species introduced beyond their native ranges are a significant factor driving environmental change, with extinctions of formerly locally representative species increasing the tendency

towards genetic, taxonomic, or functional similarity between locations, with broader consequences for ecological and evolutionary processes (Olden, Poff, Douglas, Douglas, & Fausch, 2004). Liu, Comte, and Olden (2017) have provided a review of life-history traits of the world's freshwater fishes as predictors of invasion and extinction risk, in order to support management decisions without needing to refer to individual species ecology.

The Buddhist practice of 'live release', also known by many alternative names, including 'fang sheng', 'mercy release', and 'prayer animal release', entails the release into the wild of captive animals and particularly those destined for slaughter. The practice is founded on the good intention of protection of living organisms; however, it also represents a potential pathway for the introduction of non-native and potentially invasive species, which may have perverse outcomes for

Glass in the water: Molecular phylogenetics and evolution of Indian glassy perchlets (Teleostei: Ambassidae)

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Abstract

Glassfishes of the family Ambassidae, comprising around 50 species, are distributed in the Indo-West Pacific where they inhabit marine, estuarine, and freshwater ecosystems. We investigated for the first time the molecular phylogenetic and evolutionary relationships of this group using a combined dataset of mitochondrial and nuclear genes, particularly focusing on the taxa occurring in the Indian subcontinent. Results revealed that marine and freshwater genera of Ambassidae diverged during the Paleocene (~62 mya). The enigmatic monotypic genus *Chanda* is nested within the larger clade currently recognized as *Parambassis*, indicating its paraphyly. Based on cleared and stained osteological preparations and phylogenetic placement of *Chanda nama*, we hypothesize that the elongated and protruding lower jaw is an autapomorphic character that might have evolved for the lepidophagous habit of the species. The southern Indian species of *Parambassis*, *Parambassis dayi*, and *Parambassis thomassi*, which formed a monophyletic group, probably diverged from other species of *Parambassis* and *Chanda nama* around the Eocene (~42 mya) and can potentially be recognized as a distinct genus in view of the apomorphic characters such as the presence of serration on the ventral fringe of interopercle, densely serrated palatine and ectopterygoid, and the presence of more than 30 serrations along the lower preopercle and the posterior edge. Our analysis provides new insights into the evolution and phylogenetic relationships of glassy perchlets, including detailed relationships among the Indian species within this family.

KEYWORDS

Chanda, molecular clock, osteology, *Parambassis*, Percomorpha

1 | INTRODUCTION

Percomorpha is a diverse group of fishes with unusually high diversification rates (Alfaro et al., 2009, 2018; Nelson, Grande, & Wilson, 2016). Though recent phylogenetic studies (Betancur-R et al., 2013; Near et al., 2012, 2013; Sanciangco, Carpenter, & Betancur-R, 2016;

Smith & Craig, 2007; Wainwright et al., 2012; Yagishita et al., 2009) provided new insights into the evolutionary relationships among the percomorph fishes, several groups remain poorly known. One such group of percomorphs with limited knowledge is the Asian glassy perchlets or glassfishes of the family Ambassidae. Though often grouped under Perciformes (Anderson & Heemstra, 2003; Jayaram, 2010; Kottelat, 2013), the most recent version of the "Fishes of the World" (Nelson et al., 2016) considers Ambassidae as *incertae sedis*

*Joint first authors

A new syntopic species of small barb from the Western Ghats of India (Teleostei: Cyprinidae)

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Abstract

A new species of the cyprinid genus *Pethia* is described from the Hiranyakeshi, a tributary of the Krishna River system in the Western Ghats mountain ranges of peninsular India. The new species, *Pethia sahit*, is syntopic—and shoals together—with *Pethia longicauda*, a species described recently from the same river. *Pethia sahit* is distinguished from *P. longicauda* and its congeners by a combination of characters like, incomplete lateral line with 3–6 pored scales; 19–22 scales in lateral series; 4½ scales between dorsal-fin origin and lateral-line row and 2½ scales between lateral line row and pelvic-fin origin; intercalated scale row originates above and after the 6th scale of the lateral-line scale row; dorsal fin originating behind the pelvic-fin origin; 4+13 abdominal and 12 caudal vertebrae; dorsal, pectoral, pelvic, anal and caudal fins without any bands or spots, deep yellow-orange in color or deep red with a pale tint of orange in mature males; a dark-black vertically elongate humeral spot, overlapping the 4th lateral-line scale, extending over the base of one scale above and below the 4th scale; caudal peduncle spot dark, covering 14th–16th scales in lateral-line scale row. Genetic analysis based on the mitochondrial cytochrome b gene indicates that *P. sahit* and *P. longicauda* are not sister taxa. Further, *P. sahit* has no genetically proximate congener in the Western Ghats region, and differs from known congeners from south and southeast Asia, for which genetic data are available, with genetic distance ranging from 11.8–16.4%.

Key words: freshwater fish; integrative taxonomy; *Pethia*; sympatry

Introduction

Fishes of the cyprinid genus *Pethia* are diagnosed from other cyprinid genera by a suite of characters that includes small adult size (usually less than 50 mm standard length/SL, exceptionally up to 80 mm SL), absence of rostral barbels, absent or minute maxillary barbels, last unbranched dorsal-fin ray stiff and serrated, 3 to 4 unbranched and 8 branched dorsal-fin rays, 3 unbranched and 5 branched anal-fin rays, lateral line complete, interrupted or incomplete with 19–24 scales in lateral series, and a unique color pattern consisting of a humeral spot, a black blotch on the caudal peduncle, and in some species, black blotches, spots or bars on the body (Pethiyagoda *et al.* 2012). Currently, the genus *Pethia* includes around 38 species occurring across India, Sri Lanka, Bangladesh, Nepal, Pakistan, Bhutan and Myanmar (Pethiyagoda *et al.* 2012; Dishma & Vishwanath 2013; Gurung *et al.* 2013; Knight 2013; Kottelat 2013; Katwate *et al.* 2014a, b, c, 2015, 2016; Atkore *et al.* 2015; Shangningam & Vishwanath 2018). In India, the genus is comprised of 28 valid species, of which 10 are endemic to the rivers originating in the Western Ghats mountain ranges.

The growing interest in the taxonomy and systematics of the genus *Pethia* has resulted in a flurry of new-species descriptions and clarifications of the identity of species described in the 19th century, together with the accurate delimitation of species distribution ranges (Knight *et al.* 2012; Dishma & Vishwanath 2013; Katwate *et al.*

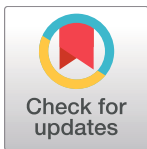
RESEARCH ARTICLE

Resolving the taxonomic enigma of the iconic game fish, the hump-backed mahseer from the Western Ghats biodiversity hotspot, India

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Data Availability Statement: All data are available within the paper and supporting supplementary files. Genetic data (sequences) are deposited in NCBI GenBank (MG769028 to MG769056) and are available open-access. Morphometric data used in the study is available online on figshare (<https://doi.org/10.6084/m9.figshare.6085982>).

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Abstract

Growing to lengths and weights exceeding 1.5 m and 45 kg, the hump-backed mahseer fish of the Western Ghats biodiversity hotspot, India, is an iconic, mega-faunal species that is globally recognized as a premier freshwater game fish. Despite reports of their high extinction risk, conservation approaches are currently constrained by their lack of valid taxonomic identity. Using an integrative approach, incorporating morphology, molecular analysis and historical photographs, this fish can now be revealed to be conspecific with *Tor remadevii*, a species lacking a common name, that was initially, but poorly, described in 2007 from the River Pambar, a tributary of the River Cauvery in Kerala. Currently known to be endemic and restricted to the River Cauvery basin in the Western Ghats, *T. remadevii* is distinguished from congeners by its prominent hump originating above the pre-opercle and extending to the origin of the dorsal fin, a well-developed mandible resulting in a terminal or slightly superior mouth position, and the dorsal orientation of the eyes. While body colouration varies (silver, bronze, greenish) and is not considered a reliable diagnostic character, orange coloration of the caudal fin (sometimes extending to all fins) is considered a consistent characteristic. Having been first brought to the attention of the scientific community in 1849, and the recreational angling (game fishing) community in 1873, it has taken over 150 years to finally provide this iconic fish with a valid scientific name. This taxonomic clarity should now assist development and delivery of urgent conservation actions commensurate with their extinction risk.



The discovery of Euryrhynchidae (Crustacea: Decapoda) in India, with the description of a new genus and species

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Abstract

A new genus and species of Euryrhynchidae is described from Kerala, India. This freshwater shrimp family was previously only known from northern South America and West Africa. Although the inclusion of the genus in Euryrhynchidae is unequivocal (e.g. shape of the accessory ramus of the antennular flagellum, frontal margin of the carapace, telson ornamentation), the presence of a number of unique characters makes the relative placement of the genus within the family unclear, but likely basal to the other genera. The new genus can be easily distinguished from all others within the family by these characters, e.g. the upper antennular flagellum and its accessory ramus being joined over three divisions, the presence of a reduced carpo-propodal brush and a well-developed branchiostegal groove.

Key words: Euryrhynchidae, systematics, subterranean, India, new genus

Introduction

The freshwater shrimp family Euryrhynchidae Holthuis, 1950 is presently composed of three genera, which are distributed in the Amazonian region in northern South America, as well as in West Africa. In the Amazon, a single genus is present, *Euryrhynchus* Miers, 1878 with seven species (Pachelle & Tavares 2018), whilst in West Africa, two further genera are recognised, the monotypic *Euryrhynchoides* Powell, 1976 and *Euryrhynchina* Powell, 1976 with two species (De Grave *et al.* 2017; Pachelle & Tavares 2018).

Although the taxonomy of the family is now well resolved (Pachelle & Tavares 2018), the phylogenetic position of the family remains poorly understood. Historically (Chace 1992; Holthuis 1993) Typhlocarididae Annandale & Kemp, 1913 were thought to be close relatives of the Euryrhynchidae. This monogeneric family has an eastern Mediterranean distribution, with three out of the four known species dwelling in subterranean freshwater in Israel and Libya, whilst the Italian *T. salentina* Caroli, 1923 is recorded both in freshwater and brackish water caves and wells (Frogia & Ungaro 2001). Pereira (1997) on the basis of a morphological cladistics analysis supported this view, although in his analysis Palaemonidae *sensu lato* (see De Grave *et al.* 2015a) are resolved as a paraphyletic clade, with Euryrhynchidae and Typhlocarididae both embedded within Palaemonidae. On the basis of a morphological review, De Grave (2007) concluded that these two families are only remotely related, and suggested Desmocarididae Borradaile, 1915 as a possible sister taxon. This monogeneric family, with two species, lives in freshwater in West Africa (Powell 1977). This view was re-enforced by Bracken *et al.* (2009) in their phylogenetic study (based on 16S and 18S), resolving these two families as sister taxa. Two further phylogenetic studies have focussed on the relationship of palaemonid shrimps (Kou *et al.* 2013; De Grave *et al.* 2015a), with both resolving the same relationship. However, it should be noted that neither of these carried out *de novo* sequencing and re-used sequences for both families from Bracken *et al.* (2009), potentially explaining the identical results.

The ecology and life histories of the West African members of Euryrhynchidae are poorly known. In contrast,



Short Communication

Phylogeny of the hillstream loach genus *Mesonoemacheilus* reveals widespread diversification through ancient drainage connections in the Western Ghats Biodiversity Hotspot

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ABSTRACT

Rivers draining the Western Ghats (WG) mountain ranges in peninsular India harbor an exceptionally diverse, unique and evolutionarily distinct assemblage of lower vertebrates with high levels of endemism, attributed to their evolution and potentially long history of isolation during the Late Cretaceous or Early Tertiary. A molecular phylogeny of hillstream loaches of the genus *Mesonoemacheilus* endemic to the WG revealed the presence of four clades which we designate as 'species groups'. A consensus of various species delimitation methods indicates the likelihood of 'at least' seven more undescribed species within *Mesonoemacheilus*. Molecular clock analysis dates the basal clade around 38 mya in the Paleogene, and subsequent diversification in the Neogene and Quaternary periods resulting in the current genetic diversity. Biogeographic analysis suggests that vicariance events which separated the rivers on either side of the two geological barriers/gaps, the Palghat and Shencottah, in the Neogene, as well as range contractions and cladogenetic events contributed to the current patterns of diversity and distribution of this genus. Our results also provide preliminary indications on the interconnections and faunal exchange between historical river drainages in the WG region.

1. Introduction

The Western Ghats mountain range (henceforth WG) and its associated river systems in peninsular India harbour an exceptionally diverse, unique and evolutionarily distinct assemblage of lower vertebrates with remarkable endemism at higher levels (four endemic families; three in amphibians and one in fish) (Biju and Bossuyt, 2003; Molur, 2008; Britz et al., 2014). The evolution of endemic lineages in the WG is largely attributed to the subcontinent's intriguing tectonic history including its long-term geological isolation during the Late Cretaceous or Early Tertiary when inter-continental faunal interchange was reduced (Briggs, 1989; Biju and Bossuyt, 2003).

Freshwater fish are the most diverse groups of lower vertebrates in the WG with more than 300 species in 37 families (Britz et al., 2014; Dahanukar and Raghavan, 2013). Diversity and endemism of fishes is highest in the southern region of the WG (between 8° and 13° N latitudes), likely a result of the unique habitat diversity (in the southern region), as well as extinction events associated with the Deccan trap

formation (in the northern region) (Dahanukar et al., 2004). Several discrete hill ranges from where small (16 km) and large (~750 km) river systems originate and drain both the eastern and western slopes, make up the WG in the southern region; the south-north distance of 1200 km broken only by two biogeographic/geological barriers, the narrow 'Shencottah Gap' at 8.5°N (7.5 km) and a much wider 'Palghat Gap' at 10°N (30 km) (Fig. 1a).

Both the Palghat and Shencottah gaps are geologically very old (pre-Cambrian, ~500 mya) and their role as a biogeographic barrier in speciation and genetic divergence has been recognized in centipedes (Joshi and Karanth, 2013), amphibians (Van Bocxlaer et al., 2012; Vijayakumar et al., 2016), birds (Robin et al., 2015), mammals (Vidya et al., 2005) and plants (Ramachandran and Swarupnandan, 2006). The evolution of river drainages can significantly influence biogeography of freshwater fish, and it has been suggested that both the eastward, and westward draining river systems originating in the WG are in a transient state (Mandal et al., 2017) with minor changes in the river drainages that could have occurred as recently as Pliocene

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Molecular phylogeny unveils hidden diversity of hillstream loaches (Cypriniformes: Cobitoidea) in the northern Western Ghats of India

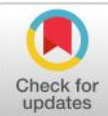
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ORIGINAL ARTICLE

WILEY

Lakes & Reservoirs
Science, Policy and Management for Sustainable Use

Population dynamics of an endemic cyprinid (*Hypselobarbus kurali*): Insights from an exploited reservoir fishery in the Western Ghats of India

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Abstract

The Western Ghats of India harbours an exceptional diversity of endemic freshwater fishes, which are threatened because of various anthropogenic stressors, including biological resource use. Lack of organized studies on the population dynamics and exploitation levels of endemic species, however, has hindered the development and implementation of systematic conservation action plans in this region. This is especially true for large cyprinid fishes threatened because of overharvest. This study examined length–weight relationships and length-structured population dynamics of an endemic large cyprinid (*Hypselobarbus kurali*), based on data obtained from an artisanal gill-net fishery in Malampuzha Reservoir. Length–weight analysis suggested the fish exhibited significantly lower exponents than expected under isometry, indicating the growth of *H. kurali* in the reservoir was negative allometric. The von Bertalanffy growth formula fitted to the length–frequency data indicated *H. kurali* grew relatively slower than other large cyprinids in this region. Statistical analysis of recruitment revealed two peaks, implying the fish have two spawning bouts each year. Analysis of mortality and exploitation of the species revealed large-sized individuals were targeted by the fishers, resulting in an exponential decline in the survivors in the virtual population analysis. Relative yield-per-recruit and relative biomass-per-recruit analysis indicated the current exploitation rate for the population was greater than the exploitation rate under which the stock would be reduced to half its unexploited biomass. Further, the current exploitation level was more than 60% of the expected maximum exploitation above which the population could collapse. The results of this study identify a serious need to develop and implement management plans to guide the future sustainability of the reservoir fishery of *H. kurali*.

KEYWORDS

exploitation, growth, large barb, length–weight relationship, mortality

1 | INTRODUCTION

The Western Ghats of Southern India is globally recognized for its diversity (>300 species) and endemism (>60%) of freshwater fish species (Dahanukar, Raghavan, Ali, Abraham, & Shaji, 2011),

as well as the associated small-scale fisheries it supports (Keskar, Raghavan, Kumkar, Padhye, & Dahanukar, 2017; Raghavan, Ali, Dahanukar, & Rosser, 2011). Unprecedented development activities in the region, however, have negatively impacted this extraordinary freshwater diversity, resulting in nearly 100 species

Population dynamics of a poorly known serranid, the duskytail grouper *Epinephelus bleekeri* in the Arabian Sea

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A demographic study on *Epinephelus bleekeri* based on a sample of 1,003 individuals caught in commercial fisheries along the Arabian Sea coast of southern India considerably extends the maximum recorded standard length for this species to 870 mm, indicates a high natural mortality rate and an exploitation level (E) greater than the $E_{\max}$.

KEYWORDS

Epinephelus bleekeri, India, Near Threatened, overfishing, reef cod

Epinepheline groupers exploited across the tropical Indo-Pacific region face a high level of extinction risk as a result of their unique life-history characteristics (e.g., late maturity, aggregate spawning and longevity), burgeoning market demand and unsustainable fisheries (Pears *et al.*, 2007; Sadovy *et al.*, 2003; Sadovy de Mitcheson *et al.*, 2012). Populations of some species (e.g., *Epinephelus akaara* (Temminck & Schlegel 1842) and *Epinephelus marginatus* (Lowe 1834)) have declined more than 50% over the past two decades and are listed as Threatened on the IUCN Red List (Cornish, 2003; Cornish & Harmelin-Vivien 2004; Sadovy de Mitcheson *et al.*, 2012). At the same time, there is an acute lack of information on the life history, ecology and populations of others. For example, at least 33 species are assessed as Data Deficient, hindering the development of species-specific conservation and fisheries management plans (Sadovy de Mitcheson *et al.*, 2012).

The duskytail grouper *Epinephelus bleekeri* (Vaillant 1878) is a medium-sized species (based on maximum recorded mass and length at first maturity) (Kandula *et al.*, 2015) occurring in the shallow waters of the Indo-West Pacific ocean from the Middle East to Taiwan and the northern coast of Australia. It is a relatively small yet important

fishery in the range countries (Heemstra & Randall, 1993; Kandula *et al.*, 2015; Russell *et al.*, 2008), but due to declining populations because of exploitation for both capture fisheries and capture-based aquaculture, *E. bleekeri* has been assessed as Near Threatened (Russell *et al.*, 2008). In India, *E. bleekeri* is exploited along the western and eastern coasts using trawls and traditional fishing gears (Kandula *et al.*, 2015; Mathew, 2003; Vargese *et al.*, 2017), but no information is available on the magnitude of catches, status and dynamics of populations or other fishery-induced wffect. This data deficiency on the demography and fishery status of *E. bleekeri* in India, where a major fishery exists and throughout its range, poses a significant challenge to their effective management and hampers updated species assessments for the IUCN Red List.

Standard length (L_S , mm) and body mass (M_B in gm) measures of exploited *E. bleekeri* ($n = 1,003$) were collected at weekly intervals (from November 2015 to June 2016) from two major landing centres, Thoppumpady (9.93° N; 76.26° E) and Munambam (10.18° N; 76.17° E) on the south-west (SW) coast of India. Data were collected randomly to avoid any size bias in the analysis. The length-mass relationship (LMR; $M_B = aL^b$) was determined following Pauly (1984) and



ORIGINAL ARTICLE

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Length-weight analysis of three needlefish species from the Lakshadweep archipelago

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Abstract

Length-weight relationships (LWRs) of three needlefishes belonging to the family Belonidae viz., *Ablennes hians*, *Tylosurus crocodilus* and *Tylosurus acus melanotus* were estimated based on samples exploited from a gill-net fishery in Androth, an island in the Lakshadweep archipelago. The estimated allometric co-efficient b value ranged from 3.047 (*T. acus melanotus*) to 3.274 (*A. hians*), and r^2 value ranged from 0.911 (*T. acus melanotus*) to 0.973 (*A. hians*). The first estimate of LWR for these three commercially exploited needlefish species from the Lakshadweep islands indicate local populations to be fairly robust and forms a basis for future management of fishing stock in the region.

1 | INTRODUCTION

The Lakshadweep archipelago includes a group of ten inhabited and 17 uninhabited islands, under the jurisdiction of the Government of India, scattered between 08°16'–13°58'N and 71°44'–74°24'E in the Southern Arabian Sea. Tuna is the major fishery (86.5%) in the region with an estimated landing of 13,500 tonnes per year (Vinay, Ramasubramanian, Krishnan, Kumar, & Ayoob, 2017), followed by needlefishes of the family Belonidae which contributes to the second largest fishery. Owing the better texture, flavor, colour and superior meat quality, there is a good demand for this fish especially during "off season" (monsoon months), when tuna fishery declines. Of six species of needlefish recorded from the region only three (*Ablennes hians*, *Tylosurus acus melanotus* and *Tylosurus crocodilus*) constitute regular fishery, with *T. acus melanotus* contributing to nearly 90% of the total needlefish landings. Much of the needlefish landings occur in Androth (the largest among the Lakshadweep islands), through a year-round subsidiary fishery contributing to 12% of the total marine fish landings. Despite the fishery being important, there is little information on length-weight relationship of needlefishes from the Lakshadweep islands, a knowledge gap that we address through this contribution.

2 | MATERIALS AND METHODS

Samples were collected on a fortnightly basis from July 2015 to May 2017 from the fish landing center at Androth (10°49'32"N & 73°40'56"E) and originated from gillnet (22–55 mm mesh size) fishery. Specimens without physical damage were carefully transferred to the laboratory in iced condition, and identified following Collette (1984, 2003). Total Length (TL) of each fish was measured using a measuring board and scale (0.1 cm accuracy), and the individual weight (W) was recorded using an electronic balance (0.1 g accuracy). The length-weight relationship described by the equation $W = a TL^b$, where W is the total weight (g), TL is the total length (cm), a is the intercept related to body form and b is the regression coefficient (Froese, 2006) was estimated, together with the parameters a , b and r^2 (coefficient of determination) using least-square regression analysis of the logarithm-transformed LWR expression $\log W = \log a + b \log TL$ (Garcia, 2010). Normalization of the data was carried out using log-log plot of the length-weight pairs and the 95% confidence limits (CI) of a , b and r^2 were estimated (Froese, 2006; Roul et al., 2017). Statistical analysis was carried out using Excel 2010 for Windows.



Patterns of Vegetation Dynamics across Mild Disturbance Gradient in a Freshwater Wetland System in Southern India

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Abstract

Ponnani *Kole* wetlands, the northward extension of Vembanad *Kole* Ramsar site in Kerala, Southern India, is facing environmental pressures due to increases in human population, changes in land use pattern, improper watershed management and urban developments. The current study describes the community assemblage pattern of macrophytes and their variations within and among areas affected by environmental disturbances in Ponnani *Kole* wetland system. The macrophyte community structures in the study site were characterized with reference to areas of saline intrusion, intense agricultural activities and sewage disposal. *Sphaeranthus africanus* and *Colocasia esculenta* were specific to sewage; *Rotala indica*, *Hedyotis corymbosa*, *Limnophila heterophylla* and *Eriocaulon setaceum* were specific to agriculture; while, *Acanthus ilicifolius*, and *Mariscus dubius* were specific to areas of saline intrusion in the study site. Mean diversity did not vary significantly among the different zones of disturbance with the exception of saline intruded areas. Taxonomically, similar species flourished well in all regions of the study except in the saline intrusion area. In undisturbed areas, considered as control, the occurrence of all macrophytes was observed in equal proportions with the exception of mangroves and suspended hydrophytes. However, in sewage disposal areas, the occurrence of 45 species was observed with unequal predominance of all taxa, viz. class, order and family of macrophytes. The implementation of decision supporting tools to aid strategy and policy makers explore land-use options and disturbance scenarios along with ecological tools assessing multiple ecosystem services will see Ponnani *Kole* wetland become established as a macrophyte dominated ecological regime which can be further developed as a conservation and educational site for tropical aquatic macrophytes.

Keywords Intensive agriculture · Saline intrusion · Sewage disposal · Plant community structure · Tropical wetlands · Species diversity

Introduction

Kole wetlands are vital ecosystems which provide agricultural produce, fish, fuel, fiber, fodder, and a host of other day-to-day necessities for thousands of inhabitants in its vicinity and are important repositories of aquatic biodiversity in particular

algal flora, macrophytic flora, avifauna and ichthyofauna. Benefits of wetlands are categorized into provisioning (food, fiber, fodder, fuel, water, and other materials), regulating (regulation of biogeochemical cycles and micro-climatic conditions), supporting (soil formation, supporting biodiversity) and cultural (aesthetics, recreational and spiritual activities) services (MEA 2005). These services ensue from the ecosystem functions and depend largely upon the biodiversity of the ecosystem. Macrophyte dominated wetlands are highly valued for recreation including bird watching, boating and other leisurely activities (Weller and Spatcher 1965). The fabulous potential of this wetland ecosystem for securing aquatic biodiversity, improving moisture regimes, replenishing aquifers and emergent eco-tourism sites has remained abhorrently under-tapped, and demands immediate attention. Usually designated as wastelands, these fragile ecosystems are being reclaimed for various developmental activities bringing

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Transcriptomics in aquaculture: current status and applications

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Abstract

Transcriptomics is the analysis of total RNA transcript in a cell, which gives a broad idea of cellular processes that are active and dormant. Recent advancement in next-generation sequencing technologies like high-throughput mRNA sequencing (RNA-seq) facilitates in deciphering the functional complexity of the whole transcriptome of an organism. In the recent past, transcriptome profiling has been widely used in aquaculture for effective identification and expression analysis of candidate genes involved in growth, reproduction, development, immunity, disease, stress and toxicology. On the paucity of a comprehensive genome sequence, transcriptomics enables the detection of molecular markers such as simple sequence repeats and single-nucleotide polymorphism associated with the trait of interest. This review summarizes the process of transcriptome analysis and the current state of transcriptomics in aquaculture related to diseases and immunity, reproduction and development, growth and nutrition, toxicology and stress. Further, this review highlights the application of transcriptomics, including generation of genetic resources, differential gene expression, analysis of molecular pathways and development of molecular markers.

Key words: aquaculture, gene expression, molecular markers, RNA-seq, transcriptomics.

Introduction

Aquaculture is a fast growing sector of agriculture with a worldwide production of 106 million tons in 2015 (FAO 2017). Though aquaculture is practiced widely across the globe, there are certain limiting factors such as economic loss due to diseases, unavailability of specific feeds and lack of genetically improved varieties (Allen & Steeby 2012). Since 2005, genome sequencing via next generation sequencing (NGS) and its applications, including metagenomics and transcriptomics has helped scientists to tackle many challenges in aquaculture (Liu *et al.* 2011a; Santos *et al.* 2014; Martínez-Porchas & Vargas-Albores 2017). In the recent past, biological science has been very much benefited from the application of various 'omic' techniques like genomics (gene analysis), transcriptomics (mRNA analysis), proteomics (protein analysis) and metabolomics (metabolite analysis) to understand the underlying molecular mechanism of various biological processes. Many of the recent studies in aquaculture display the reverberations of these omic techniques. As a result, comprehensive reviews related to the application of genomics (Yáñez *et al.* 2015;

Abdelrahman *et al.* 2017), metagenomics (Martínez-Porchas & Vargas-Albores 2017; Ortiz-Estrada *et al.* 2018), proteomics (Rodrigues *et al.* 2012) and metabolomics (Young & Alfaro 2016) in aquaculture emerged recently. However, there is a dearth of comprehensive reviews regarding the application of transcriptomic in aquaculture and the available reviews focus mainly on immunity, diseases and nutrition (Martin *et al.* 2016; Martin & Król 2017; Sudhagar *et al.* 2018; Ye *et al.* 2018). In contrast to the relatively stable genome, variations in the transcriptome can be observed with the developmental stage, physiological condition, and the external environment of an organism. This makes it a powerful tool for examining the relationship between the genotype and phenotype. Though proteomics and metabolomics are equally dynamic and effective, reproducibility and complexity of the analysis are the major drawbacks (Horgan & Kenny 2011). NGS has been used to generate reference genomes, transcriptomes and genomic resources to detect single nucleotide polymorphisms (SNPs) and other molecular markers that have many downstream specific applications such as the creation of linkage maps and recognition of quantitative trait loci