Eco. Env. & Cons. 29 (July Issue) pp. S103-S110
Copyright@ EM International
ISSN 0971–765X

Special Issue on "Int. Conf. on Impact of Clim. Change on Aq. Life and Mtgn. Measures for a Sust. Blue Economy", 23-25 Nov, 2022, PG & Res. Dept. of Zoology, FMNC, Kollam, Kerala, India.

DOI No.: http://doi.org/10.53550/EEC.2023.v29isp2.017

Study on Mangrove-associated Shellfish Diversity of Aayiramthengu Mangrove Forest, Kerala, India

Sreeraj B. and Nisha Thomas P.*

PG & Research Department of Zoology, Fatima Mata National College (Autonomous), Kollam 691 001, India

ABSTRACT

Fishery resources of mangrove forests are very productive because they act as the natural habitat for various species of fish, shrimps and crabs. Aayiramthengu mangrove forest, lying between Latitude 9° 02′- 9° 16′ N and Longitude 76° 20′ - 76° 32′ E was selected for the study. The present study was conducted during a period of four months from April 2022 to July 2022 to document the shellfish diversity existing in the Aayiramthengu Mangrove Forest. Their conservation status according to IUCN 2022 was also checked. Three species of bivalves belonging to the family Mytilidae, ten species of crabs under four families, twelve gastropods belonging four families and five species of prawns under the family Penaeidae were found to be occur in the study area. A total of 30 shellfishes were collected from the mangrove forest and their IUCN status was found to be Not Evaluated (NE). The present study indicates that there is an abundance of Gastropods and crabs in the study area, but the diversity of bivalves and prawns was comparatively less. Diversity among mangrove vegetations was also analysed. Six species of mangroves were found in the study area under six different families and the IUCN status of all these mangrove vegetations were found to be of Least Concern (LC).

Key words : *Aayiramthengu Mangrove Forest, Kerala, Shellfish Diversity, IUCN, Mytilidae*

Introduction

Biodiversity refers to the abundance and the variety within and among fauna and flora as well as the ecosystem and the ecological processes to which they belong and is thus usually considered as ecosystem at species and genetic levels. It is essential for stabilization of ecosystem, protection of overall environmental quality for understanding intrinsic wealth of all species on the earth. The species diversity of an ecosystem is related to the amount of both living and non-living organic matter present in it.

The mangroves dominate almost 1/4th of world's tropical coastline. The world's total mangrove area which spans 30 countries including various island nations is about 1,00,000 km^2. In 1997, Spalding reported that mangroves occupy 18,100,000 ha worldwide. In 1986, Tomlinson described the distribution of mangroves in 118 countries. During 1980's and 1990's, around 35% of the mangrove forest were lost worldwide. The human population growth and development of coastal zone were largely attributed to this global loss of mangroves. Overexploitation for timber, aquaculture, urban development forms were specific reasons for the loss. It has been said that "Mangroves play an important role in buffering coastlines against storm surges and tsunamis through wave attenuation" (Kathiresan and Rajendran, 2005; Wolanski, 2007; Barbier *et al*., 2008; Teh *et al*., 2009).

India has a long coastline of about 7516.6 km, including the island territories (Anonymous, 1984) having a mangrove cover of about 6,749 km, which forms the fourth largest mangrove area in the world

(Naskar and Mandal, 1999). In India, the states like West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Andaman and Nicobar Islands, Kerala, Goa, Maharashtra, and Gujarat occupy vast area of Mangroves. The area under mangroves in Gujarat is the second largest along the Indian coast, after Sunderbans. The Kerala state, which has 44 rivers and a wide network of estuaries and backwaters with tidal action, once had 700 km^2 of mangroves along its coast (Ramachandran *et al*., 1986) and has currently dwindled to 9 km^2 (FSI, 2019), which led to the loss of biodiversity as well as the carbon sequestration potential (Basha, 1991). The mangrove patches that still survive are distributed across ten coastal districts of the state (Sreelekshmi *et al*, 2021).

The finfish and shellfish diversity and fishery resources of backwaters of Kerala have not been well studied. Hydrography, sediment characteristics in the context of biotic and fishery resources of Kayamkulam backwater was studied by Mary John (1955, 1958) through a preliminary survey. Environmental and fishery resources of the site was studied by CIFRI (Anon., 1999). A study by Ratheesh, Manoj and Lakshmi in 2017 on 'Diversity of Mangroves in Asramam, Kollam District, Kerala' reported that dominance of *Sonneratia caseolaris* was distributed in all the quadrates studied, followed by *Rhizophora apiculata*. Kathiresan in 2003 reported that, there are three to four species of mangrove which are rarely found along the Kerala coast. The study is intended to understand the different mangrove species and associated shellfish species diversity in the Aayiramthengu mangrove forest region of Kollam, India. This mangrove ecosystem which is a part of Kayamkulam backwater was declared as an environmental hotspot after being ravaged by the Tsunami in 2004 and threatened with extinction. A total of 15 pure mangroves and 33 mangrove associates have been recorded from the entire coastal area of Kerala (Vidyasagaran *et al*., 2014). Individual studies on mangrove diversity or its faunal diversity have been conducted.

Materials and Methods

Study Area

The study area, Aayiramthengu mangrove forest (Lat. 9° 02'- 9° 16' N and Long. 76° 20' - 76° 32' E) is situated in Kollam district of Kerala, India. It occurs adjacent to the Arabian sea and along the banks of estuarine water bodies in the form of narrow patches or continuous belts. A total of 15 pure mangroves and 33 mangrove associates have been recorded from the entire coastal area of Kerala (Vidyasagaran *et al*., 2014). The mangrove ecosystem is a part of Kayamkulam estuary, which is a narrow stretch of tropical backwater on the west coast of Peninsular India. Individual studies on mangrove diversity and its faunal diversity have been conducted.

Collection and Identification

The specimens for the present study were collected from Aayiramthengu mangrove ecosystem during the months of May-August, 2022. Shell fish sampling was conducted with the help of local fishermen using cast nets and hand nets. Species were also collected from the fishermen. Hand-picking method was also been used. The length and weight of the specimen employed. Live colouration was noted in the field, and number and type of species in each capture was recorded. Photographs were also taken for further reference. The samples collected was preserved in 5% Formalin and species-level identification was done using books, monographs, reprints,etc. Crustaceans and molluscs were identified with the help of FAO (1984) and Fisher and Hureau (1985) respectively. Mangrove species of the site were also collected, identified and recorded. The conservation status of the specimen, based on IUCN criteria, was documented as per IUCN (2022). To identify any new species found in the catch, molecular studies (DNA Barcoding) were conducted. The sample tissues were collected and preserved in 75% ethanol, and submitted to Rajiv Gandhi Center for Biotechnology (RGCB), Poojappura, Thiruvananthapuram (Kerala) for DNA Barcoding.

Results and Discussion

The present study was conducted mainly to document the shellfish diversity existing in Aayiramthengu mangrove forest. Three species of bivalves belonging to the family Mytilidae, ten species of crabs under four families, twelve gastropods belonging to four families and five species of prawns under the family Penaeidae were found to occur in the study area (Table 1). A total of 30 shellfishes were collected from the mangrove forest and their IUCN status was found to be Not Evaluated (NE). Diversity among mangrove vegetations

was also analysed (Table 2). The shell fish and family-wise distribution were graphically represented in Fig. 1 & 2. Six species of mangroves were found in the study representing six different families and the IUCN status of all these mangrove vegetations were found to be of Least Concern (LC).

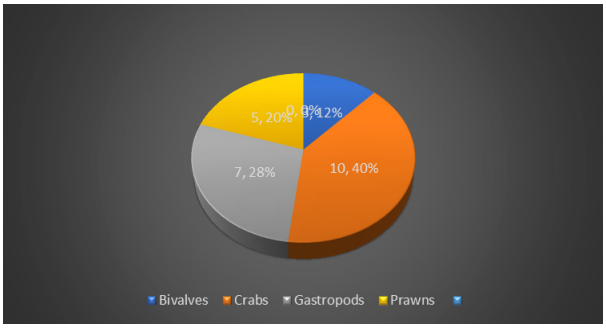

Fig. 1. Shellfish wise distribution of species

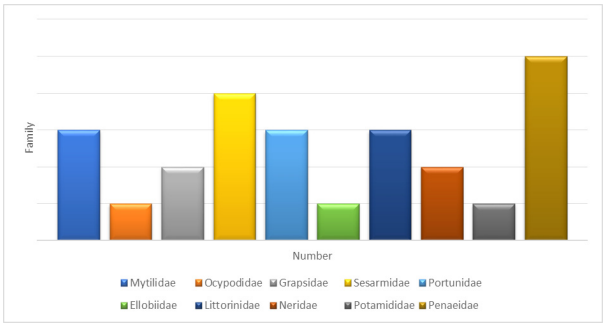

Fig. 2. Family-wise distribution of shellfishes.

One crab and one gastropod sample were difficult to identify based on their morphological characters. So, the tissue samples were collected from those specimens as per the protocol and analysed for molecular level confirmation of the species. The sequence obtained was confirmed as *Neosarmatium malabaricum* using NCBI blast analysis. DNA barcoding of partial Cytochrome C Oxidase subunit I gene resulted in a 643bp length sequence with 68% AT and 32% GC content (Fig. 3). Sequences of six species under three genera were retrieved from GenBank database of NCBI for further analysis. Upon phylogenetic analysis using maximum likelihood method based on Kimura 2-parameter model, the sequence clustered with *N. malabaricum* (267805) with a bootstrap value of 99 (Fig. 4). All the species in *Neosarmatium* genus formed a single clad with strong support. Other two genera formed a distinct group.

CAGGAATAGTTGGAACTTCATTAAGATTAATT
ATTCGAGCAGAATTAAGACAACCTGGC
AGTTTAATTGGTAATGATCAAATTTATAA
TGTAGTTGTTACAGCTCATGCATTTGTAATA
ATTTTCTTTATAGTTATACCTATTATAATT GGA
GGATTTGGTAATTGATTAGTTCCTTTAAT
GTTAGGAGCACCAGATATAGCATTCCCA
CGTATAAATAATATAAGATTTTGATTAT
TACCTCCCTCTTTATCTTTATTGTTAACAA
GAAGTATAGTTGAAAGAGGTGTTGGAACA
GGATGAACTGTGTATCCTCCTCTTGCT
GCTGCTATCGCTCACGCAGGAGCTTCTGTA
GATTTAGGAATTTTCTCACTTCAT TTAGCAG
GAGTTTCATCCATTTTAGGAGCAGTAAATTTT
ATAACAACAGTAATCAATATACGCTCTTA
TGGTATAACTATAGACCAAATACCCTTATTT
GTCTGATCAGTATTTATTACTGCCATCTTACT
TCTTTTATCACTTCCAGTTTTAGCAGGTGCTA
TTACTATACTTTTAACAGATCGTAACTTGAAT
ACATCTTTTTTTGATCCTGCTGGAGGAGGAG
ACCCTGTACTTTATCAACATTTATTTTGATTTT
TTGGTCA

Fig. 3. Sequence of partial COI gene of *N. malabaricum*

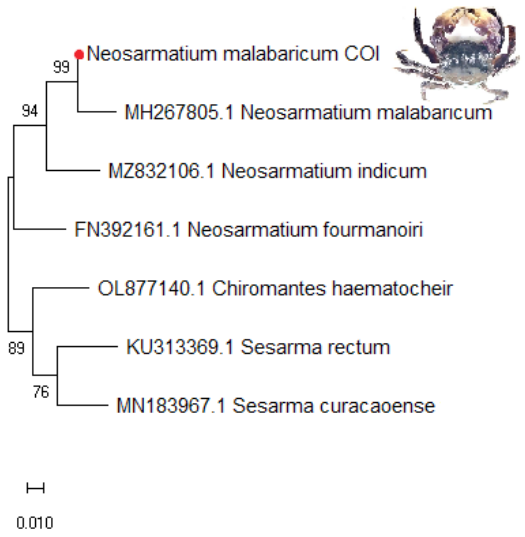

Fig. 4. Maximum likelihood tree of *N. malabaricum* using COI gene

Discussion

During the present study, a total of 30 shellfishes were collected from the mangrove forest. Diversity among mangrove vegetations was also analysed. Of the six species of mangroves observed in the area,

Table 1. Classified list of shellfishes of Aayiramthengu mangrove forest and their conservation status

Sl. No.	Scientific Name	Common name	Class	Order	Family	Conservation Status
Bivalve						
1	*Mytella strigata* (Hanley, 1843)	Charru mussel	Bivalvia	Mytilida	Mytilidae	NE
2	*Perna perna* (Linnaeus, 1758)	Indian brown mussel	Bivalvia	Mytilida	Mytilidae	NE
3	*Perna viridis* (Linnaeus, 1758)	Asian brown mussel	Bivalvia	Mytilida	Mytilidae	NE
Crabs						
4	*Austruca annulipes* (H. Milne Edwards, 1837)	Ring-legged Fiddler Crab	Malacostraca	Decapoda	Ocypodidae	NE
5	*Metopograpsus cannicci* (Innocenti, Schubart & Fratini, 2020)	-	Malacostraca	Decapoda	Grapsidae	NE
6	*Metopograpsus thukuhar* (Owen, 1839)	Alamihi crab	Malacostraca	Decapoda	Grapsidae	NE
7	*Neosarmatium malabaricum* (Henderson, 1893)	Violet mudflat crab	Malacostraca	Decapoda	Sesarmidae	NE
8	*Parasesarma pictum* (De Haan, 1835)	Mudflat crab	Malacostraca	Decapoda	Sesarmidae	NE
9	*Parasesarma plicatum* (Latreille, 1803)	Orange claw-Marsh crab	Malacostraca	Decapoda	Sesarmidae	NE
10	*Perisesarma dusumieri* (H. Milne Edwards, 1853)	Yellow- claw Mudflat crab	Malacostraca	Decapoda	Sesarmidae	NE
11	*Portunus pelagicus* (Linnaeus, 1758)	Flower crab or Sand crab	Malacostraca	Decapoda	Portunidae	NE
12	*Portunus segnis* (Forskal, 1775)	Flower crab	Malacostraca	Decapoda	Portunidae	NE
13	*Scylla serrata* (Forskål, 1775)	Giant Mud crab	Malacostraca	Decapoda	Portunidae	NE
Gastropoda						
14	*Achatina fulica* (Bowdich, 1822)	Giant African Snail	Gastropoda	Stylommatophora	Achatinidae	NE
15	*Bufonaria echinata* (Link, 1807)	spiny frog shell	Gastropoda	Littorinimorpha	Bursidae	NE
16	*Cassidula nucleus* (Gmelin, 1791)	Pulmonate snail	Gastropoda	Ellobiida	Ellobiidae	NE
17	*Littoraria intermedia* (Philippi, 1846)	Dotted periwinkles	Gastropoda	Littorinimorpha	Littorinidae	NE
18	*Littoraria pallescens* (Philippi, 1846)	Mangrove snail	Gastropoda	Littorinimorpha	Littorinidae	NE
19	*Littoraria scabra* (Linnaeus, 1758)	The mangrove periwinkle	Gastropoda	Littorinimorpha	Littorinidae	NE
20	*Littoraria undulata* (Gray, 1839)	Periwinkle or Robust Shell	Gastropoda	Littorinimorpha	Littorinidae	NE
21	*Neripteron violaceum* (Gmelin, 1791)	Red mouth nerite snail	Gastropoda	Cycloneritida	Neritidae	NE
22	*Nerita plicata* (Linnaeus, 1758)	Plicate nerite	Gastropoda	Cycloneritida	Neritidae	NE
23	*Pirenella cingulata* (Gmelin, 1791)	Girdled horn shell	Gastropoda (unassigned)	Caenogastropoda	Potamididae	NE
24	*Telescopium telescopium* (Linnaeus, 1758)	Horn Snail or Telescope Snail	Gastropoda	Caenogastropoda	Potamididae	NE
25	*Turritella attenuata* (Reeve, 1849)	sea snail	Gastropoda	Caenogastropoda	Turritellidae	NE
Prawns						
26	*Metapenaeus affinis* (H. Milne Edwards, 1837)	Jinga shrimp	Malacostraca	Decapoda	Penaeidae	NE
27	*Metapenaeus dobsoni* (Miers, 1878)	Kadal shrimp	Malacostraca	Decapoda	Penaeidae	NE
28	*Metapenaeus monoceros* (Fabricius, 1798)	Speckled shrimp	Malacostraca	Decapoda	Penaeidae	NE
29	*Penaeus indicus* (H. Milne Edwards, 1837)	Indian white prawn	Malacostraca	Decapoda	Penaeidae	NE
30	*Penaeus semisulcatus* (De Haan, 1844	Green tiger prawn or Grooved tiger prawn	Malacostraca	Decapoda	Penaeidae	NE

the IUCN status of all these mangrove vegetations were found to be Least Concern (LC). Three species of bivalves belonging to the family Mytilidae, ten species of crabs under four families, twelve species of gastropods belonging four families and five species of prawns under the family penaeidae were found to occur in the study area.

A previous study carried out by Deepthi and Reeja in 2019 on megafaunal diversity in Aayiramthengu mangrove ecosystem. In this study,

Table 2. Classified list of Mangrove species with their family and IUCN status

Sl. No.	Mangrove Species	Family	IUCN Status
1	*Acanthus ilicifolius*	Acanthaceae	Least concern
2	*Acrostichum aureum*	Ptedridaceae	Least concern
3	*Aegiceras corniculatum*	Myrsinaceae	Least concern
4	*Avicennia officinalis*	Avicenniaceae	Least concern
5	*Bruguiera gymnorhiza*	Rhizophoraceae	Least concern
6	*Excoecaria agallocha*	Euphorbiaceae	Least concern

they documented 23 species of fishes belonging to 18 families . Of the 18 families, Cichlidae has the highest representation with 3 species followed by Cyprinidae, Carangidae and Mugilidae with 2 species each. The fish fauna of Aayiramthengu mangrove is composed of marine, estuarine and freshwater fishes. This study also reported 3 species of prawns, 4 species of crabs and two species of molluscs during the study period. Many species collected from this mangrove area were juveniles of commercially important species. Another work conducted under the supervision of Nisha Thomas in 2021 on fish diversity associated with different mangrove species of the same ecosystem linked the ichthyofaunal diversity to six different mangrove species in this area. The study reported representatives of Muraenidae, Scatophagidae, Teraponidae, Batrachidae, etc., as new finds as against the usual Mugilidae, Carangidae and Cichlidae, Ambassidae, Gerreidae and Siganidae fish species, and reasoned that their presence could be due to increasing salt intrusion in the region. A checklist of brachyuran mangrove crabs from Kerala was presented by Kurian and Apreshgi with re-validaton of nomenclature since many of the crab species have been renamed so far, and no reports have been published from mangroves of Kerala. They identified a total of 18 true mangrove crabs from different mangroves associated with estuaries along the western coastline of Kerala State, of which four crab genera were renamed and revalidated. A study on mangroves and prawn diversity by Amala and Jessy in 2018 evaluated the availability of some of the prawns among mangroves such *as Fenneropenaeus indicus, Metapenaeus dobsoni, Metapenaeus affinis, Macrobranchium rosenbergii, Metapenaeus monoceros* through interview and enquiry method with local fishermen and other officials. A preliminary study on the ecology of Ayiramthengu Mangrove was conducted by Praseetha and Rajani in 2015 and they revealed the occurrence of 9 species belonging to 7 families. The mangrove species *Bruguiera cylindrica* and *Avicennia marina* were two common species identified during the study.

The species *Neosarmatium malabaricus* currently obtained from the study area revealed a difference in colour pattern upon close observation. One species was light purple coloured and the others were bright purple in colour. Assuming that it could be a mutated or a new species, DNA sequencing was performed. NCBI blast analysis confirmed that they were all *N. malabaricum*. DNA barcoding of partial Cytochrome c Oxidase subunit I gene resulted a 643bp length sequence with 68% AT and 32% GC content. Sequences of six species under three genera were retrieved from GenBank database of NCBI for further analysis. Upon phylogenetic analysis using maximum likelihood method based on Kimura 2-parameter model the sequence clustered with *N. malabaricum* (267805) with a bootstrap value of 99. All the species in *Neosarmatium* genus formed a single clad with strong support. Other two genera formed a distinct group.

The present study indicates the presence of a few new species in the study area, though most of the species obtained were previously reported. Despite this, there were some notable absentees. Though many stresses like habitat alterations, over exploitation, pollution, introduction of exotic fishes etc. may have caused a decline in fisheries of Aayiramthengu mangrove area and decline in abundance of particular species, the impact of climate change in the area calls for further observation. Moreover, the present work was unable to make any claim of local extinction of fish species.

Conclusion

Three species of bivalves belonging to the family Mytilidae, ten species of crabs under four families, twelve gastropods belonging to four families and five species of prawns under the family penaeidae were found to be occur in the study area. A total of 30 shellfishes were collected from the mangrove for-

est and their IUCN status was found to be Not Evaluated (NE). Mangrove diversity was distributed among six species belonging to six different families. The IUCN status of all these mangrove vegetations were found to be Least Concern (LC).

One crab and one gastropod sample which could not be identified on the basis of their morphological characters was analysed on a molecular level with NCBI blast analysis. Though the gastropod sample couldn't be identified, the resulted sequence of crab was confirmed as *Neosarmatium malabaricum*.

The present study indicates that there is an abundance of gastropods and crabs in the study area, but the diversity of bivalves and prawns was comparatively less. This is suggestive of the fact that the aquatic conditions may be conducive for gastropods and crabs. Whether there is a transition in habitat due to climate change needs further observation and holds much scope for future studies.

Acknowledgements

The authors are thankful to Head, PG & Research Department of Zoology, Fatima Mata National College (Autonomous), Kollam, India, for the guidance and also for providing the necessary facilities during the present work.

Conflict of Interest

The authors declare no conflict of interest.

References

Abraham, K. M. and Apreshgi, K. P. 2020. Checklist of brachyuran mangrove crabs of Kerala, India. *The Journal of Threatened Taxa (JoTT).* 17153-17159.

Amala, A. and Jessy, J. K. 2018. A Study of Mangroves and Prawn Diversity in Kavanattinkara. *International Journal of Science and Research (IJSR).* 2319-7064.

Andrews, J. 1994. Technical and Extenstion series- Central Marine Fisheries Research Institute, Cochin, India. *ISSN*. 12-17.

Ansar, C. P., Mogalekar, H. S., Sudhan, C., Chauhan, D. L., Golandaj, A. and Canciyal, J. 2017. Finfish and Shellfish diversity of Vembanad Lake in the Kumarakom region of Kottayam, Kerala, India. *Journal of Entomology and Zoology Studies.* 5(2) : 351-357.

Anu, S., Ravinesh, R., Shijith, B. V. and Kumar, B. A. 2017. Biodiversity associated with the mussel beds of Vizhinjam coast, Kerala, India. *Journal of Aquatic Biology & Fisheries | Vol. 5 |*.36-53.

Apreshgi, K.P. and Abraham, K. M. 2019. Brachyuran crab diversity in an isolated mangrove patch of the Cochin backwaters, Central Kerala, India. *Journal of Aquatic Biology & Fisheries.* 8-14.

Apreshgi, K.P. and Abraham, K. M. 2019. Brachyuran Mangrove Crab Diversity of Puthuvype Mangrove Belt, Cochin, Kerala. *Conference Paper, June 2019.*

Balasubramanian, T. and Khan, A. T. 2004. Checklist of fish fauna of Ayiramthengu mangroves, Kollam district, Kerala, India. *Environmental Information System (ENVIS).* 4-23.

Bella, K., Sahadevan, P., Sreekanth, G. B. and Raghavan, R. 2022. A checklist of fish and shellfishes of the Poonthura estuary, southwestern coast of India. *Journal of Threatened Taxa.* 21409–21420.

Bhat, M., Patel, K. J. and Trivedi, J. N. 2021. First record of MetopograpsuscannicciInnocenti, Schubart and Fratini, 2020 (Crustacea: Decapoda: Grapsidae) from India. *Journal of Animal Diversity.* 44-47.

BigDye Terminator v3.1 Cycle sequencing Kit – User Manual, Applied Biosystems

BijuKumar, A., Ravinesh, R., Oliver, P.G., Tan, S.K. and Sadasivan, K. 2019. Rapid Bio-invasion of alien mussel *Mytellastrigata* (hanley, 1843) (bivalvia: mytilidae) along Kerala coast, India: will this impact the livelihood of fishers in Ashtamudi lake? *Journal of Aquatic Biology & Fisheries. 7 :* 31-45.

BijuKumar, A., Shaji, C.P. and Laladhas, K.P. 2014. Vernacular names of freshwater fishes of kerala. *Journal of Aquatic Biology & Fisheries.* 2(1). 81-91.

Carney, J. A. 2017. Shellfish collection in Senegambian mangroves: A female knowledge system in a priority conservation region. *Journal of Ethnobiology.* 37(3): 440–457.

Dahdouh-Guebas, F., Verheyden., Genst, W. D., Hettiarachchi, S. and Koedam, N. 2000. Four decade vegetation dynamics in Sri Lankan mangroves as detected from sequential aerial photography: Acase study in Galle. *Bulletin of Marine Science.* 67(2): 741-759.

Deepthi, G.R. and Jose, R. 2019. A Study on Megafaunal Diversity in Ayiramthengu Mangrove Ecosystem, Kollam District, Kerala. *Science Chronicle - A peer reviewed Multidisciplinary Science Journal.* 8(1&2): 31-39.

Drummond, A. J., Ashton, B., Buxton, S., Cheung, M., Cooper, M., Heled, J., Kearse M., Moir, R., Stones-Havas, S., Sturrock, S., Thierer, T. and Wilson, A. 2010. Geneious v5.1, Available from http://www.geneious.com

Dutta, J., Fazli, P. and Mitra, A. 2020. Macro-benthic molluscan spectrum in three maritime eastern states and one union Territory of India. *Ela Journal of Forestry and Wildlife.* 823-834.

Edwin, S. 2002. Mangrove ecosystem biodiversity: a case study. Project work submitted to Central Institute of Fisheries Education, Deemed University, Mumbai. 25-137.

ExoSAP-IT – User Guide, GE Healthcare

FAO 1984. Species Identification Sheets for Fishery Purposes. *Food and Agricultural Organization of the United Nations.*105 Pp.

Fish Base 2022. World Wide Web electronic publication. http://www.fishbase.org.

Folmer, O., Black, M., Hoeh, W., Lutz, R. and Vrijenhoek, R. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Mol. Mar. Biol. Biotechnol.* 3: 294–299

Harshith, U. P., Apoorva, M. D., Precilla, D. S. and Anita, D. D.L. 2016. Crab diversity in mangrove and coastal ecosystem. *Conference on "Conservation and Sustainable Management of Ecologically Sensitive Regions in Western Ghats.* 360-366.

IUCN, 2011. IUCN Red list of Threatened Species.version 2011.1. (Accessed on 12.06.2012).

Jayachandran, P. R., Bijoy, N. S., Sreedevi, O. K. and Sanu, V. F. 2013. Influences of Environmental Factors on Fish Assemblage in the Tropical Estuary of South West Coast of India, A Case Study of Kodungallur Azhikode Estuary. *International Journal of Marine Science.* 3(2) : 4-16.

Jayaram, K.C. 1999. The freshwater fishes of the Indian region. 1-511.

Lakshmi, D. P., Joseph, A. and Ajmal, K. S. Diversity of Brachyuran Crabs of Cochin Backwaters, Kerala, India. *Marine Faunal Diversity.* 75-86.

Loneragan, N.R., Ahmad, A. N., Connolly, R. M., Manson, F. J. 2005. Prawn landings and their relationship with the extent of mangroves and shallow waters in western peninsular Malaysia. *Estuarine, Coastal and Shelf Science.* 63 *:* 187–200.

MacNae, W. 1974. Mangrove forests and Fisheries.*Food and Agriculture Organization of the United Nations Development Programme, Rome, August 1974.* 1-30.

Nandan, B. S. 2005. Fishery of selected prawn Species in kayamkulam backwater. Project submitted to Central Inland Fisheries Research Institute. 18-21.

Panikkaveetil, N. T. 2021. A Study of the Fish Diversity Associated with Different Mangrove Species of Ayiramthemgu Region in Kollam, Kerala, India. *Journal of Aquatic Biology & Fisheries*. 16-18.

Peter, K. L., Ravichandran, S. and Prema, M. 2019. Resurrection of Gelasimusvariegatus Heller, 1862, A Fiddler Crab Closely Related to Austrucabengali (Crane, 1975) and *A. triangularis* (A. Milne-Edwards, 1873) (Decapoda, Brachyura, Ocypodidae), from the Bay of Bengal, Indian Ocean. *Academia Sinica, Taiwan.*1-21.

Pillai, N. T. and Harilal, C.C. 2015. Status of mangrove diversity in the coastal environments of Kerala. *Eco chronicle.* 30-34.

Praseetha, T. and Rajani, V. 2015. A Preliminary Study on Ecology of Ayiramthengu Mangrove – Kollam Dist., Kerala, India. *International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 9.*335-350.

Rahees, V. V. N. and Vidyasagaran, K. 2015. Floristic diversity and structural analysis of mangrove forests at Ayiramthengu, Kollam district, Kerala. *Journal of Plant Development Sciences.* 7 (2) : 105-108.

Ranjana, V.S. and Amina, S. 2018. Zooplankton diversity of Ayiramthengu Mangrove region Kollam (dist.), Kerala. *Indian J. Sci. Res.* 20(1) : 91-95.

Rao, S., Sivalingam, D., Nair, R. and Unnithan, K. S. 1987**.** Oyster resources of Athankarai estuary, Southeast coast of India. *CMFRI Bulletin*. 16-29.

Ratheesh, N., Manoj, K. B. and Lekshmi, S. 2017. Diversity of Mangroves in Asramam, Kollam District, Kerala. *Journal of Advances in Biological Science.* 4 (1): 20-24.

Remya, A. and Amina, S. 2018. Biodiversity Status of Fishes in Kayamkulam Backwater, Kerala. *Indian J. Sci. Res.* 20(1) : 96-102.

Roger, J., Zimmerman., Thomas, Y. and Minello, J. 1985. Recruitment and Distribution of Postlarval and Early Juvenile Penaeid Shrimp in a Large Mangrove Estuary in the Gulf of Guayaquil During 1985. *International Coastal Resource Project.* 233-245.

Sahadevan, P. 2016. Diversity of fishes, Crustaceans and Molluscs of Puthuvypeen of Ernakulam District, Kerala, South India. *International Journal of Fisheries and Aquatic Studies.* 4(6): 101-107.

Saher, N. U. and Qureshi, N. A. 2011. Diversity and distribution of mangrove crabs in three intertidal areas of Balochistan, Pakistan. *Pakistan Journal of Marine Sciences.* 20(1&2) : 27-36.

Sahu, S.C., Suresh, H.S., Murthy, I.K. and Ravindranath, N.H. 2015. Mangrove Area Assessment in India: Implications of Loss of Mangroves. *ISSN: 2157-7617 JESCC, an Open Access Journal*. 1-7.

Sarker, M. N., Mitra, S., Pramanick, P., Zaman, S. and Mitra, A. 2021. Mangrove associate based shrimp feed: an innovation in the aquaculture sector. *Journal of Mechanics of Continua and Mathematical Sciences.* 43-61.

Satheeshkumar, P. 2012. Mangrove vegetation and community structure of brachyuran crabs as ecological indicators of Pondicherry coast, South east coast of India. *Iranian Journal of Fisheries Sciences.* 184-203.

Sebastian, A. and Sr. Kavumkal, J. J. 2018. A Study of Mangroves and Prawn Diversity in Kavanattinkara. *International Journal of Science and Research (IJSR).* 594-604.

Singh, A.K., Ansari, A., Kumar, D. and Sarkar, U. K. 2012. Status, Biodiversity and Distribution of Mangroves in India: An overview. *Uttar Pradesh Biodiversity Board*.

Sreelekshmi, S. 2018. Diversity, stand structure, and zonation pattern of mangroves in southwest coast of India. *Journal of Asia-Pacific Biodiversity.* 573-582.

Sreelekshmi, S., Bijeesh.,Veettil, K. S., Nandan, B. and

Harikrishnan, M. 2021. Mangrove forests along the coastline of Kerala, southern India: Current status and future prospects. *Regional Studies in Marine Science.* 1-10.

Stoner, A. L. and Zimmerman, R. J. 1988. Food pathways associated with penaeid shrimps in a mangrove-fringed estuary. *Fish. Bull.* 86 : 543–55.

Surya, S. and Hari, N. 2021. Diversity analysis and present status of Mangroves from Kerala, West Coast of India. *International Journal of Advanced and Innovative Research*. 1-14.

Vidyasagaran, K. and Madhusoodanan, V. K. 2014. Distribution and plant diversity of mangroves in the west coast of Kerala, India. *Journal of Biodiversity and Environmental Sciences (JBES)*.38-44.

World Register of Marine Species (WORMS).