

Building evidence for conservation globally

# Journal of Threatened TAXA



Open Access

10.11609/jott.2024.16.9.25791-25950

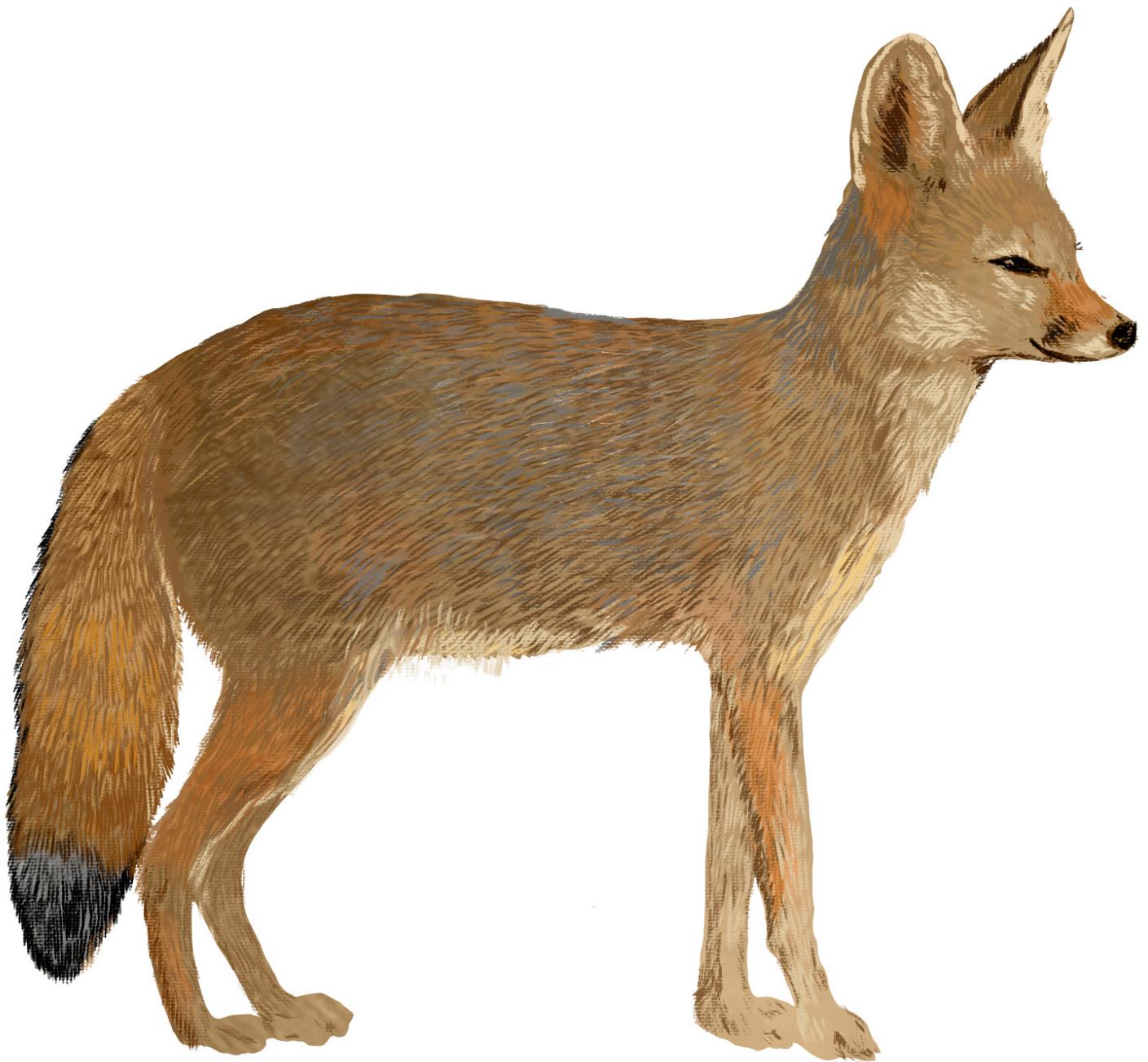
[www.threatenedtaxa.org](http://www.threatenedtaxa.org)

26 September 2024 (Online & Print)

16(9): 25791-25950

ISSN 0974-7907 (Online)

ISSN 0974-7893 (Print)





## Publisher

**Wildlife Information Liaison Development Society**[www.wild.zooreach.org](http://www.wild.zooreach.org)

Host

**Zoo Outreach Organization**[www.zooreach.org](http://www.zooreach.org)

43/2 Varadarajulu Nagar, 5<sup>th</sup> Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India  
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India  
Ph: +91 9385339863 | [www.threatenedtaxa.org](http://www.threatenedtaxa.org)  
Email: sanjay@threatenedtaxa.org

## EDITORS

## Founder &amp; Chief Editor

**Dr. Sanjay Molur**Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO),  
43/2 Varadarajulu Nagar, 5<sup>th</sup> Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India

## Deputy Chief Editor

**Dr. Neelesh Dahanukar**

Noida, Uttar Pradesh, India

## Managing Editor

**Mr. B. Ravichandran**, WILD/ZOO, Coimbatore, Tamil Nadu 641006, India

## Associate Editors

**Dr. Mandar Paingankar**, Government Science College Gadchiroli, Maharashtra 442605, India**Dr. Ulrike Streicher**, Wildlife Veterinarian, Eugene, Oregon, USA**Ms. Priyanka Iyer**, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

## Editorial Board

**Dr. Russel Mittermeier**

Executive Vice Chair, Conservation International, Arlington, Virginia 22202, USA

**Prof. Mewa Singh Ph.D., FASc, FNA, FNASC, FNAPsy**Ramanna Fellow and Life-Long Distinguished Professor, Biopsychology Laboratory, and  
Institute of Excellence, University of Mysore, Mysuru, Karnataka 570006, India; Honorary  
Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; and Adjunct  
Professor, National Institute of Advanced Studies, Bangalore**Stephen D. Nash**Scientific Illustrator, Conservation International, Dept. of Anatomical Sciences, Health Sciences  
Center, T-8, Room 045, Stony Brook University, Stony Brook, NY 11794-8081, USA**Dr. Fred Pluthero**

Toronto, Canada

**Dr. Priya Davidar**

Sigur Nature Trust, Chadapatti, Mavinhalia PO, Nilgiris, Tamil Nadu 643223, India

**Dr. John Fellowes**Honorary Assistant Professor, The Kadoorie Institute, 8/F, T.T. Tsui Building, The University of  
Hong Kong, Pokfulam Road, Hong Kong**Prof. Dr. Mirco Solé**Universidade Estadual de Santa Cruz, Departamento de Ciências Biológicas, Vice-coordenador  
do Programa de Pós-Graduação em Zoologia, Rodovia Ilhéus/Itabuna, Km 16 (45662-000)  
Salobrinho, Ilhéus - Bahia - Brasil**Dr. Rajeev Raghavan**

Professor of Taxonomy, Kerala University of Fisheries &amp; Ocean Studies, Kochi, Kerala, India

## English Editors

**Mrs. Mira Bhojwani**, Pune, India**Dr. Fred Pluthero**, Toronto, Canada**Mr. P. Ilangovan**, Chennai, India**Ms. Sindhura Stothra Bhashyam**, Hyderabad, India

## Web Development

**Mrs. Latha G. Ravikumar**, ZOO/WILD, Coimbatore, India

## Typesetting

**Mrs. Radhika**, ZOO, Coimbatore, India**Mrs. Geetha**, ZOO, Coimbatore India

## Fundraising/Communications

**Mrs. Payal B. Molur**, Coimbatore, India

## Subject Editors 2021–2023

## Fungi

Dr. B. Shivaraju, Bengaluru, Karnataka, India

Dr. R.K. Verma, Tropical Forest Research Institute, Jabalpur, India

Dr. Vatsavaya S. Raju, Kakatiya University, Warangal, Andhra Pradesh, India

Dr. M. Krishnappa, Jnana Sahyadri, Kuvempu University, Shimoga, Karnataka, India

Dr. K.R. Sridhar, Mangalore University, Mangalagangotri, Mangalore, Karnataka, India

Dr. Gunjan Biswas, Vidyasagar University, Midnapore, West Bengal, India

Dr. Kiran Ramchandra Ranadive, Annasaheb Magar Mahavidyalaya, Maharashtra, India

## Plants

Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India

Dr. N.P. Balakrishnan, Ret. Joint Director, BSI, Coimbatore, India

Dr. Shonil Bhagwat, Open University and University of Oxford, UK

Prof. D.J. Bhat, Retd. Professor, Goa University, Goa, India

Dr. Ferdinand Boero, Università del Salento, Lecce, Italy

Dr. Dale R. Calder, Royal Ontario Museum, Toronto, Ontario, Canada

Dr. Cleofas Cervancia, Univ. of Philippines Los Baños College Laguna, Philippines

Dr. F.B. Vincent Florens, University of Mauritius, Mauritius

Dr. Merlin Franco, Curtin University, Malaysia

Dr. V. Irudayaraj, St. Xavier's College, Palayamkottai, Tamil Nadu, India

Dr. B.S. Kholia, Botanical Survey of India, Gangtok, Sikkim, India

Dr. Pankaj Kumar, Department of Plant and Soil Science, Texas Tech University, Lubbock, Texas, USA

Dr. V. Sampath Kumar, Botanical Survey of India, Howrah, West Bengal, India

Dr. A.J. Solomon Raju, Andhra University, Visakhapatnam, India

Dr. Vijayasanchari Raman, University of Mississippi, USA

Dr. B. Ravi Prasad Rao, Sri Krishnadevaraya University, Anantapur, India

Dr. K. Ravikumar, FRLHT, Bengaluru, Karnataka, India

Dr. Aparna Watve, Pune, Maharashtra, India

Dr. Qiang Liu, Kishuangbanna Tropical Botanical Garden, Yunnan, China

Dr. Noor Azhar Mohamed Shazili, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia

Dr. M.K. Vasudeva Rao, Shiv Ranjani Housing Society, Pune, Maharashtra, India

Prof. A.J. Solomon Raju, Andhra University, Visakhapatnam, India

Dr. Mander Datar, Agharkar Research Institute, Pune, Maharashtra, India

Dr. M.K. Janarthanan, Goa University, Goa, India

Dr. K. Karthigeyan, Botanical Survey of India, India

Dr. Errol Vela, University of Montpellier, Montpellier, France

Dr. P. Lakshminarasimhan, Botanical Survey of India, Howrah, India

Dr. Larry R. Noblick, Montgomery Botanical Center, Miami, USA

Dr. K. Haridasan, Pallavur, Palakkad District, Kerala, India

Dr. Analinda Manila-Fajard, University of the Philippines Los Baños, Laguna, Philippines

Dr. P.A. Sinu, Central University of Kerala, Kasaragod, Kerala, India

Dr. Afroz Alam, Banasthali Vidyapith (accredited A grade by NAAC), Rajasthani, India

Dr. K.P. Rajesh, Zamorin's Guruvayurappan College, GA College PO, Kozhikode, Kerala, India

Dr. David E. Boufford, Harvard University Herbaria, Cambridge, MA 02138-2020, USA

Dr. Ritesh Kumar Choudhary, Agharkar Research Institute, Pune, Maharashtra, India

Dr. A.G. Pandurangan, Thiruvananthapuram, Kerala, India

Dr. Navendu Page, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, India

Dr. Kannan C.S. Warrier, Institute of Forest Genetics and Tree Breeding, Tamil Nadu, India

## Invertebrates

Dr. R.K. Avasthi, Rohtak University, Haryana, India

Dr. D.B. Bastawade, Maharashtra, India

Dr. Partha Pratim Bhattacharjee, Tripura University, Suryamaninagar, India

Dr. Kailash Chandra, Zoological Survey of India, Jabalpur, Madhya Pradesh, India

Dr. Ansie Dippenaar-Schoeman, University of Pretoria, Queenswood, South Africa

Dr. Rory Dow, National Museum of Natural History Naturalis, The Netherlands

Dr. Brian Fisher, California Academy of Sciences, USA

Dr. Richard Gallon, Ilandudno, North Wales, LL30 1UP

Dr. Hemant V. Ghate, Modern College, Pune, India

Dr. M. Monwar Hossain, Jahangirnagar University, Dhaka, Bangladesh

Mr. Jatishwar Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.

Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK

Dr. George Mathew, Kerala Forest Research Institute, Peechi, India

For Focus, Scope, Aims, and Policies, visit [https://threatenedtaxa.org/index.php/JoTT/aims\\_scope](https://threatenedtaxa.org/index.php/JoTT/aims_scope)For Article Submission Guidelines, visit <https://threatenedtaxa.org/index.php/JoTT/about/submissions>For Policies against Scientific Misconduct, visit [https://threatenedtaxa.org/index.php/JoTT/policies\\_various](https://threatenedtaxa.org/index.php/JoTT/policies_various)

continued on the back inside cover

Cover: Bengal Fox *Vulpes bengalensis*—digital illustration. © Alagu Raj.



## Habitat heterogeneity and taxonomic diversity of fish fauna in estuaries: a study from southern Sri Lanka

Kirivithanage Sandun Nalaka Bandara 

Department of Zoology, Faculty of Natural Sciences, The Open University of Sri Lanka, Nawala, Nugegoda 11222, Sri Lanka.

Department of Zoology, Faculty of Science, University of Ruhuna, Matara 81000, Sri Lanka.

[kvban@ou.ac.lk](mailto:kvban@ou.ac.lk)

**Abstract:** A survey was conducted to identify fish fauna related to the dominant habitats, viz., (i) Honduwa Lake (stagnate water), (ii) estuarine area with mangroves, (iii) freshwater marshy area with floating aquatic vegetation, (iv) canals, and (v) river, in the Dedduwa estuary of southern Sri Lanka. Thirty-nine species of fish including two endemics (to the island) were identified, including members of major migratory families such as Anguillidae and Megalopidae. Based on the abundance of species, the Bray-Curtis similarity index indicated a clear separation of the canal and freshwater marsh, with other studied areas. Similarly, the taxonomic diversity of the canal and freshwater marsh was high, indicating high variation and diversity of the species and genera. Protection of mangroves and related habitats is important to maintain the stability and long-term existence of fish fauna in the estuary. Effective monitoring is proposed for detecting and eliminating illegal encroachments, mangrove clearance, and illegal fishing activities. Moreover, improving the knowledge and awareness among members of the local community, politicians, and environment officers about the importance of the region's biodiversity implementing strong policies, and creating a strong responsible stakeholder bond are required to ensure the long-term sustainability of the estuary.

**Keywords:** Brackishwater, catadromy, conservation, fish diversity, fish migration, mangroves, taxonomic distinctness.

**Editor:** Mandar Paingankar, Government Science College Gadchiroli, Maharashtra, India.

**Date of publication:** 26 September 2024 (online & print)

**Citation:** Bandara, K.S.N. (2024). Habitat heterogeneity and taxonomic diversity of fish fauna in estuaries: a study from southern Sri Lanka. *Journal of Threatened Taxa* 16(9): 25816–25830. <https://doi.org/10.11609/jott.7832.16.9.25816-25830>

**Copyright:** © Bandara 2024. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

**Funding:** This study was funded by the Environment Foundation (Guarantee) Limited, Sri Lanka under the fauna and flora study for Dedduwa development project.

**Competing interests:** The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Author details:** DR. SANDUN BANDARA is a senior lecturer in the Department of Zoology at the Open University of Sri Lanka. He is keen on aquatic ecology, fisheries biology, life history strategies of fishes and conservation biology. Currently, he is the senior coordinator of the course unit 'Ecology' in the department.

**Acknowledgements:** I would like to acknowledge Ms. Zaineb Akbarally and Ms. Chaturangi Wickramaratne of the Environment Foundation (Guarantee) Limited for their cooperation and support extended to this study. I am also thankful to Prof. U. S. Amarasinghe, Prof. Sevvandi Jayakody, Dr. Suranjan Fernando, Dr. Kumudu P. Kopiyawattage and Ms. Achini Wathsala for their valuable comments in preparing this manuscript.



## INTRODUCTION

Estuaries are considered one of the most productive coastal ecosystems in the tropics (Whittaker & Likens 1975; Whitfield & Elliott 2011; Sreekanth et al. 2017). Ecologically, estuaries are highly significant as they provide critical ecosystem services including coastal protection (Barbier 2020), carbon sequestration (Douglas et al. 2022; Das et al. 2023), sediment filtration (Schubel & Carter 1984; Teuchies et al. 2013), and habitat enrichment (Cardoso 2021; Denis et al. 2022). These ecosystem services are essential in sustaining the coastal biodiversity and well-being of aquatic taxa (Cardoso 2021). Among the various ecological services, the most significant is habitat provisioning and maintaining ecosystem integrity in coastal environments (Blaber et al. 1989; Sreekanth et al. 2020). Estuaries form a transition zone between river and maritime environments and are hence always influenced by tidal fluctuation and freshwater fluxes (Potter et al. 2010). These heterogenous physico-chemical changes featured unique and variable habitat formations such as mangroves, shallow open waters, freshwater and saltwater marshes, swamps, sandy beaches, mud and sand flats, rocky shores, river deltas, tidal pools, and seagrass beds enhancing the habitat complexity and species composition in estuaries (Hagan & Able 2003). The diversified habitats in the estuaries are known to provide nurseries and feeding grounds for fish essentially for larval stages (Potter et al., 2013; Guerreiro et al. 2021). Therefore, estuaries provide refuges for a wide variety of fishes including both marine and freshwater species to complete their life cycles (Blaber et al. 1989; Whitfield & Elliott 2002; Elliott et al. 2007).

Distribution of fishes in an estuary is fundamentally determined by habitat heterogeneity, prey predator relationship, and water chemistry (Jackson et al. 2001; Maes et al. 2005; Kadye et al. 2008; Sreekanth et al. 2020). The productivity of the habitats is equally important to determine the dietary compositions of fishes (Hagan & Able 2003). The climatic fluctuations and changes in precipitation determine the level of productivity (e.g., accumulation of autochthonous and allochthonous nutrients) and trophic relationship among fishes (Gillanders et al. 2011; Sreekanth et al. 2019). The lowland reaches of rivers are characterized by high levels of suspended solids inducing high turbidity (Cyrus & Blaber 1987). Hence, productivity is largely determined by the nutrient loads from the upper reaches of the river. In the freshwater–seawater transition zone, these particles are effectively ‘trapped’ due to flocculation and converging suspended sediment fluxes

(Kranck 1981). River mouths, estuaries, or transitional waters represent the transition between freshwater and marine environments and are influenced by both aquatic realms (Robinson et al. 1999). This makes estuaries unique ecosystems with a range of salinity gradients, from freshwater to seawater in addition to lentic and lotic habitats (Ruhl 2013). Fish species with the ability to tolerate huge salinity gradients can be identified in these various habitats and microhabitats (Barletta et al. 2005; Breine et al. 2011). Hence, species richness in estuaries is commonly dominated by marine species (Whitfield 1999; Franco et al. 2008). Moreover, fishes show migration between estuaries and other ecosystems and are also benefited by the estuaries markedly in larval development and predator avoidance (Dando 1984; Leggett 1984).

Estuaries in Sri Lanka are highly characterized by the variability in size, shape, configuration, ecohydrology, and tidal fluxes (Miththapala 2013). These wetlands cover approximately 93,075 ha in Sri Lanka’s coastal zone (Department of Coast Conservation and Coastal Resource Management 2018). Though these ecosystems provide important habitats for fish taxa, proper ecological studies are scarce to determine the pattern of fish assemblages associated with the various habitats. Ministry of Forestry and Environment (1999) reported 53 fish species in mangrove ecosystems in Sri Lanka. Estuaries a highly dynamic ecosystems, and these facts provide essential evidence to determine conservation priorities in coastal environment management. These mangrove and estuarine areas are increasingly subjected to degradation due to anthropic interventions including tourism, sewage disposal, the introduction of exotic species, and river diversions (Samarakoon & Samarawickrama 2012; Miththapala 2013). Therefore, these ecosystems are particularly important for integrating sound ecological management with sustainable economics (Meire et al. 2005). Hence, the current study was conducted to understand the common characteristics of habitat heterogeneity and fish faunal assemblages associated with estuarine ecosystems.

## MATERIALS AND METHODS

### Study area

Dedduwa estuary is fed by the Bentota River and is situated in the southwestern part of Sri Lanka. Ecologically, the Dedduwa estuary is remarkably important as it comprises diversified mangroves and

related estuarine habitats, which provide essential living environments for assemblages of fauna and flora. The study area is approximately 8 km<sup>2</sup> (Figure 1) and consists of five different types of habitats, viz.: (i) 'Honduwa' Lake (lentic), (ii) marshy area with associate aquatic vegetation, (iii) mangroves, (iv) canals, and (v) river. The Honduwa area is characterized by stagnant saline water (approximately 0.95 km<sup>2</sup>). There are two major canals connected to Honduwa; one runs through the inland and connects to the estuary and the other is from the estuary to the sea. Therefore, the Honduwa

Lake often experiences the gradients of salinity fluctuation. The maximum depth is approximately 2.1 m. *Sonneratia caseolaris* and *Rhizophora apiculata* are the most dominant mangroves in the area with other associates such as *Dillenia suffruticosa*, *Derris trifoliate*, and *Acrostichum aureum*. The marshy area is approximately 0.1 km<sup>2</sup>. This area contains open water with floating aquatic vegetation. Most of the open water area is covered by aquatic vegetation such as *Aponogeton crispus*, *Pistia stratiotes*, *Ceratophyllum demersum*, *Ipomoea aquatica*, *Hydrilla verticillata*,

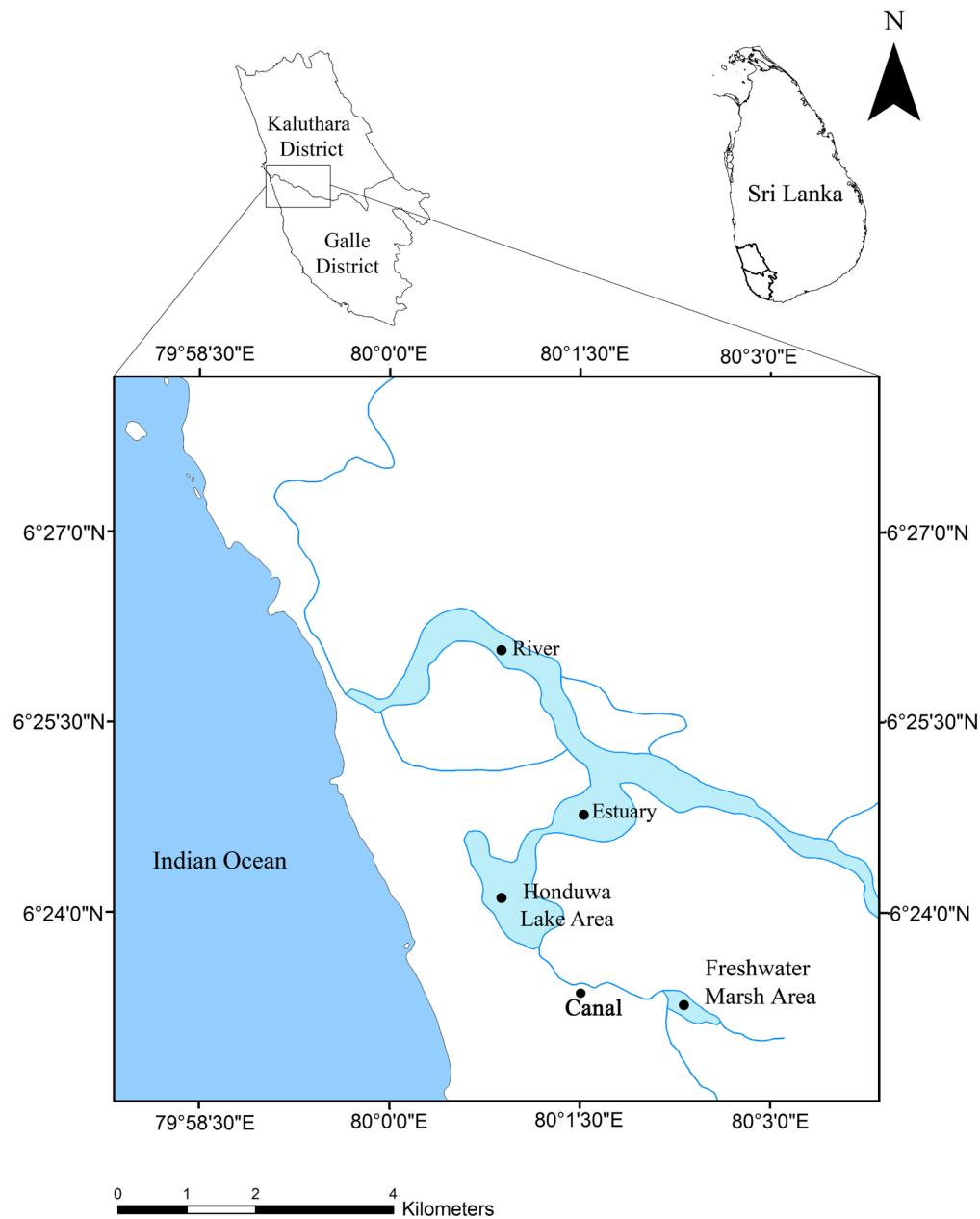


Figure 1. Location of Dedduwa estuary, Sri Lanka. The different sites surveyed for the fish fauna are also marked.

*Utricularia aurea*, *Nymphaeidae* spp., *Nymphaea* spp., *Eichhornia crassipes*, and *Salvinia molesta*. The floating and marginal vegetation provide vital refugees for aquatic invertebrates. Hence, this marshy area is rich with wetland ichthyofauna. Some areas are entirely infested with invasive aquatic plants like *Salvinia molesta* and submerged during the rainy period. Therefore, the abundance of aquatic fauna possibly shows great fluctuations year-round. Water pools with aquatic weeds provide good nursery grounds for small fishes. This area is highly influenced by human alterations. Hence, associated vegetation has been invaded by invasive plants such as *Annona glabra* and *Typha angustifolia*. The marsh located next to Honduwa Lake (see Figure 1) is approximately 0.86 km<sup>2</sup> in extent. This area contains mixed vegetation of mangroves and freshwater aquatic plants. Most of the area has open water and is probably ideal for euryhaline fish species. Much of the riparian vegetation is densely covered by alien *D. suffruticosa* which provides a shady environment for aquatic fauna. A patchy distribution of mangroves can be seen in the marginal areas and provide nursery grounds for various fish species. The canal contains slow-moving water. Due to less salinity compared to the estuary or river mouth and high turbulence, this water may provide proper living environments for rheophilic freshwater species and anadromous fishes. The canal extends for 2.19 km and most of the area is covered by mangroves. This is an important migratory pathway for both marine and brackish water fish species and is highly influenced by tidal fluctuations. Mixed vegetation with several species of mangrove (e.g., the considerable distribution of *Nypa fruticans*) and mangrove associates can be seen in the area.

#### Data collection

Fish samples were collected from September to October 2019 in each of the five sites using a dragnet of the dimension of 1.5 x 1.5 m with a 2 mm mesh size. Although some other sampling methods such as gillnets cast nets and traps were also used, the data collected from those sampling methods were excluded from analysis due to the inconsistency of the samplings. Every accessible location with different biological (e.g., different vegetation types) and physical characteristics (e.g., in different water depths and flow rates) was surveyed, and data were collected for the analysis. Altogether 117 samples were collected for the analysis covering all the habitat types (Table 1). The number of individuals of different species caught in every sampling effort was recorded separately. The anthropogenic

activities that were carried out at each sampling site were observed such as disposal of sewage and fishing activities. Also, the abundance of microhabitat types was noted in different segments of the river and estuary (see Table 5 in the results section).

#### Diversity indices

The diversity of fish in each site was estimated using the following different methods in Primer V.5.2.2 software (Clark & Warwick 2001).

i. Shannon-Wiener index (H') (Shannon 1948)

$$H = - \sum p_i \ln p_i$$

where  $p_i$  = the proportion of species  $i$  relative to the total number of species

ii. Margalef diversity index (d) (Margalef 1958)

$$d = \frac{S - 1}{\ln N}$$

where S is the number of species, and N is the total number of individuals in the sample.

iii. Brillouin index (Brillouin 1956), HB, was calculated using:

$$HB = \frac{\ln N - \sum_{i=1}^s \ln n_i}{N}$$

where N is the total number of individuals in the sample,  $n_i$  is the number of individuals belonging to the  $i^{th}$  species, and s is the species number. The Brillouin index measures the diversity of a collection, as opposed to the Shannon index which measures a sample.

iv. Fisher's alpha, S (Fisher et al. 1943)

This is a parametric index of diversity given below assumes that the abundance of species follows the In series distribution:

$$\frac{S}{N} = \frac{(1-x)}{x[-\ln(1-x)]}$$

where S is the number of taxa, N is the number of individuals

$$\alpha = \frac{N(1-x)}{x}$$

where  $\alpha$  the diversity index

v. Simpson index, D (Simpson 1949)

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

where N is the total number of individuals in the sample, and n is the number of individuals belonging to a certain species. It measures the 'evenness' of the community ranging from 0 to 1.

vi. Pielou's evenness index (J) (Pielou 1969, 1975)

$$J = H/\log(S)$$

If H is the observed Shannon-Wiener index, the maximum value this could take is  $\log(S)$ , where S is the total number of species in the habitat.

**Table 1. Summary of the sampling efforts of five different aquatic habitats in the Dedduwa estuary, Sri Lanka.**

Habitat	Total number of samples
Honduwa Lake area	27
Estuarine area	24
Canal area	32
Rivermouth	15
Mashy area with floating aquatic vegetation	19

### Taxonomic distinctness tests

To determine the taxonomic distance the following approach was adopted. Species were classified to all major taxonomic levels in a Linnean classification following the taxonomy of the fauna (Beesley et al. 1998). A constant path length ( $\omega = 1$ ) between levels was used to calculate the taxonomic distance between species pairs (Warwick & Clarke 1995). Average Taxonomic Distance (AvTD) was calculated using presence/absence data from each site. Using each separate dataset, taxonomic distinctness was quantified using the TAXDTEST procedure in the PRIMER-V.5.2.2 software package (Clarke & Warwick 2001). The 'variation in taxonomic distinctness' [VarTD, Lambda (+)] between every pair of species recorded in a study. It matches the previously defined 'average taxonomic distinctness' [AvTD, Delta (+)], which is the mean path length through the taxonomic tree connecting every pair of species in the list. VarTD is simply the variance of these pairwise path lengths and reflects the unevenness of the taxonomic tree. Samples from the master list were used to generate an expected distribution of values, including a mean and 95% confidence interval. The expected distribution was represented visually as a funnel plot, showing values for different numbers of species, and the observed values were overlaid on the plot. This was used to test the null hypothesis that each observed value had the same value as one predicted using the master list, rejected at the 5% significance level (Clarke & Warwick 2001; Smith & Rule 2002), i.e., sites falling outside the 95% confidence limits were interpreted as having an AvTD value significantly lower (or higher) than expected.

### Comparative analysis of ichthyofaunal diversity and abundance

To compare the diversity and abundance of fish in each habitat type, the mean abundance data of each species were used. The similarities of fish communities among sampling sites were determined by the Bray-Curtis similarity coefficient (Bray & Curtis 1957). The

In (x+1) transformation was used before analysis due to the presence of zero values. The ordination of non-metric Multidimensional Scaling (MDS) of sampling sites was determined based on the Bray-Curtis similarity matrix (Clarke & Warwick 2001) using the PRIMER-5 software package (Version 5.2.2). Bray-Curtis similarity analysis was done by using two different approaches. One approach was the analysis performed by separating abundance data for the different species into the five habitat types identified (Table 1) and the second approach was considering all the sampling locations as a single data set and freely clustered it according to the similarity of species composition in each location.

## RESULTS

Altogether 41 species of fish were identified including marine, true estuarine, and freshwater species (Table 2). A higher number of species was recorded at the Honduwa Lake and the estuary (18 species in each habitat) while the lowest (12 species) was recorded associated with the river (Table 4). Of these, *Clarias brachysoma* and *Horadandia atukorali* were the endemic freshwater species identified. Species namely *Oryzias dancena*, *Etroplus suratensis*, *Ambassis ambassis*, *Butis butis*, and *Bhava vittatus* were identified in all five different habitat types (Table 2). The results of the present study did not show any dominant group in the assemblage. In Honduwa Lake, estuary, and river the most dominant species were *Ambassis ambassis*, *Butis butis*, *O. dancena*, and *Etroplus suratensis* contributing 88.4%, 77.9%, and 74.5 % in abundance respectively (Figure 2). The most abundant species in freshwater marsh habitats were *Horadandia atukorali* (42.3%) and in the canal area was *Ehirava fluviatilis* (29%) (Figure 2). The occurrence of dominant species in saline waters (e.g., estuarine area and Honduwa Lake) showed approximately a similar pattern in abundance. Comparing saline habitats with freshwater habitats (e.g. marsh with aquatic vegetation) a remarkable difference in patterns of species dominance was observed (Figure 2).

When the Bray-Curtis similarity index based on the abundance of fish species is considered, the freshwater marshy habitat was separated from other sampling sites at about the 28.9% level of similarity (Figure 3). The similarity level of fish abundance in the canal area with Honduwa Lake is approximately 51.2% (Figure 3). Also, the canal area with Honduwa Lake further separated from the rest of the sampling sites in the MDS ordination

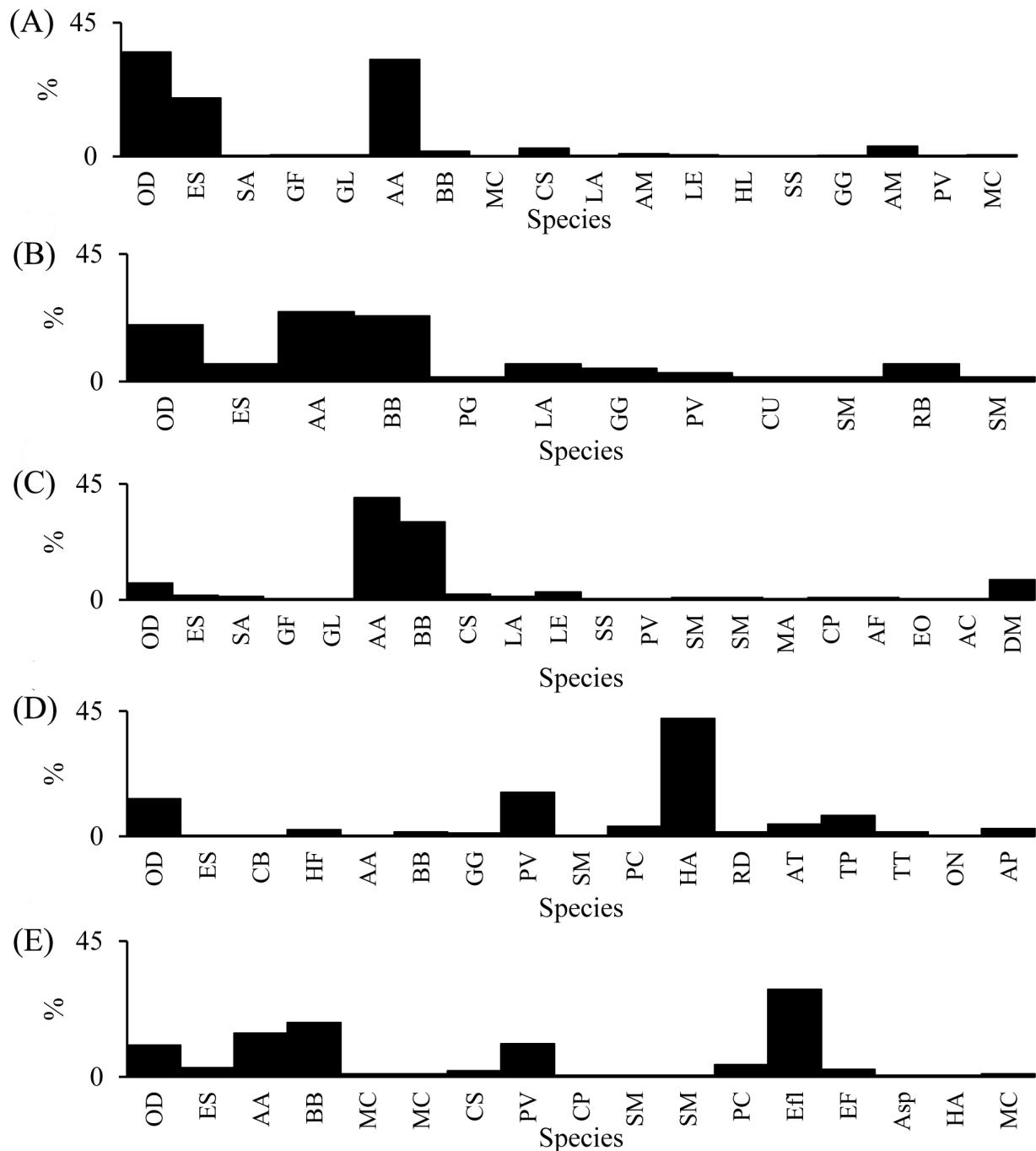


Figure 2. Relative abundance of identified fish species in five habitats studied in the Dedduwa Estuary, Sri Lanka: A—Honduwa Lake | B—River | C—Estuarine area | D—Freshwater Marshy habitat | E—Canal. Abbreviations of the species are given in Table 2.

(Figure 4). The diversity indices Shanon, Brillouin, and Simpson showed the highest diversity in river and canal habitats. Margalef index showed the highest species richness in estuarine habitats. The evenness of the species is approximately high in estuary and canal (Table 3).

The Bray Curtis similarity analysis for the species abundance of different habitats indicated five

distinct clusters in a 25% similarity level (Figure 5). It differentiates the freshwater marsh and the canal into a single cluster (I) possibly due to the similarity of habitat choices of freshwater fishes associated with the two areas (e.g., low salinity). Honduwa Lake, canal, estuary, and some sampling locations in the river are grouped into a single cluster at 20% similarity level. As majority of the species in these four habitats are common except a

**Table 2. Checklist of ichthyofauna recorded from the different habitats in the Dedduwa estuary, Sri Lanka. Endemic species are mentioned in bold letters. The migratory habit of relevant fishes is also mentioned as superscripted abbreviations after the scientific name. All the abbreviations are explained after the table.**

Family	Scientific name (abbreviation)	Common name	Conservation status				Habitats			Salinity range		Source
			NCS	GCS	HLH	ES	RI	FWM	CN			
1. Adrianichthyidae	<i>Oryziás dánena</i> (OD)	Rice fish	NE	LC	+	+	+	+	+	Polyhaline	Roberts 1998	
2. Ambassidae	<i>Ambassis ambassis</i> <sup>Ind.</sup> (AA)	Commoner's glassy	NE	LC	+	+	+	+	+	Polyhaline	Fricke 1999	
3. Anabantidae	<i>Anabas testudineus</i> <sup>Ind.</sup> (AT)	Climbing perch	LC	LC					+	Mesohaline	Talwar and Jhingran 1991	
4. Anguillidae	<i>Anguilla</i> spp. <sup>cat.</sup> (AS)	Eel							+	Polyhaline	Kottelat 2013	
5. Aplochelidae	<i>Aplochelius parvus</i> (AP)	Dwarf panchax	LC	LC				+		Mesohaline	Seegers 1997	
6. Ariidae	<i>Arius maculatus</i> <sup>Ind.</sup> (AM)	Spotted catfish	NE	NE	+					Polyhaline	Kailola 1999	
7. Carangidae	<i>Caranx sexfasciatus</i> <sup>Ampl.</sup> (CS)	Bigeye trevally	NE	LC	+	+	+	+	+	Polyhaline	Paxton 1989	
8. Channidae	<i>Channa punctata</i> <sup>Ind.</sup> (CP)	Spotted snakehead	LC	LC				+		Mesohaline	Pethiyagoda 1991	
9. Channidae	<i>Channa striata</i> <sup>Ind.</sup> (CS)	Striped snakehead	LC	LC				+	+	Mesohaline	Pethiyagoda 1991	
10. Cichlidae	<i>Eretmodus suratensis</i> (ES)	Pearl spot	LC	LC	+	+	+	+	+	Mesohaline	Pethiyagoda 1991	
11. Cichlidae	<i>Oreochromis niloticus</i> <sup>Ind.</sup> (ON)	Nile tilapia	EX	LC		+	+			Mesohaline	Trewavas 1983	
12. Clariidae	<i>Clarias brachysoma</i> * (CB)	Walking catfish	VU	NE				+		Oligohaline	Pethiyagoda 1991	
13. Clupeidae	<i>Anodontostoma chacunda</i> <sup>Ampl.</sup> (AC)	Chacunda gizzard shad	NE	LC	+					Polyhaline	Whitehead 1985	
14. Clupeidae	<i>Davidiella malabarica</i> <sup>Ampl.</sup> (DM)	Day's round herring	NE	LC	+					Polyhaline	Whitehead 1985	
15. Clupeidae	<i>Ehirava fluviatilis</i> <sup>Ampl.</sup> (EF)	Malabar sprat	NE	LC					+	Polyhaline	Whitehead 1985	
16. Cyprinidae	<i>Plesiotpuntius bimaculatus</i> (PB)	Redside barb	LC	LC				+		Oligohaline	Pethiyagoda 1991	
17. Cyprinidae	<i>Bhava vittatus</i> (PV)	Silver barb	LC	LC	+	+	+	+	+	Mesohaline	Pethiyagoda 1991	
18. Cyprinidae	<i>Rasbora dandia</i> (RD)	Broadline striped rasbora	LC	LC				+		Oligohaline	Silva et al. 2010	
19. Cyprinidae	<i>Horadandia atukorai</i> * (HA)	Green carplet	VU					+	+	Mesohaline	Pethiyagoda 1991	
20. Eleotridae	<i>Butis butis</i> <sup>Ampl.</sup> (BB)	Duckbill sleeper	NE	LC	+	+	+	+	+	Polyhaline	Hoese 1986	
21. Eleotridae	<i>Eleotris fusca</i> <sup>Ampl.</sup> (EF)	Dusky sleeper	NE	LC				+		Polyhaline	Maugé 1986a	
22. Gerreidae	<i>Gerres filamentosus</i> <sup>Ampl.</sup> (GF)	Whipfin silver-biddy	NE	LC	+	+				Polyhaline	Woodland 1984	
23. Gerreidae	<i>Gerres limbatus</i> <sup>Ampl.</sup> (GL)	Saddleback silver-biddy	NE	LC	+	+				Polyhaline	Iwatsuki et al. 2001	
24. Gobiidae	<i>Glossogobius giuris</i> <sup>Ampl.</sup> (GG)	Tank goby	LC	LC	+	+	+	+		Polyhaline	Maugé 1986b	
25. Gobiidae	<i>Caragobius urolepis</i> <sup>Ampl.</sup> (CU)	Scaleless worm goby	NE	LC	+	+				Mesohaline	Kottelat et al. 1993	
26. Gobiidae	<i>Oligolepis cf. acutipennis</i> <sup>Ampl.</sup> (OA)	Sharptail goby	NE	LC						Polyhaline	Maugé 1986b	
27. Gobiidae	<i>Gobius malabaricus</i> <sup>Ampl.</sup> (GM)	Malabar goby	NE	LC		+	+			Polyhaline	Maugé 1986b	
28. Hemirhamphidae	<i>Hemirhamphus limbatus</i> <sup>Ind.</sup> (HL)	Congaturi halfbeak	NE	LC	+					Polyhaline	Collette and Su 1986	
29. Heteropneustidae	<i>Heteropneustes fossilis</i> (HF)	Asian stinging catfish	LC	LC				+		Mesohaline	Rainboth 1994	

Family	Scientific name (abbreviation)	Common name	Conservation status	Habitats				Salinity range		Source
			NCS	GCS	HLH	ES	FWM	CN		
30.	Leiognathidae	<i>Leiognathus equulus</i> Amp. (LE)	Common ponyfish	NE	LC	+			Polyhaline	James 1984
31.	Lutjanidae	<i>Lutjanus argentimaculatus</i> Oce. (LA)	Mangrove red snapper	NE	LC	+	+		Polyhaline	Allen 1985
32.	Megalopidae	<i>Megalops cyprinoides</i> Amp. (MC)	Indo-Pacific tarpon	NE	DD	+			Polyhaline	Whitehead 1984
33.	Monodactylidae	<i>Monodactylus argenteus</i> (MA)	Silver moony	NE	LC	+			Polyhaline	Heemstra 1984
34.	Mugilidae	<i>Mugil cephalus</i> cat. (MC)	Flathead grey mullet	NE	LC	+			Polyhaline	Harrison 1995
35.	Osphronemidae	<i>Pseudosphromenus cupanus</i> (PC)	Spiketail paradisefish	LC	LC	+			Mesohaline	Pethiyagoda 1991
36.	Osphronemidae	<i>Trichopodus trichopterus</i> (TT)	Three spot gourami	EX	LC	+			Oligohaline	Rainboth 1996
37.	Osphronemidae	<i>Trichopodus pectoralis</i> (TP)	Snakeskin gourami	EX	LC	+			Oligohaline	Rainboth 1996
38.	Scatophagidae	<i>Scatophagus argus</i> Amp. (SA)	Spotted scat	NE	LC	+			Polyhaline	Schofield 2021
39.	Sillaginidae	<i>Sillago sihama</i> Amp. (SS)	Silver sillago	NE	LC	+			Polyhaline	McKay 1992
40.	Soleidae	<i>Brachirus orientalis</i> Amp. (BO)	Oriental sole	NE	NE	+			Polyhaline	Munroe 2001
41.	Tetraodontidae	<i>Chelonodon potoca</i> Amp. (CP)	Milk spotted puffer	NE	LC	+			Polyhaline	Kottelat et al 1993

Amp.—Ampelidromous | Ana.—Anadromous | Cat.—Catadromous | CN—Canal | DD—Data deficiency | E—English | ES—Estuary | EX—Exotic | FWM—Freshwater marshy area | GCS—Global conservation standards | HLH—Honduwa Lake habitat | LC—Least concern | NCS—National conservation standards | Oce.—Oceanodromous | pot—Potamodromous | RI—River | S—Sinhala | VU—Vulnerable; \* /bold—Endemic

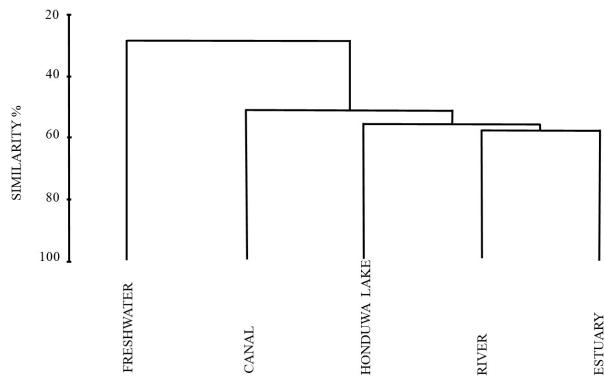


Figure 3. Bray-Curtis similarity of the sampling sites of Dedduwa Estuary, Sri Lanka based on the relative abundance of fish species.

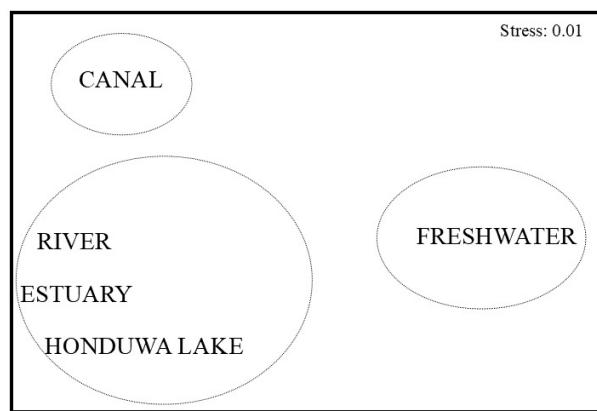
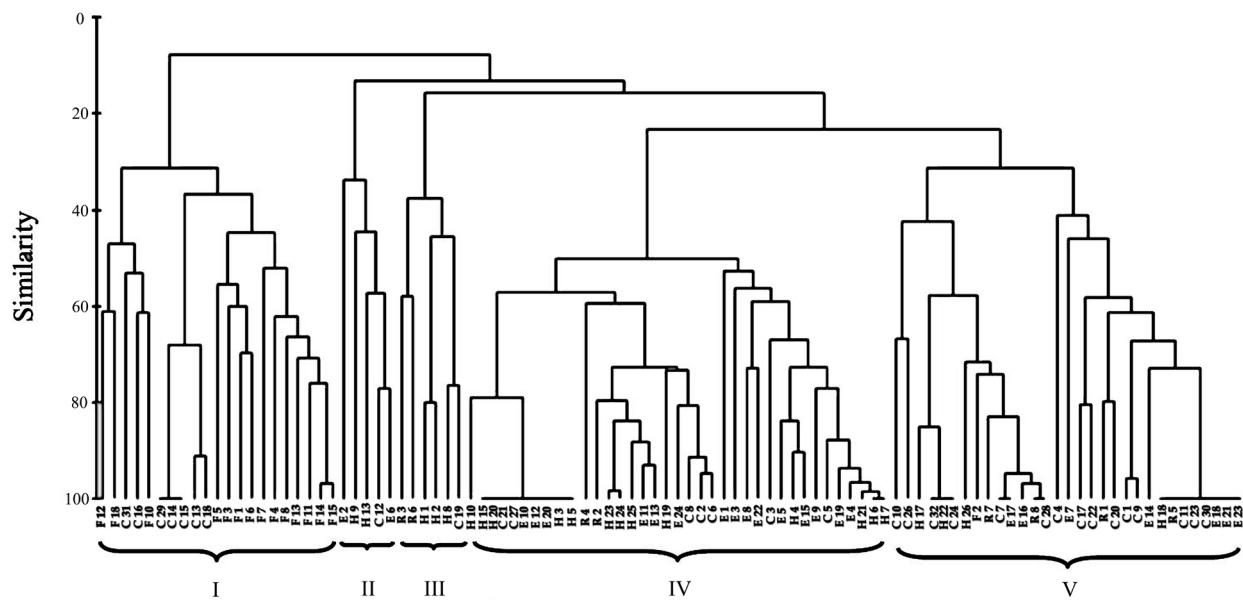


Figure 4. Two-dimensional MDS ordination of sampling sites of Dedduwa Estuary, Sri Lanka according to the relative abundance of fish species.

few species such as *Megalops cyprinoides*, *Scatophagus argus*, *Monodactylus argenteus*. These four habitats were somewhat similar due to the presence of mangroves. *B. butis* and *A. ambassis*, are almost equally distributed among canal, estuary, river, and Honduwa Lake, indicating approximately a similar species composition among sites. At the 25% similarity level, this cluster split into two distinct clusters, possibly due to the higher number of *A. ambassis* and *B. butis* caught in cluster V compared to cluster IV. Cluster II and III contained different species whereas Cluster III contained *O. dancena* and *E. suratensis* which were not observed in Cluster II. The Margelef species richness index was higher in clusters I and IV which were associated with freshwater/canal habitat and a combination of canal, estuary, Honduwa Lake, and river respectively. Simpson index was high in clusters I, II, and V (Table 4). The values of Fisher and Pielou's indices are comparatively higher in clusters I, II and V. Similarly, Shannon and Brillouin



**Figure 5.** Bray-Curtis similarity of the sampling sites of Dedduwa Estuary, Sri Lanka based on the relative abundance of fish species in different sampling efforts. Five different clusters with a 25% similarity level are marked separately. C—Canal | E—Estuarine area | F—Freshwater marsh | H—Honduwa Lake | R—River.

indices indicate high species richness and evenness in clusters I, II, and V (Table 4).

The taxonomic diversity of the area is within the expected diversity (see Figure 6A). The taxonomic diversity is expressed as observed average taxonomic distinctions (Figure 6A) and variation of taxonomic distinctions (Figure 6B). Honduwa Lake and the estuary are occupied by nearly similar species. Therefore, taxonomic diversity shows an approximately similar variation (Figure 6A). The canal includes species in different genera such as *Anguilla*, *Eleotris*, and *Channa* and therefore, the canal is different from the other four habitats with taxonomic diversity (Figure 6A). Freshwater habitat was occupied by distinctive genera such as *Rasbora*, *Anabas*, *Horadandia*, *Channa*, *Clarias*, *Heteropneustes*, and *Puntius*. Therefore, freshwater habitats also showed high and distinctive taxonomic diversity beyond the expected taxonomic variation compared to other habitats (Figure 6B). The overall taxonomic diversity is shown in Fig. 7 indicating probability contours (back-transformed ellipses) between AvTD and VarTD with a range of sublist sizes.

The fish fauna seems influenced by the various fishing activities of the fishers. Though commercial fishing activities are uncommon, artisanal fishers operate their vessels in every accessible area. Brush piles were found in Honduwa Lake in the northern part of the estuary. Encircling nets were operated in the river, Honduwa Lake, and the estuarine area. No operation of encircling

nets was observed in the canal segment (Table 5).

## DISCUSSION

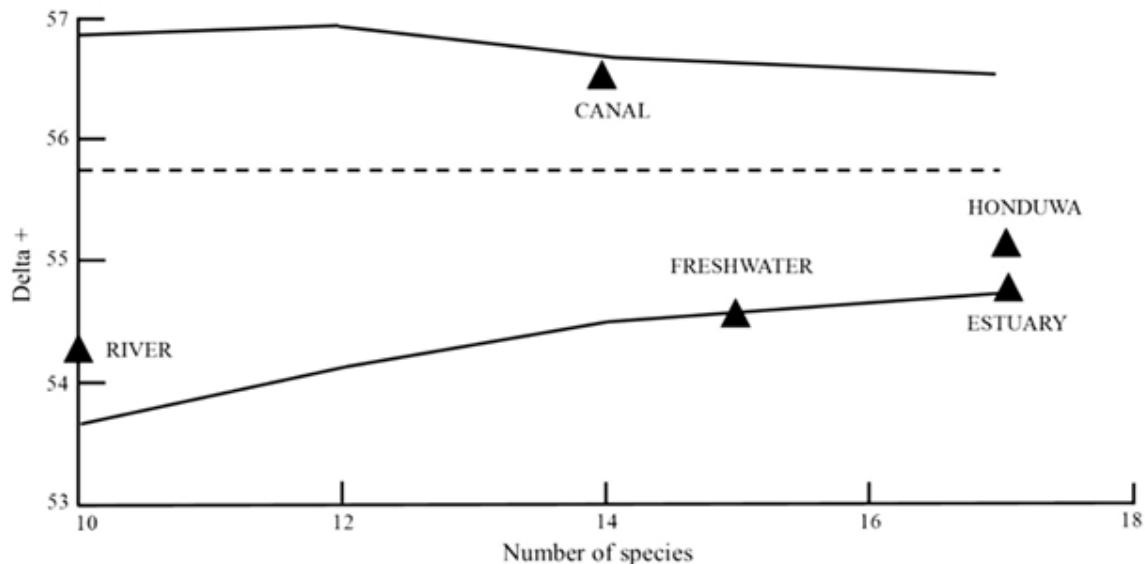
The fish fauna of estuarine systems has long been regarded as dominated by estuarine-dependent or estuarine-opportunistic marine species, with the movement of fishes among different salinity gradients being largely determined by the distribution of various habitats and tidal influences (Vieira & Musick 1994). The current finding of 41 fish species from the estuary and related habitats provides insight into the importance of habitat assessment and biodiversity conservation. The fish assemblage in the area is highly vulnerable to being threatened due to the proposed future development activities. Some species have a wide distribution and are found in several habitats while others show a more confined distribution restricted to specialized habitats (see Figure 2). The current study reveals that the distribution of fish species in Honduwa Lake, the Dedduwa Estuary, and the river shows a closely similar pattern. The distribution of species in the canal and freshwater marsh area is different from Honduwa Lake, estuarine area, and river (Figure 4). The variation of salinity could be the major limiting factor for the species distribution among these habitats. The major difference among the three systems is that the Honduwa and the estuarine area act as a lentic ecosystem while the

**Table 3.** Different diversity indices and related diversity values were calculated to represent the fish diversity of studied habitats in the Dedduwa Estuary, Sri Lanka.

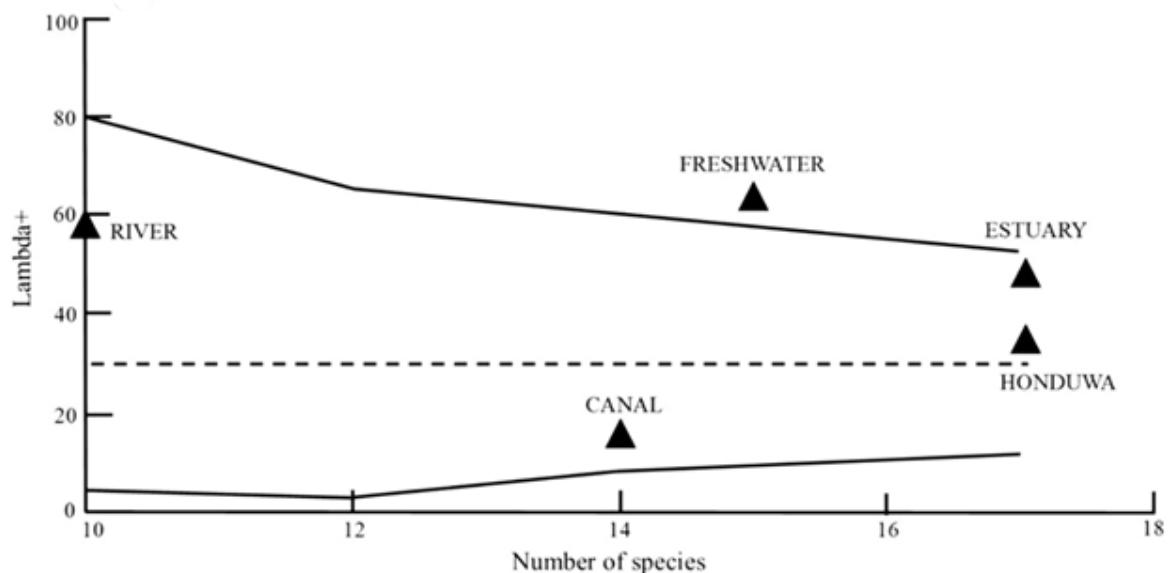
	S	N	Margelef index	Pielou's evenness	Fisher evenness	Brillouin	Shanon	Simpson index
Honduwa	18	576	2.67	0.55	3.52	1.54	1.59	0.74
River	12	213	2.04	0.81	2.72	1.90	2.03	0.84
Estuary	18	164	3.06	0.59	4.41	1.60	1.72	0.74
Canal	15	377	2.74	0.74	4.01	1.89	2.02	0.84
Freshwater	16	253	2.52	0.68	3.38	1.79	1.90	0.77

S—Total number of species or species richness | N—Number of individuals tested for the analysis.

(A)



(B)

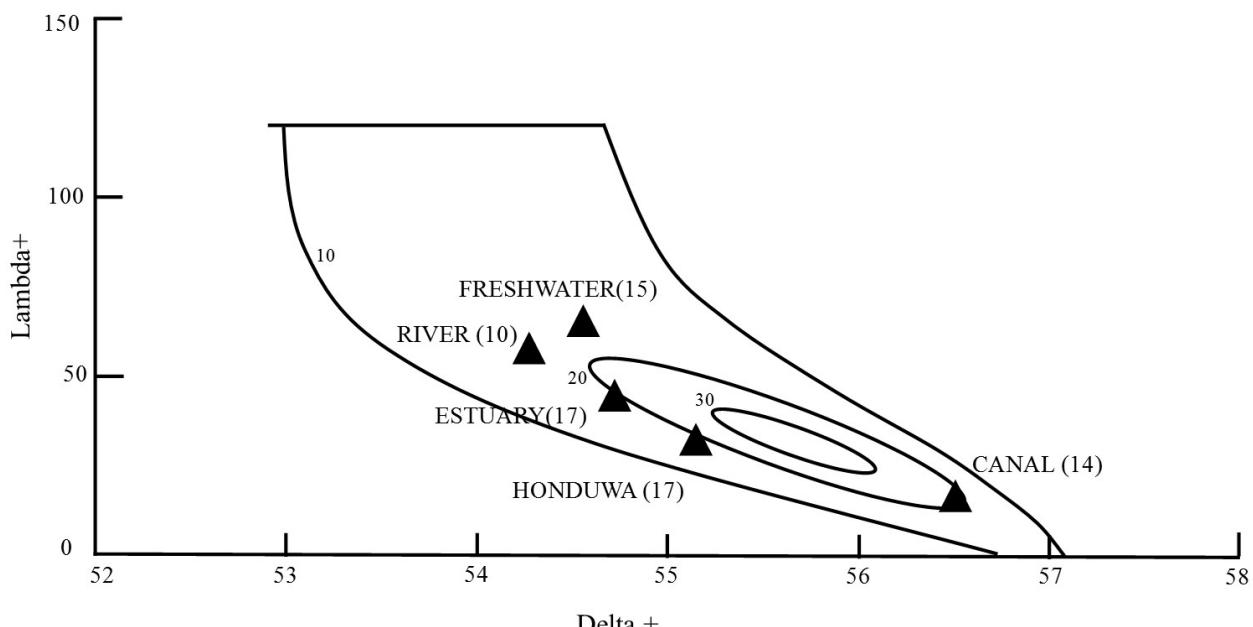


**Figure 6.** Confidence funnels showing values of (A) observed average taxonomic distinctness (AvTD,  $\Delta+$ ) and (B) variation in taxonomic distinctness (VarTD,  $\Lambda+$ ) of fish diversity of Dedduwa estuary, Sri Lanka overlaid on the predicted mean and its 95% confidence interval related.

**Table 4.** Different diversity indices and related diversity values were calculated to represent the fish diversity of the Dedduwa Estuary, Sri Lanka, for different given clusters in Bray-Curtis similarity analysis in Figure 6.

Cluster	S	N	Margelef index	Pielou's evenness	Fisher evenness	Brillouin	Shanon	Simpson index
I	18	346	2.91	0.67	4.03	1.86	1.94	0.78
II	13	403	2.00	0.78	2.56	1.96	2.02	0.79
III	11	747	1.51	0.46	1.82	1.07	1.09	0.51
IV	18	406	2.83	0.51	3.85	1.40	1.47	0.68
V	14	227	2.40	0.80	3.29	1.80	1.91	0.81

S—Total number of species or species richness | N—Number of individuals tested for the analysis.



**Figure 7.** Probability contours (back-transformed ellipses) between AvTD and VarTD with a range of sublist sizes:  $m = 10, 20; Plot is based on 1,000 simulations. Simulated fish assemblages were generated from a total species list representing all fishes collected over all surveys.$

river is a lotic ecosystem. This difference may have also brought about differences in ichthyofaunal diversity and distribution among habitats.

According to the results presented in this study, the species distribution in the two different salinity gradients in freshwater and brackish water habitats is comparatively different (Figure 3). The species with a wide range of distribution probably are euryhaline (Bulger et al. 1993). Majority of the species recognized as the juvenile stage which denoted mangroves of the riparian habitat provide proper feeding and nursery ground for juvenile stages. The glass eels of *Anguilla* spp. found from the canal area provides evidence of the breeding migration of the catadromous species (Table 2). IUCN (2011), describes the breeding migration of *Anguilla bicolor* (Level fin eel) in the Kala

Oya River basin of Sri Lanka and further explains the importance of seagrass beds as refuges of the glass eels. The current finding of glass eels associated with canals and estuaries is particularly important because it explains the eel migration and probably a good indicator of future conservation actions. Nevertheless, the presence of fishes with different migration types such as Amphidromous, Anadromous, Potadromous, and Oceanodromous highlights the importance of the estuary for stabilizing the community structure of fishes (Table 2).

The results show the freshwater habitats (e.g. canal and marsh) are clearly distinguished from brackish water habitats according to the species composition (Figure 6). These canals in more inland areas are connected with freshwater habitats and provide perfect habitats

**Table 5. The presence of aquatic vegetation and related anthropogenic activities at the five sampling sites of the Dedduwa Estuary, Sri Lanka.**

	Presence of aquatic vegetation		Anthropogenic activities		
	Presence of mangroves	Presence of aquatic weeds	Encircling nets	Disposal of waste	Brush park
Honduwa Lake habitat	H	-	+	-	+
Estuary	H	-	+	-	-
River	H	-	+	+	-
Canal	L	+	-	-	-
Freshwater marsh	-	+	-	+	-

H—high | L—Low | +/-—Presence/Absence.

for Polyhaline (conditions ranging from a salinity of 18–30 ppt), Mesohaline (waters with a salinity between 5 and 18 ppt), and Oligohaline (waters with salinity from 0.5–5 ppt) species (Karleskint 1998) because with high salinity influx, those species probably migrate towards the headwaters of the canal and streams probing for fewer salinity areas (Table 2).

In this analysis, different indices were used to describe the diversity of fish fauna in different habitats in the estuarine area. Because different diversity indices give results in different integrity. The Shannon index is based on percentage composition by species (Magurran 1988). When the randomness of the sampling cannot be guaranteed, the Brillouin index was used to calculate the heterogeneity (Southwood & Henderson 2000). This is because several sampling locations were inaccessible, due to the abundance of crocodiles, snags, and high water depth. Shannon index gives similar results where proportional abundance and number of species in the sample remain constant (Magurran 1988). The Brillouin index measures diversity as opposed to the sample. Both Shanon and Brillouin indices have given approximately similar results as indicated by Magurran (2004). Simpson index is more biased towards the most abundant species rather than species richness (May 1975). Pielou's evenness is an index that measures diversity along with species richness. Compared with indices such as Simpson's index or Shannon's index, a more thorough description of a community structure can be interpreted using Pielou's evenness (Heip & Herman 2001). Margalef's diversity index is a species richness index (Gamito 2010). Many species richness measures suffer from the problem that they are strongly dependent on sampling effort. The greater the sampling effort potentially the higher the index value. Thus, comparing metrics from samples collected with differing levels of sampling effort can be difficult and possibly misleading (Gamito 2010). As mentioned

above (see methodology section) data generated from the alternative sampling efforts were excluded from the analysis, and the analysis may have been affected due to insufficient representation of fish species in the samples. Further considering the diversity measurements, Fisher's Alpha ( $\alpha$ ) is widely used as a diversity index to compare communities varying in the number of individuals (N), because theoretically independent of sample size. This is highly dependent on the sample size and the total number of species (Magurran 1988). Hence, Honduwa Lake habitat and estuarine area (Table 3) and Cluster I and IV (Table 4) show higher Fisher's alpha indices.

The average taxonomic distinctness index (AvTD,  $\Delta+$ ) measures the average taxonomic distance between species at a site, or the average path length joining every pair of individuals in a sample, using a standard Linnean classification, i.e. species, genus, family, order, class etc. (Warwick & Clarke 1995). The variation in taxonomic distinctness index (VarTD,  $\Lambda+$ ) measures the variation in the average distance between species pairs (Clarke & Warwick 2001). The taxonomic diversity of the fish fauna observed in the area is within the expected range (Figure 6) confirming the high accuracy of the sampling. Except for migratory species, the distribution of the fish fauna in the estuarine areas is location-specific (Bruno et al. 2013). This specifies the ecological significance and conservation needs of the different types of habitats to conserve different species. Results show the freshwater habitats are unique to several endemic species, especially around marshes including *Horadandia atukorali* and *Clarias brachysoma*. These two species are highly localized for aquatic habitats with submerged vegetation (Pethiyagoda 1991).

The area is extremely popular for the tourism industry. The high visitor pressure and pollution of the freshwater systems seem to be a major threat to the freshwater fish fauna. The loss of riparian habitats was also observed during the field observations. Freshwater

species abundance was higher in inland marshes and canals where there is less tidal effect. Though, mesohaline freshwater species like *Channa* spp. and *Puntius* spp. (Table 2) were observed in these freshwater segments, those species were not detected in the brackish water areas. The abundance and distribution of freshwater species increased notably with rainfall. These abiotic factors are important to explain the range expansion of the freshwater species in estuarine systems (Drinkwater & Frank 1994).

## CONCLUSIONS

Fish fauna in the Dedduwa estuary provides insight into habitat preference and fish assemblages. The mutualistic relationship between fishes and habitats promotes the stability and functionality of this wetland habitat. The presence of the two endemic and vulnerable species—*Horadandia atukorali* and *Clarias brachysoma*—in marshy freshwater habitat and catadromous migration of *Anguilla* spp. highlights the conservation importance. In the current study freshwater systems are associated with canals where water quality is often vulnerable due to anthropogenic inputs such as sewage and solid waste and are likely to have noticeable impacts on the freshwater and amphidromous fishes. Though the species richness in the studied habitat was approximately similar, higher variations were observed in the abundance of different species. This demonstrates the habitat-orientated species distribution and ontogenetic habitat shifting of different species in the study area. The presence of fish species with different migratory habits denoted the importance of the estuary as a refuge and feeding ground for juvenile fish during their critical development stages. Therefore, current habitat alterations and pollution loads from different sources would affect the movement of the fishes and must be kept to be minimum.

## REFERENCES

**Allen, G.R. (1985).** FAO Species Catalogue, Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fish. Synop. Rome: FAO 125(6): 208.

**Barbier, E.B. (2020).** Estuarine and Coastal Ecosystems as Defense Against Flood Damages: An Economic Perspective. *Frontiers in Climate* 2: 594254. <https://doi.org/10.3389/fclim.2020.594254>

**Barletta, M., A. Barletta-Bergan, U. Saint-Paul & G. Hubold (2005).** The role of salinity in structuring the fish assemblages in a tropical estuary. *Journal of Fish Biology* 66: 45–72. <https://doi.org/10.1111/j.0022-1112.2005.00582.x>

**Beesley, P.L., G.J.B. Ross & A. Wells (1998).** *Mollusca: The Southern Synthesis*. CSIRO Publishing, Melbourne. 1: 1234

**Blaber, S.J.M., D.T. Brewer & J.P. Salini (1989).** Species composition and biomasses of fishes in different habitats of a tropical northern Australian estuary: their occurrence in the adjoining sea and estuarine dependence. *Estuarine, Coastal and Shelf Science* 29(6): 509–531. [https://doi.org/10.1016/0272-7714\(89\)90008-5](https://doi.org/10.1016/0272-7714(89)90008-5)

**Bray, R.J. & J.T. Curtis (1957).** An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* 27: 325–349. <https://doi.org/10.2307/1942268>

**Breine, J., J. Maes, F. Ollevier & M. Stevens (2011).** Fish assemblages across a salinity gradient in the Zeeschelde estuary (Belgium). *Belgian Journal of Zoology* 141 (2):21–44. JRC67245. [http://www.naturalsciences.be/institute/associations/rbzs\\_website/bjz/back/pdf/BJZ\\_141\\_2/Breine\\_BJZ\\_141\\_2.pdf](http://www.naturalsciences.be/institute/associations/rbzs_website/bjz/back/pdf/BJZ_141_2/Breine_BJZ_141_2.pdf)

**Brillouin, L. (1956).** *Science and Information Theory*. 2<sup>nd</sup> Edition. Academic Press, New York, 50 pp.

**Bulger, A.J., B.P. Hayden, M.E. Monaco, D.M. Nelson & M.G. McCormick-Ray (1993).** Biologically-based estuarine salinity zones derived from a multivariate analysis. *Estuaries* 16: 311–322. <https://doi.org/10.2307/1352504>

**Cardoso, P.G (2021).** Estuaries: Dynamics, Biodiversity, and Impacts, pp. 1–12. In: Leal Filho, W., A.M. Azul, L. Bauldli, A. Lange Salvia & T. Wall (eds.). *Life Below Water. Encyclopedia of the UN Sustainable Development Goals*. Springer, Cham. [https://doi.org/10.1007/978-3-319-71064-8\\_17-1](https://doi.org/10.1007/978-3-319-71064-8_17-1)

**Clarke, K.R. & R.M. Warwick (2001).** Change in marine communities: an approach to statistical analyses and interpretation, 2<sup>nd</sup> Edition. PRIMER-E, Plymouth.

**Collette, B.B. & J. Su (1986).** The halfbeaks (Pisces, Beloniformes, Hemiramphidae) of the Far East. *Proceedings of the Academy of Natural Sciences of Philadelphia* 138(1): 250–301. <https://www.jstor.org/stable/4064855>

**Cyrus, D.P. & S.J.M. Blaber (1987).** The influence of turbidity on juvenile marine fish in the estuaries of Natal, South Africa. *Continental Shelf Research* 7: 1411–1416. [https://doi.org/10.1016/0278-4343\(87\)90046-X](https://doi.org/10.1016/0278-4343(87)90046-X)

**Dando, P.R (1984).** Reproduction in estuarine fish, pp. 155–170. In: Potts, G.W. & R.J. Wootton (eds.). *Fish Reproduction: Strategies and Tactics*. Academic Press, London.

**Das, I., A. Chanda, A. Akhand & S. Hazra (2023).** Carbon Biogeochemistry of the Estuaries Adjoining the Indian Sundarbans Mangrove Ecosystem: A Review. *Life* 13(4): 863. <https://doi.org/10.3390/life13040863>

**Denis, J., K. Rabhi, F. Le Loc'h, F. Ben Rais Lasram, K. Boutin, M. Kazour, M. Diop, M.C. Gruselle & R. Amara (2022).** Role of estuarine habitats for the feeding ecology of the European eel (*Anguilla anguilla* L.). *PLoS One*. 6:17(7): e0270348. <https://doi.org/10.1371/journal.pone.0270348>

**Department of Coast Conservation and Coastal Resource Management (2018).** Sri Lanka coastal zone and coastal resource management plan –2018. Colombo : Ministry of Mahaweli Development and Environment, 58 pp

**Douglas, T.J., G. Schuerholz & S.K. Juniper (2022).** Blue carbon storage in a northern temperate estuary subject to habitat loss and chronic habitat disturbance: Cowichan estuary, British Columbia, Canada. *Frontiers in Marine Science* 9: 857586. <https://doi.org/10.3389/fmars.2022.857586>

**Drinkwater, K.F. & K.T. Frank (1994).** Effects of river regulation and diversion on marine fish and invertebrates. *Aquatic Conservation* 4: 135–151.

**Elliott, M., A.K. Whitfield, I.C. Potter, S.J.M. Blaber, D.P. Cyrus, F.G. Nordlie & T.D. Harrison (2007).** The guild approach to categorizing estuarine fish assemblages: a global review. *Fish and Fisheries* 8: 241–268.

**Fisher, R.A., A.S. Corbet & C.B. Williams (1943).** The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology* 12: 42–58.

**Franco, A., M. Elliott, P. Franzoi & P. Torricelli (2008).** Life strategies of

fishes in European estuaries: the functional guild approach. *Marine Ecology Progress Series* 354: 219–228. <https://doi.org/10.3354/meps07203>

**Fricke, R. (1999).** *Fishes of the Mascarene Islands (Réunion, Mauritius, Rodriguez): An Annotated Checklist, with Descriptions of New Species*. Koeltz Scientific Books, Koenigstein, Theses Zoologicae 31: 759 pp.

**Gamito, S. (2010).** Caution is needed when applying Margalef diversity index. *Ecological Indicators* 10: 550–551

**Gillanders, B.M., T.S. Elsdon, I.A. Halliday, G.P. Jenkins, J.B. Robins & F.J. Valesini (2011).** Potential effects of climate change on Australian estuaries and fish utilizing estuaries: a review. *Marine and Freshwater Research* 62: 1115–1131. <https://doi.org/10.1071/MF11047>

**Guerreiro, M. A., F. Martinho, J. Baptista, F. Costa, M. Â. Pardal & A. L. Primo (2021).** Function of estuaries and coastal areas as nursery grounds for marine fish early life stages. *Marine Environmental Research* 170: 105408. <https://doi.org/10.1016/j.marenvres.2021.105408>.

**Hagan, S.M. & K.W. Able (2003).** Seasonal changes of the pelagic fish assemblage in a temperate estuary. *Estuarine, Coastal and Shelf Science* 56: 15–29. [https://doi.org/10.1016/S0272-7714\(02\)00116-6](https://doi.org/10.1016/S0272-7714(02)00116-6)

**Harrison, I.J. (1995).** Mugilidae. Lisas. In: Fischer W, Krupp, W. Schneider, C. Sommer, K.E. Carpenter & V. Niem (eds.). *Guia FAO para-Identificación de Especies para lo Fines de la Pesca. Pacífico Centro-Oriental*. FAO, Rome, 3: 1293–1298.

**Heemstra, P.C. (1984).** Monodactylidae. In: Fischer, W. & G. Bianchi (eds.). *FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51)*. Vol. 3. FAO, Rome.

**Heip, C. & P. Herman (2001).** Indices of diversity and evenness. *Océanis* 24: 61–87.

**Hoese, D.F. (1986).** Eleotridae, pp. 807–811. In: Smith, M.M. & P.C. Heemstra (eds.). *Smiths' Sea Fishes*. Springer-Verlag, Berlin, 1191 pp.

**IUCN (2011).** An environmental and fisheries profile of the Puttalam Lagoon system. *Regional Fisheries Livelihoods Programme for South and Southeast Asia (GCP/RAS/237/SPA)* Field Project Document 2011/LKA/CM/05. xvii + 237 pp.

**Iwatsuki, Y., S. Kimura & T. Yoshino (2001).** *Gerres limbatus* Cuvier and *G. lucidus* Cuvier from the Indo-Malay Archipelagos, the latter corresponding to young of the former (Perciformes: Gerreidae). *Ichthyological Research* 48(3): 307–314. <https://doi.org/10.1007/s10228-001-8151-4>

**Jackson, D.A., P.R. Peres-Neto & J.D. Olden (2001).** What controls who is where in freshwater fish communities—the roles of biotic, abiotic, and spatial factors. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 157–170. <https://doi.org/10.1139/f00-239>

**James, P.S.B.R. (1984).** Leiognathidae, pp. 2782–2806. In: Fischer W. & G. Bianchi (eds.). *FAO Species Identification Sheets for Fishery Purposes. Western Indian Ocean (Fishing Area 51)*. Vol. 2. FAO, Rome.

**Kadye, W.T., N.A.G. Moyo, C.H.D Magadza & S. Kativu (2008).** Stream fish assemblages in relation to environmental factors on a Montane Plateau (Nyika Plateau, Malawi). *Environmental Biology of Fishes* 83: 417–428. <https://doi.org/10.1007/s10641-008-9364-4>

**Kailola, P.J. (1999).** Ariidae (=Tachysuridae): sea catfishes (fork-tailed catfishes). In: Carpenter K.E & V.H. Niem (eds.). *FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Batoid fishes, Chimaeras and Bony Fishes part 1 (Elopidae to Linophrynidae)*. FAO, Rome 3: 1827–1879.

**Karleskint, G. (1998).** *Introduction to Marine Biology*. Harcourt Brace & Company, 378 pp.

**Kottelat, M. (2013).** The fishes of the inland waters of southeast Asia: a catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. *Raffles Bulletin of Zoology* 27: 1–663.

**Kottelat, M., A.J. Whitten, S.N. Kartikasari & S. Wirjoatmodjo (1993).** *Freshwater Fishes of Western Indonesia and Sulawesi*. Periplus Editions, Hong Kong, 221 pp.

**Kranck, K. (1981).** Particulate matter grain-size characteristics and flocculation in a partially mixed estuary. *Sedimentology* 28: 107–114.

**Leggett, W.C. (1984).** Fish Migrations in Coastal and Estuarine Environments: A Call for New Approaches to the study of an old Problem. In: Mc Cleave, J.D., G.P. Arnold, J.J. Dodson & W.H. Neill (eds.). *Mechanisms of Migration in Fishes. NATO Conference Series, Vol 14*. Springer, Boston, MA. [https://doi.org/10.1007/978-1-4613-2763-9\\_11](https://doi.org/10.1007/978-1-4613-2763-9_11)

**Maes, J., M. Stevens & F. Ollevier (2005).** The composition and community structure of the ichthyofauna of the upper Scheldt Estuary: synthesis of a 10-year data collection (1991–2001). *Journal of Applied Ichthyology* 21: 86–93. <https://doi.org/10.1111/j.1439-0426.2004.00628.x>

**Magurran, A.E. (1988).** *Ecological Diversity and Its Measurement*. Princeton University Press, New Jersey, 179 pp.

**Magurran, A.E. (2004).** *Measuring Biological Diversity*. Blackwell Publishing, 350 Main Street, Malden, MA 02148- vili + 256 pp.

**Margalef, R. (1958).** Temporal succession and spatial heterogeneity in phytoplankton, pp. 323–347. In: Buzzati-Traverso (ed.). *Perspectives in Marine Biology*. University of California Press, Berkeley.

**Maugé, L.A. (1986a).** Eleotridae. In: Daget, J., J.P. Gosse & D.F.E. Thys van den Audenaerde (eds.). Checklist of the *Freshwater Fishes of Africa (CLOFFA)*. ISBN, Brussels; MARC, Tervuren; and ORSTOM, Paris 2: 389–398.

**Maugé, L.A. (1986b).** Gobiidae. In: Daget, J., J.P. Gosse & D.F.E. Thys van den Audenaerde (eds.). Checklist of the freshwater fishes of Africa (CLOFFA). ISBN, Brussels; MARC, Tervuren; and ORSTOM, Paris 2: 358–388.

**May, R.M. (1975).** Patterns of species abundance and diversity, pp. 81–120. In: Cody, M.L & J.M. Diamond (eds.). *Ecology and evolution of communities*. Harvard University Press, Cambridge, MA.

**McKay, R.J. (1992).** FAO Species Catalogue. Sillaginid fishes of the world (family Sillaginidae). An annotated and illustrated catalogue of the sillago, smelt or Indo-Pacific whiting species known to date. Rome: FAO. *FAO Fisheries Synopses* 125(14): 87.

**Meire, P., T.J. Ysebaert, S. Van Damme, E. Van den Bergh, T. Maris & E. Struyf (2005).** The Scheldt estuary: a description of a changing ecosystem, In: Meire, P et al (ed.) *Ecological structures and functions in the Scheldt Estuary: from past to future*. *Hydrobiologia* 540 (1–3): 1–11. <https://doi.org/10.1007/s10750-005-0896-8>

**Ministry of Forestry and Environment (1999).** Biodiversity Conservation in Sri Lanka: A Framework for Action. Ministry of Forestry and Environment, Battaramulla, Sri Lanka, 133 pp.

**Miththapala, S. (2013).** *Lagoons and Estuaries –Coastal Ecosystems Series, Volume 4*. Colombo: IUCN, International Union for Conservation of Nature and Natural Resources, 72 pp.

**Munroe, T.A. (2001).** Soleidae. Soles. In: Carpenter, K.E & V. Niem (eds.). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles. FAO, Rome 6: 3878–3889.

**Paxton, J.R., D.F. Hoese, G.R. Allen & J.E. Hanley (1989).** Pisces. Petromyzontidae to Carangidae. *Zoological Catalogue of Australia*, Australian Government Publishing Service, Canberra 7: 665.

**Pethiyagoda, R. (1991).** *Freshwater fishes of Sri Lanka*. The Wildlife Heritage Trust of Sri Lanka, Colombo, 362 pp.

**Pielou, E.C. (1969).** An Introduction to Mathematical Ecology. Wiley, New York, 286 pp.

**Pielou, E.C. (1975).** *Ecological diversity*. Wiley, New York, 165 pp.

**Potter, I. C., B. M. Chuwen, S. D. Hoeksema & M. Elliott (2010).** The concept of an estuary: a definition that incorporates systems which can become closed to the ocean and hypersaline. *Estuarine, Coastal and Shelf Science* 87:497–500. <https://doi.org/10.1016/j.ecss.2010.01.021>

**Potter, I. C., J. R. Tweedley, M. Elliott & A. K. Whitfield (2013).** The ways in which fish use estuaries: a refinement and expansion of

the guild approach. *Fish and Fisheries* 16: 230–239. <https://doi.org/10.1111/faf.12050>

**Rainboth, W. (1994).** Inland fishes of India and adjacent countries. *Reviews in Fish Biology and Fisheries* 4: 135–136. <https://doi.org/10.1007/BF00043269>

**Rainboth, W.J. (1996).** Fishes of the Cambodian Mekong. FAO species identification field guide for fishery purposes. *FAO, Rome*, 265 pp.

**Roberts, T.R. (1998).** Systematic observations on tropical Asian medakas or rice fishes of the genus *Oryzias*, with descriptions of four new species. *Ichthyological Research* 45(3): 213–224. <https://doi.org/10.1007/BF02673919>

**Robinson, M.C., K.P. Morris & K.R. Dyer (1999).** Deriving fluxes of suspended particulate matter in the Humber Estuary, UK, using airborne remote sensing. *Marine Pollution Bulletin* 37: 155–163. [https://doi.org/10.1016/S0025-326X\(98\)00118-0](https://doi.org/10.1016/S0025-326X(98)00118-0)

**Ruhl, N. (2013).** The lotic-lentic gradient in reservoirs and estuaries. Dissertation, Department? Ohio University, Athens, OH.

**Samarakoon, J. & S. Samarawickrama (2012).** An Appraisal of Challenges in the Sustainable Management of the Micro-tidal Barrier-built Estuaries and Lagoons in Sri Lanka. IUCN Sri Lanka Country Office, Colombo.

**Schofield, P.J. (2021).** "Scatophagus argus (Linnaeus, 1766)". Nonindigenous Aquatic Species Database, Gainesville, FL. U.S. Geological Survey. Accessed on 10 May 2023.

**Schubel, J.R. & H.H. Carter (1984).** The estuary works as a filter for fine-grained suspended sediment, pp. 81–107. In: Kennedy, V.S. (ed.). *The Estuary as a Filter*. Academic Press, Orlando.

**Seegers, L. (1997).** Killifishes of the world: Old world killis II: (Aplocheilus, Epiplatys, Nothobranchius). Aqualog, Verlag: A.C.S. GmbH, Germany, 112 pp.

**Shannon, C.A. (1948).** Mathematical theory of communication. *The Bell System Technical Journal* 27: 379–423.

**Silva, A., K. Maduwage & R. Pethiyagoda (2010).** A review of the genus *Rasbora* in Sri Lanka, with description of two new species (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters* 21(1): 27–50.

**Simpson, E. (1949).** Measurement of diversity. *Nature* 163: 6888.

**Smith, S.D.A. & M.J. Rule (2002).** Artificial substrata in a shallow sublittoral habitat: do they adequately represent natural habitats or the local species pool? *Journal of Experimental Marine Biology and Ecology*, 277: 25–41. [https://doi.org/10.1016/S0022-0981\(02\)00242-3](https://doi.org/10.1016/S0022-0981(02)00242-3)

**Southwood, T.R.E. & P.A. Henderson (2000).** *Ecological Methods*, 3<sup>rd</sup> Edition. Blackwell Scientific, 575 pp.

**Sreekanth, G.B., A.K. Jaiswar, P.U. Zacharia, D.G. Pazhayamadom & S.K. Chakraborty (2019).** Effect of environment on spatio-temporal structuring of fish assemblages in a monsoon-influenced tropical estuary. *Environmental Monitoring & Assessment* 191: 305. <https://doi.org/10.1007/s10661-019-7436-x>

**Sreekanth, G.B., N.M. Lekshmi & N.P. Singh (2017).** Temporal patterns in fish community structure; environmental perturbations in a well-mixed tropical estuary. *PNAS India Sec-B: Biological Sciences* 87(1): 135–145.

**Sreekanth, G.B., A.K. Jaiswar, H.B. Shivkumar, B. Manikandan, E.B. Chakurkar (2020).** Fish composition and assemblage structure in tropical monsoonal estuaries: estuarine use and feeding guild approach. *Estuarine, Coastal and Shelf Science* 244: 106911. <https://doi.org/10.1016/j.ecss.2020.106911>

**Teuchies J, W. Vandenbruwaene, R. Carpenter, L. Bervoets, S. Temmerman, C. Wang, T. Maris, T.J. Cox, A. Van Braeckel & P. Meire (2013).** Estuaries as filters: the role of tidal marshes in trace metal removal. *PLoS One* 8(8): e70381. <https://doi.org/10.1371/journal.pone.0070381>.

**Trewavas, E. (1983).** Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Museum of Natural History, London, UK, 583 pp.

**Vieira, J.P. & J.A. Musick (1994).** Fish faunal composition in warm-temperate and tropical estuaries of Western Atlantic. *Atlântica* 16: 31–53.

**Warwick, R.M. & K.R. Clarke (1995).** New "biodiversity" measures reveal a decrease in taxonomic distinctness with increasing stress. *Marine Ecology Progress Series* 129: 301–305.

**Whitehead, P.J.P. (1985).** FAO Species Catalogue. Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO Fisheries Synopsis. Rome: FAO 125(7/1): 1–303.

**Whitfield, A. & M. Elliott (2011).** Ecosystem and Biotic classifications of estuaries and coasts, pp. 99–124. In: E. Wolanski & D. McLusky (eds.), *Treatise on Estuarine and Coastal Science*. Academic Press, Waltham. <https://doi.org/10.1016/B978-0-12-374711-2.00108-X>

**Whitfield, A.K. & M. Elliott (2002).** Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. *Journal of Fish Biology* 61: 229–250. <https://doi.org/10.1111/j.1095-8649.2002.tb01773.x>

**Whitfield, A.K. (1999).** Ichthyofaunal assemblages in estuaries: a South African case study. *Reviews in Fish Biology and Fisheries* 9: 151–186. <https://doi.org/10.1023/A:1008994405375>

**Whittaker, R. H. & G. E. Likens (1975).** The biosphere and man, pp. 305–328. In: Lieth, H. & G.E. Whittaker (ed.). *Primary Production of the Biosphere*. Springer-Verlag, New York, viii+340 pp.

**Woodland, D.J. (1984).** Gerreidae. In: Fischer, W. & G. Bianchi (eds.) *FAO Species Identification Sheets for Fishery Purposes. Western Indian Ocean fishing area 51. Vol. 2*. FAO, Rome.



Dr. John Noyes, Natural History Museum, London, UK  
Dr. Albert G. Orr, Griffith University, Nathan, Australia  
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium  
Dr. Nancy van der Poorten, Toronto, Canada  
Dr. Karen Schnabel, NIWA, Wellington, New Zealand  
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India  
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India  
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India  
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India  
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India  
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India  
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain  
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong  
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India  
Dr. M. Nithyanandan, Environmental Department, La Al Kuwait Real Estate. Co. K.S.C., Kuwait  
Dr. Himender Bharti, Punjabi University, Punjab, India  
Mr. Purnendu Roy, London, UK  
Dr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan  
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India  
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam  
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India  
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore  
Dr. Lionel Monod, Natural History Museum of Geneva, Genève, Switzerland.  
Dr. Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India  
Dr. Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil  
Dr. Kuri R. Arnold, North Dakota State University, Saxony, Germany  
Dr. James M. Carpenter, American Museum of Natural History, New York, USA  
Dr. David M. Claborn, Missouri State University, Springfield, USA  
Dr. Karen Schnabel, Marine Biologist, Wellington, New Zealand  
Dr. Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil  
Mr. Monsoon Jyoti Gogoi, Assam University, Silchar, Assam, India  
Dr. Heo Chong Chin, Universiti Teknologi MARA (UiTM), Selangor, Malaysia  
Dr. R.J. Shiel, University of Adelaide, SA 5005, Australia  
Dr. Siddharth Kulkarni, The George Washington University, Washington, USA  
Dr. Priyadarshan Dharma Rajan, ATREE, Bengaluru, India  
Dr. Phil Alderslade, CSIRO Marine And Atmospheric Research, Hobart, Australia  
Dr. John E.N. Veron, Coral Reef Research, Townsville, Australia  
Dr. Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.  
Dr. Yu-Feng Hsu, National Taiwan Normal University, Taipei City, Taiwan  
Dr. Keith W. Wolfe, Antioch, California, USA  
Dr. Siddharth Kulkarni, The Hormiga Lab, The George Washington University, Washington, D.C., USA  
Dr. Tomas Ditrich, Faculty of Education, University of South Bohemia in Ceske Budejovice, Czech Republic  
Dr. Mihaly Foldvari, Natural History Museum, University of Oslo, Norway  
Dr. V.P. Uniyal, Wildlife Institute of India, Dehradun, Uttarakhand 248001, India  
Dr. John T.D. Caleb, Zoological Survey of India, Kolkata, West Bengal, India  
Dr. Priyadarshan Dharma Rajan, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Bangalore, Karnataka, India

#### Fishes

Dr. Neelesh Dahanukar, IISER, Pune, Maharashtra, India  
Dr. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México  
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore  
Dr. Rajeev Raghavan, St. Albert's College, Kochi, Kerala, India  
Dr. Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK  
Dr. E. Vivekanandan, Central Marine Fisheries Research Institute, Chennai, India  
Dr. Davor Zanella, University of Zagreb, Zagreb, Croatia  
Dr. A. Biju Kumar, University of Kerala, Thiruvananthapuram, Kerala, India  
Dr. Akhilesh K.V., ICAR-Central Marine Fisheries Research Institute, Mumbai Research Centre, Mumbai, Maharashtra, India  
Dr. J.A. Johnson, Wildlife Institute of India, Dehradun, Uttarakhand, India  
Dr. R. Ravinesh, Gujarat Institute of Desert Ecology, Gujarat, India

#### Amphibians

Dr. Sushil K. Dutta, Indian Institute of Science, Bengaluru, Karnataka, India  
Dr. Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

#### Reptiles

Dr. Gernot Vogel, Heidelberg, Germany  
Dr. Raju Vyas, Vadodara, Gujarat, India  
Dr. Pritpal S. Soorae, Environment Agency, Abu Dubai, UAE.  
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey  
Prof. Chandrashekher U. Rironker, Goa University, Taleigao Plateau, Goa, India  
Dr. S.R. Ganesh, Chennai Snake Park, Chennai, Tamil Nadu, India  
Dr. Himansu Sekhar Das, Terrestrial & Marine Biodiversity, Abu Dhabi, UAE

#### Birds

Dr. Hem Sagar Baral, Charles Sturt University, NSW Australia  
Mr. H. Biju, Coimbatore, Tamil Nadu, India  
Dr. Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK  
Dr. Priya Davidar, Pondicherry University, Kalapet, Puducherry, India  
Dr. J.W. Duckworth, IUCN SSC, Bath, UK  
Dr. Rajah Jayopal, SACON, Coimbatore, Tamil Nadu, India  
Dr. Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India  
Dr. V. Santharam, Rishi Valley Education Centre, Chittoor Dt., Andhra Pradesh, India  
Dr. S. Balachandran, Bombay Natural History Society, Mumbai, India  
Mr. J. Praveen, Bengaluru, India  
Dr. C. Srinivasulu, Osmania University, Hyderabad, India  
Dr. K.S. Gopi Sundar, International Crane Foundation, Baraboo, USA  
Dr. Gombobaatar Sundev, Professor of Ornithology, Ulaanbaatar, Mongolia  
Prof. Reuven Yosef, International Birding & Research Centre, Eilat, Israel  
Dr. Taej Mundkur, Wetlands International, Wageningen, The Netherlands  
Dr. Carol Inskip, Bishop Auckland Co., Durham, UK  
Dr. Tim Inskip, Bishop Auckland Co., Durham, UK  
Dr. V. Gokula, National College, Tiruchirappalli, Tamil Nadu, India  
Dr. Arkady Lelej, Russian Academy of Sciences, Vladivostok, Russia  
Dr. Simon Dowell, Science Director, Chester Zoo, UK  
Dr. Mário Gabriel Santiago dos Santos, Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, Vila Real, Portugal  
Dr. Grant Connette, Smithsonian Institution, Royal, VA, USA  
Dr. P.A. Azeez, Coimbatore, Tamil Nadu, India

#### Mammals

Dr. Giovanni Amori, CNR - Institute of Ecosystem Studies, Rome, Italy  
Dr. Anwaruddin Chowdhury, Guwahati, India  
Dr. David Mallon, Zoological Society of London, UK  
Dr. Shomita Mukherjee, SACON, Coimbatore, Tamil Nadu, India  
Dr. Angie Appel, Wild Cat Network, Germany  
Dr. P.O. Nameer, Kerala Agricultural University, Thrissur, Kerala, India  
Dr. Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK  
Dr. Heidi S. Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA  
Dr. Karin Schwartz, George Mason University, Fairfax, Virginia.  
Dr. Lala A.K. Singh, Bhubaneswar, Orissa, India  
Dr. Mewa Singh, Mysore University, Mysore, India  
Dr. Paul Racey, University of Exeter, Devon, UK  
Dr. Honnavalli N. Kumara, SACON, Anaikatty P.O., Coimbatore, Tamil Nadu, India  
Dr. Nishith Dharaiya, HNG University, Patan, Gujarat, India  
Dr. Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy  
Dr. Justus Joshua, Green Future Foundation, Tiruchirappalli, Tamil Nadu, India  
Dr. H. Raghuram, The American College, Madurai, Tamil Nadu, India  
Dr. Paul Bates, Harison Institute, Kent, UK  
Dr. Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA  
Dr. Dan Challender, University of Kent, Canterbury, UK  
Dr. David Mallon, Manchester Metropolitan University, Derbyshire, UK  
Dr. Brian L. Cypher, California State University-Stanislaus, Bakersfield, CA  
Dr. S.S. Talmale, Zoological Survey of India, Pune, Maharashtra, India  
Prof. Karan Bahadur Shah, Budhanilkantha Municipality, Kathmandu, Nepal  
Dr. Susan Cheyne, Borneo Nature Foundation International, Palangkaraya, Indonesia  
Dr. Hemanta Kafley, Wildlife Sciences, Tarleton State University, Texas, USA

#### Other Disciplines

Dr. Aniruddha Belsare, Columbia MO 65203, USA (Veterinary)  
Dr. Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India (Molecular)  
Dr. Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA (Communities)  
Dr. Ulrike Streicher, University of Oregon, Eugene, USA (Veterinary)  
Dr. Hari Balasubramanian, EcoAdvisors, Nova Scotia, Canada (Communities)  
Dr. Rayanna Helleni Santos Bezerra, Universidade Federal de Sergipe, São Cristóvão, Brazil  
Dr. Jamie R. Wood, Landcare Research, Canterbury, New Zealand  
Dr. Wendy Collinson-Jonker, Endangered Wildlife Trust, Gauteng, South Africa  
Dr. Rajeshkumar G. Jani, Anand Agricultural University, Anand, Gujarat, India  
Dr. O.N. Tiwari, Senior Scientist, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India  
Dr. L.D. Singla, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India  
Dr. Rupika S. Rajakaruna, University of Peradeniya, Peradeniya, Sri Lanka  
Dr. Bharat Baviskar, Wild-CER, Nagpur, Maharashtra 440013, India

#### Reviewers 2021–2023

Due to paucity of space, the list of reviewers for 2021–2023 is available online.

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.

Print copies of the Journal are available at cost. Write to:

The Managing Editor, JoTT,  
c/o Wildlife Information Liaison Development Society,  
43/2 Varadarajulu Nagar, 5<sup>th</sup> Street West, Ganapathy, Coimbatore,  
Tamil Nadu 641006, India  
ravi@threatenedtaxa.org

**Journal of Threatened Taxa** is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

## Articles

### Feeding dynamics of sympatric large carnivores in an anthropogenic landscape of the Indian Terai

– Vivek Ranjan, Syed Ainul Hussain, Ruchi Badola, Gaurav Vashistha & Parag Madhukar Dhakate, Pp. 25791–25801

### Avifaunal diversity assessment and conservation significance of Therhangal Bird Sanctuary, Ramanathapuram, Tamil Nadu: insights about breeding waterbirds

– H. Byju, H. Maitreyi, N. Raveendran & Reshma Vijayan, Pp. 25802–25815

### Habitat heterogeneity and taxonomic diversity of fish fauna in estuaries: a study from southern Sri Lanka

– Kirivithanage Sandun Nalaka Bandara, Pp. 25816–25830

### Successful establishment of a coral nursery for active reef restoration in Kavaratti Island, Lakshadweep archipelago

– C.A. Riyas, K.K. Idreesbabu, Rajeev Raghavan & S. Sureshkumar, Pp. 25831–25842

### Taxonomic review of genus *Gazalina* Walker (Thaumetopoeinae: Notodontidae: Lepidoptera) from India

– Amritpal Singh Kaleka, Gagan Preet Kour Bali & Navkiran Kaur, Pp. 25843–25855

### Diversity and distribution pattern of ebony trees *Diospyros* L. (Ebenaceae) in the forests of central Western Ghats, India

– H.S. Shashwathi & Y.L. Krishnamurthy, Pp. 25856–25871

### Tree community structure of selected green patches of Guwahati, Assam, India with special reference to spatio-temporal changes in vegetation

– Maitreyee Goswami, Jijnyasha Bayan, Uma Dutta, Arup Kumar Hazarika & Kuladip Sarma, Pp. 25872–25881

## Communications

### First record of leucistic Sloth Bear *Melursus ursinus* Shaw, 1791 (Mammalia: Carnivora: Ursidae) in Panna Tiger Reserve, India

– Sankarshan Chaudhuri, Supratim Dutta & K. Ramesh, Pp. 25882–25887

### Occurrence and distribution of Indian Pangolin *Manis crassicaudata* (Mammalia: Pholidota: Manidae) in the protected area network of Jammu Shiwaliks, India

– Ajaz Ansari & Neeraj Sharma, Pp. 25888–25893

### The first report of an assassin bug of the genus *Ademula* McAtee & Malloch (Reduviidae: Emesinae) from India and its rediscovery from Sri Lanka

– H. Sankararaman, Tharindu Ranasinghe, Anubhav Agarwal, Amila Sumanapala & Hemant V. Ghate, Pp. 25894–25903

### Preference and plasticity in selection of host for oviposition in Black Marsh Dart *Onychargia atrocyana* Selys, 1865 (Odonata: Zygoptera: Platycnemididae)

– Pathik K. Jana, Priyanka Halder Mallick & Tanmay Bhattacharya, Pp. 25904–25912

### New records of termite species (Blattodea: Rhinotermitidae, Termitidae) from southern India

– A.V. Anushya & P.R. Swaran, Pp. 25913–25919

### A study on the association between *Tridax* Daisy *Tridax procumbens* L. and butterflies at Shivaji University Campus, Maharashtra, India

– Aarati Nivasrao Patil & Sunil Madhukar Gaikwad, Pp. 25920–25930

## Short Communications

### Rare Honey Badger *Mellivora capensis* (Schreber, 1776) sighted in Tarai East Forest Division, Haldwani, Uttarakhand, India

– Prashant Kumar, Bhaskar C. Joshi, Anand Singh Bisht & Himanshu Bagri, Pp. 25931–25934

### Additional documentation of the Slender Skimmer *Orthetrum sabina* (Drury, 1770) preying on the Pied Paddy Skimmer *Neurothemis tullia* (Drury, 1773) in Nepal

– Mahamad Sayab Miya & Apeksha Chhetri, Pp. 25935–25938

## Notes

### First photographic record of the Red Giant Gliding Squirrel *Petaurista petaurista* Pallas, 1766 (Mammalia: Rodentia: Sciuridae) from Sattal, Uttarakhand, India

– Hiranmoy Chetia, Jayant Gupta & Murali Krishna Chatakonda, Pp. 25939–25941

### Red Pierrot *Talicada nyseus nyseus* (Guérin-Meneville, 1843): an addition to the butterfly fauna of Arunachal Pradesh, India

– Roshan Upadhyaya, Renu Gogoi, Ruksha Limbu, Manab Jyoti Kalita & Rezina Ahmed, Pp. 25942–25944

### *Ranunculus cantoniensis* DC. (Ranunculaceae): an addition to the flora of West Bengal, India

– Jayantanath Sarkar, Srijan Mukhopadhyay & Biswajit Roy, Pp. 25945–25948

## Book Review

### Flowers of labour – Commelinaceae of India: Book review

– Rajeev Kumar Singh, Pp. 25949–25950

## Publisher & Host



Threatened Taxa