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# Ichthyofaunal integrity and environmental features trade-off in the Sundarbans, India

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**Abstract.** Herein, we studied the ichthyofaunal diversity of the Bidyadhari River in the Indian Sundarbans for three consecutive months (April 2018-June 2018). The fishes collected in this study were netted from two collection points using bag nets. We also measured some environmental parameters during the time of netting. From the collection, we determined the Simpson's index of diversity (1-D), the Shannon-Wiener index (H), evenness (E) and the Sorenson's coefficient of community (CC) to find out the species richness, abundance, evenness and the levels of similarity of the two collection points. We also converted the H values to their true diversities (effective number of species [ENS]) for an adequate comparison. The indices and coefficient (H = 3.72-3.94, E = 0.830-0.832, 1-D = 0.973-0.979 and CC = 0.87) indicate that the overall integrity of biodiversity of the two collecting points is high. From the true diversity values, we ascertained that the first point, having 62 species of fishes, is 1.24 times as diverse as the second one, having 50 species. We have attributed the fish diversity to a compound of abiotic and biotic factors, which we explain in the discussion part. We also documented 20 fish species, new records for the Indian Sundarbans; some are new records from West Bengal. Furthermore, we discuss the possible reasons for their occurrence. Our study brings the number of fish species recorded from the Indian Sundarbans to 378.

**Keywords:** Clupeidae, distribution, diversity indices, ecology, mangroves, range extension, salinity

## 1. Introduction

One of the end goals of conservation is to designate zones for rebuilding or protection. To effectively understand the strength of a conservation or restoration framework, recognizing the organic components in a community is required (Marzluff and Ewing, 2008). Researchers need to propose straightforward, engineered and—if possible—cheap means to assess the natural status of streams and rivers (Darwall and Vie', 2005).

Their peculiar life-history traits, versatility and affectability to changes in natural surroundings make fishes great bio-markers and are regularly utilized for appraising the biotic integrity of waterways (Karr, 1981; Welcomme et al., 2006). Fish diversity consists of species richness (number of species in a characterized territory), species abundance (relative number of species) and phylogenetic diversity (connections between various groups of species). These three are related to shifts in environmental features and changes in fish assemblage seasonally (Brinda et al., 2010).

The Sundarbans mangrove forest lies in the eastern Indian state of West Bengal, comprising about half of the total mangrove area of India; 2112 sq. km (FSI, 2019). It is one of the most productive ecosystems globally, and the local people depend on it for sustenance (Andharia,

2020). Fishes considerably subsidize the economy of the region (Mishra and Gopi, 2017).

In the present case study, we looked at the diversity of fish species, their dominance and their similarity in the two fish collection points on the Bidyadhari River in the Indian Sundarbans. We tried to recognize the role of environmental factors in the composition of the region's fishes. Also, some species of fishes we encountered are new records for the Indian Sundarbans and West Bengal. These records give us insight into their distribution and the possible reasons for their range extension. We have provided brief taxonomic descriptions of the newly recorded fishes in the results section.

## 2. Materials and Methods

### 2.1. Study Area

The location of the Sundarbans mangrove delta is between 21°27'30"N to 22°30'00"N (latitude) and 89°02'00"E to 90°00'00"E (longitude) (Padhy et al., 2020). It lies in the eastern Indian state of West Bengal, bounded by the Bangladesh Sundarbans in the east, the River Hooghly in the west, Nadia district in the north (the Dampier-Hodges line) and the Bay of Bengal in the South. The Indian Sundarbans is a UNESCO world heritage site with rich floral and faunal diversity (Sarkar and Bhattacharya, 2003). Mangrove plant species of the family Rhizophoraceae dominates the delta (Barik and Chowdhury, 2014).

For this study, we carried out ichthyofaunal sampling at two collection points/stations (hereafter also referred to as community)-point 1: 22°02.75'N, 88°44.48'E and point 2: 21°59.68'N, 88°42.76'E on the Bidyadhari River, a principal river system in the Sundarbans (Figure 1).

### 2.2. Field Sampling and Taxonomic Analysis

From April 2018 to June 2018, the summer season and the beginning of monsoon, we accompanied fishers to the two collecting stations on the Bidyadhari River for ten consecutive days every month. The fishers used ‚Behundi/ Benthi Jaal', a form of bagnet. The net had a width of 40 m, length of 53 m and a height of 14 m, with the tapering end having a 2.8 m diameter. The mesh size was 1 mm, made of nylon monofilament. The fishers deployed the nets right before the onset of high tide and the soak time was for three hours. The pH value and water temperature were measured using portable meters (HI98121, Hanna Instruments Inc.). The

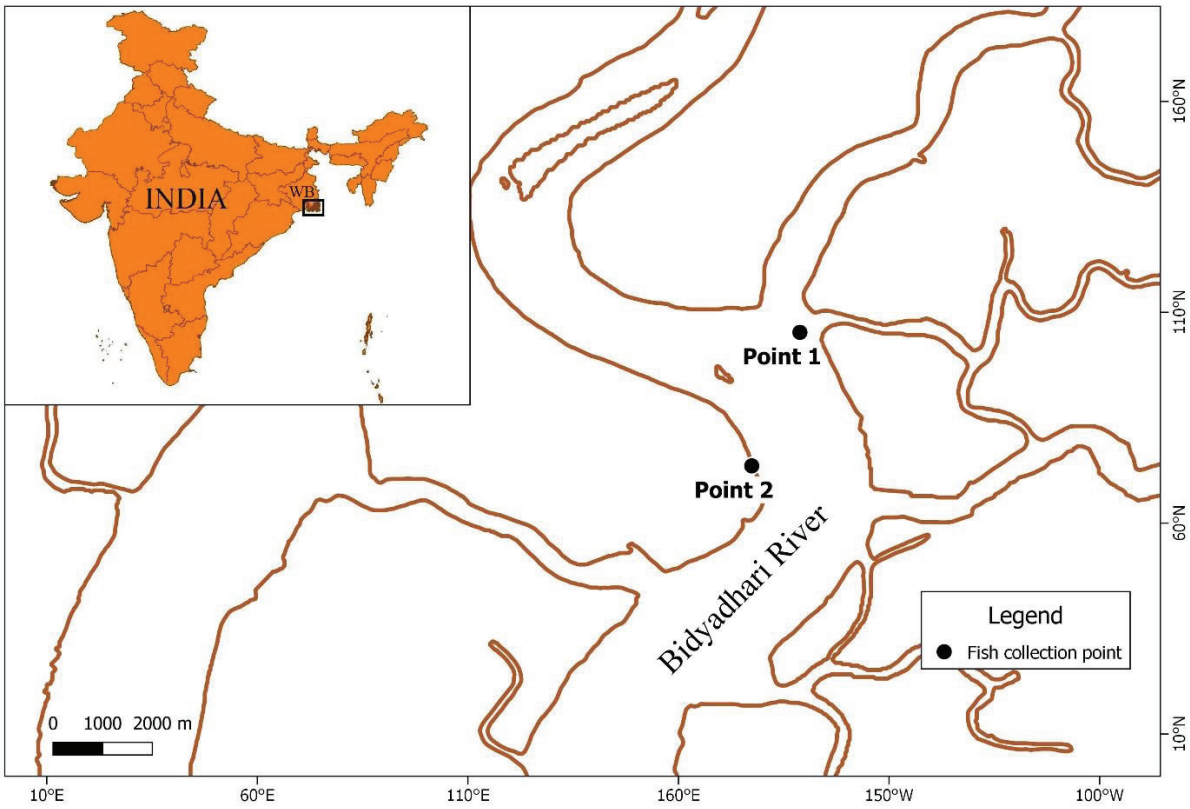


Figure 1. Map showing the two fish collection points on the Bidyadhari River. Inset map: Location of the Sundarbans (box) in the eastern Indian state of West Bengal (WB)

salinity of the water was measured using a refractometer (ERS-10, Erma Inc.). We also measured dissolved oxygen (DO-5509, Lutron Electronic Enterprise Co., Ltd.) and the euphotic depth (using a Secchi disk).

The fish were collected opportunistically from the catch. They were fixed in 10% formalin and later stored in 70% ethanol. The specimens were deposited and catalogued in the national zoological collection at the Zoological Survey of India. Counts and measurements were made on the left side of fish specimens using a digital vernier calliper (CD-6" ASX, Mitutoyo Co.) and stereoscopic microscope (EZ4, Leica Microsystems).

### 2.3. Species Composition and Nomenclature

We followed standard literature to identify the fishes (e.g., Whitehead, 1985; Talwar and Jhingran, 1991; Smith-Vaniz, 1999). We used online databases to ascertain valid scientific names and the current systematic position of the families (e.g., Fricke et al., 2021; Van der Laan et al., 2021). We used the current conservation status in the International Union for Conservation of Nature (IUCN) Red List (2021) for each recorded species.

### 2.4. Statistical Analysis

Diversity indices (Simpson's, Shannon-Wiener and evenness) were computed using the PAST (PAleontological STatistics) software version 3.20 (Hammer et al., 2001). The Sorenson's similarity coefficient, the mean and standard deviation values of environmental parameters were calculated using the statistics package of Microsoft® Excel®. The Shannon values were turned to true biodiversity values (ENS) by calculating their exponents in Microsoft® Excel®.

## 3. Results

### 3.1. Ichthyofaunal Composition

The ichthyofaunal composition of the two collecting points is 446 individuals, comprising 112 species belonging to 88 genera, in 43 families and 17 orders, under two classes: Chondrichthyes and Actinopterygii. We collected 62 species of fishes from the first community and 50 species from the second one. The complete list of fishes collected from both points is in Table 1, following the current classification (Van der Laan et al., 2021) with their respective IUCN conservation statuses. There was no notable difference in fish species composition amongst the three months.

The fish fauna of the two points showed that community 1 has a higher number of fish species. The different orders of fish and their representation in percentage (Figure 2) are as follows: Perciformes (23.2%) with 26 species, followed by Carangiformes (17%) with 19 species and Clupeiformes (14.2%) with 16 species. The fourth order is Gobiiformes (9.8%) with 11 species, followed by Scombriformes (6.2%) with seven species. Cumulatively, these five

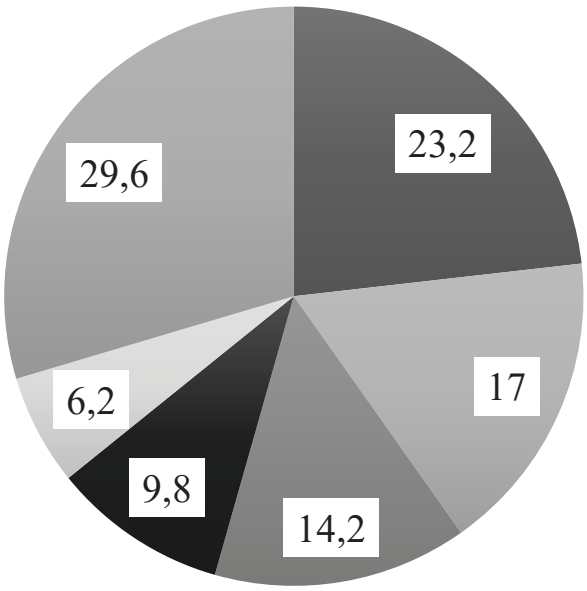


Figure 2. Major fish orders (expressed in percentage) from the two collection points in the Indian Sundarbans

orders comprise 70% of the total species encountered. The rest 30% is comprised of 12 orders: Siluriformes (5.3%), Mugiliformes (4.5%), Cypriniformes (4.5%), Acanthuriformes (4.5%), Tetraodontiformes (1.8%), Anguilliformes (1.8%), Centrarchiformes (1.8%), Beloniformes (1.8%), Myliobatiformes (0.9%), Aulopiformes (0.9%), Cichliformes (0.9%) and Gadiformes (0.9%).

Fish species contributing the highest dominance from the collection: *Amblypharyngodon mola*-27 individuals, *Bregmaceros mcclellandi*-22 individuals, *Escualosa thoracata*-21 individuals, *Puntius sophore*-13 individuals, *Gonialosa manmina*-12 individuals, *Coilia ramcarati*-11 individuals, *Periophthalmus novemradiatus*-10 individuals, *Ilisha kampeni*-10 individuals, *Salmostoma bacaila*-10 individuals and *Planiliza tade*-10 individuals.

We recorded 20 fish species for the first time from the Indian Sundarbans region (Table 1). Our study effectively brings the total number of fish species documented from the Indian Sundarbans to 378. Some of the fishes recorded are new records from West Bengal as well.

Table 1. The list of fishes collected from the two points in the Indian Sundarbans (explanations: NE, not evaluated; DD, data deficient; LC, least concern; VU, vulnerable; NT, near threatened; *, new records).

| Order | Family | Species | Common name | IUCN status |
|---|---|---|---|---|
| Myliobatiformes | Dasyatidae | *Brevitrygon imbricata* (Bloch & Schneider, 1801) | Scaly whipray | DD |
| Anguilliformes | Muraenidae | *Gymnothorax tile* (Hamilton, 1822) | Indian mud moray | LC |
| Anguilliformes | Congridae | *Uroconger lepturus* (Richardson, 1845) | Slender conger | LC |
| Clupeiformes | Clupeidae | *Escualosa thoracata* (Valenciennes, 1847) | White sardine | LC |
| Clupeiformes | Clupeidae | *Gonialosa manmina* (Hamilton, 1822) | Ganges River gizzard shad | LC |
| Clupeiformes | Clupeidae | *Sardinella longiceps* Valenciennes, 1847 | Indian oil sardine* | LC |
| Clupeiformes | Clupeidae | *Sardinella fimbriata* (Valenciennes, 1847) | Fringescale sardinella* | LC |
| Clupeiformes | Clupeidae | *Tenualosa toli* (Valenciennes, 1847) | Toli shad | VU |
| Clupeiformes | Engraulidae | *Setipinna taty* (Valenciennes, 1848) | Scaly hairfin anchovy | LC |
| Clupeiformes | Engraulidae | *Setipinna tenuifilis* (Valenciennes, 1848) | Common hairfin anchovy | DD |
| Clupeiformes | Engraulidae | *Coilia ramcarati* (Hamilton, 1822) | Ramcarat grenadier anchovy | DD |
| Clupeiformes | Engraulidae | *Thryssa gautamiensis* Babu Rao, 1971 | Gautama thryssa | DD |
| Clupeiformes | Engraulidae | *Thryssa kammalensoides* Wongratana, 1983 | Godavari thryssa* | DD |
| Clupeiformes | Engraulidae | *Thryssa spinidens* (Jordan & Seale, 1925) | Bengal thryssa* | DD |
| Clupeiformes | Engraulidae | *Stolephorus commersonnii* Lacepede, 1803 | Commerson's anchovy | LC |
| Clupeiformes | Pristigasteridae | *Raconda russeliana* Gray, 1831 | Raconda | LC |
| Clupeiformes | Pristigasteridae | *Pellona ditchela* Valenciennes, 1847 | Indian pellona | LC |
| Clupeiformes | Pristigasteridae | *Ilisha megaloptera* (Swainson, 1838) | Bigeye ilisha | LC |

| Order | Family | Species | Common name | IUCN status |
|---|---|---|---|---|
| Clupeiformes | Pristigasteridae | *Ilisha kampeni* (Weber & De Beaufort, 1913) | Kampen's ilisha | LC |
| Cypriniformes | Cyprinidae | *Cirrhinus mrigala* (Hamilton, 1822) | Mrigala | LC |
| Cypriniformes | Cyprinidae | *Pethia ticto* (Hamilton, 1822) | Tic-tac-toe barb | LC |
| Cypriniformes | Cyprinidae | *Puntius sophore* (Hamilton, 1822) | Pool barb | LC |
| Cypriniformes | Danionidae | *Salmostoma bacaila* (Hamilton, 1822) | Large razorbelly minnow | LC |
| Cypriniformes | Danionidae | *Amblypharyngodon mola* (Hamilton, 1822) | Mola carplet | LC |
| Siluriformes | Plotosidae | *Plotosus canius* Hamilton, 1822 | Gray eel catfish | NE |
| Siluriformes | Bagridae | *Mystus gulio* (Hamilton, 1822) | Long whiskers catfish | LC |
| Siluriformes | Bagridae | *Sperata seenghala* (Sykes, 1839) | Giant river-catfish | LC |
| Siluriformes | Ariidae | *Netuma thalassina* (Ruppell, 1837) | Giant sea catfish | NE |
| Siluriformes | Ariidae | *Nemapteryx nenga* (Hamilton, 1822) | Engraved catfish | NE |
| Siluriformes | Ariidae | *Arius arius* (Hamilton, 1822) | Threadfin sea catfish | LC |
| Aulopiformes | Synodontidae | *Harpadon nehereus* (Hamilton, 1822) | Bombay duck | NT |
| Gadiformes | Bregmacerotidae | *Bregmaceros mcclellandi* Thompson, 1840 | Unicorn cod | NE |
| Scombriformes | Stromateidae | *Pampus chinensis* (Euphrasen, 1788) | Chinese silver pomfret | NE |
| Scombriformes | Stromateidae | *Pampus argenteus* (Euphrasen, 1788) | Silver pomfret | NE |
| Scombriformes | Scombridae | *Scomberomorus lineolatus* (Cuvier, 1829) | Streaked seerfish* | LC |
| Scombriformes | Scombridae | *Scomberomorus guttatus* (Bloch & Schneider, 1801) | Indo-Pacific king mackerel | DD |
| Scombriformes | Trichiuridae | *Lepturacanthus savala* (Cuvier, 1829) | Savalai hairtail | NE |
| Scombriformes | Trichiuridae | *Lepturacanthus pantului* (Gupta, 1966) | Coromandel hairtail | DD |
| Scombriformes | Trichiuridae | *Eupleurogrammus glossodon* (Bleeker, 1860) | Longtooth hairtail* | NE |
| Gobiiformes | Eleotridae | *Butis butis* (Hamilton, 1822) | Crazy fish | LC |
| Gobiiformes | Gobiidae | *Boleophthalmus boddarti* (Pallas, 1770) | Boddart's goggle-eyed goby | LC |
| Gobiiformes | Gobiidae | *Odontamblyopus rubicundus* (Hamilton, 1822) | Rubicundus eelgoby | LC |
| Gobiiformes | Gobiidae | *Pseudapocryptes elongatus* (Cuvier, 1816) | Elongate mudskipper | LC |
| Gobiiformes | Gobiidae | *Periophthalmus novemradiatus* (Hamilton, 1822) | Pearse's mudskipper | DD |

| Order | Family | Species | Common name | IUCN status |
|---|---|---|---|---|
| Gobiiformes | Gobiidae | *Acentrogobius cyanomos* (Bleeker, 1849) | Threadfin blue goby* | LC |
| Gobiiformes | Gobiidae | *Glossogobius giuris* (Hamilton, 1822) | Tank goby | LC |
| Gobiiformes | Gobiidae | *Scartelaos histophorus* (Valenciennes, 1837) | Walking goby | LC |
| Gobiiformes | Gobiidae | *Trypauchen vagina* (Bloch & Schneider, 1801) | Pink worm goby | LC |
| Gobiiformes | Gobiidae | *Oxyurichthys microlepis* (Bleeker, 1849) | Maned goby* | LC |
| Gobiiformes | Gobiidae | *Gobiopsis macrostomus*_ Steindachner, 1861 | Lockjaw goby | LC |
| Carangiformes | Latidae | *Lates calcarifer* (Bloch, 1790) | Barramundi | LC |
| Carangiformes | Sphyraenidae | *Sphyraena jello* Cuvier, 1829 | Pickhandle barracuda* | NE |
| Carangiformes | Polynemidae | *Eleutheronema tetradactylum* (Shaw, 1804) | Fourfinger threadfin | NE |
| Carangiformes | Polynemidae | *Leptomelanosoma indicum* (Shaw, 1804) | Indian threadfin | NE |
| Carangiformes | Polynemidae | *Polynemus paradiseus* Linnaeus, 1758 | Paradise threadfin | LC |
| Carangiformes | Paralichthyidae | *Pseudorhombus arsius* (Hamilton, 1822) | Largetooth flounder | NE |
| Carangiformes | Soleidae | *Solea ovata* Richardson, 1846 | Ovate sole* | LC |
| Carangiformes | Cynoglossidae | *Cynoglossus lingua* Hamilton, 1822 | Long tonguesole | LC |
| Carangiformes | Cynoglossidae | *Cynoglossus quadrilineatus* (Bleeker, 1851) | Fourlined tonguesole* | LC |
| Carangiformes | Cynoglossidae | *Cynoglossus cynoglossus* (Hamilton, 1822) | Bengal tonguesole | LC |
| Carangiformes | Cynoglossidae | *Cynoglossus arel* (Bloch & Schneider, 1801) | Largescale tonguesole | DD |
| Carangiformes | Cynoglossidae | *Cynoglossus semifasciatus* Day, 1877 | Bengal tonguesole* | DD |
| Carangiformes | Cynoglossidae | *Cynoglossus macrolepidotus* (Bleeker, 1851) | Largescale tonguesole* | NE |
| Carangiformes | Cynoglossidae | *Paraplagusia bilineata* (Bloch, 1787) | Double-lined tonguesole | NE |
| Carangiformes | Toxotidae | *Toxotes chatareus* (Hamilton, 1822) | Spotted archerfish | LC |
| Carangiformes | Carangidae | *Caranx sexfasciatus* Quoy & Gaimard, 1825 | Bigeye trevally | LC |
| Carangiformes | Carangidae | *Scomberoides commersonnianus* Lacepede, 1801 | Talang queenfish | LC |
| Carangiformes | Carangidae | *Scomberoides tala* (Cuvier, 1832) | Barred queenfish | LC |
| Carangiformes | Carangidae | *Megalaspis cordyla* (Linnaeus, 1758) | Torpedo scad | LC |
| Cichliformes | Cichlidae | *Oreochromis mossambicus* (Peters, 1852) | Mozambique tilapia | VU |

| Order | Family | Species | Common name | IUCN status |
|---|---|---|---|---|
| Beloniformes | Belonidae | *Strongylura strongylura* (van Hasselt, 1823) | Spottail needlefish | NE |
| Beloniformes | Hemiramphidae | *Hyporhamphus limbatus* (Valenciennes, 1847) | Congaturi halfbeak | LC |
| Mugiliformes | Mugilidae | *Planiliza macrolepis* (Smith, 1846) | Largescale mullet | LC |
| Mugiliformes | Mugilidae | *Planiliza tade* (Fabricius, 1775) | Tade mullet | DD |
| Mugiliformes | Mugilidae | *Chelon melinopterus* (Valenciennes, 1836) | Otomebora mullet | LC |
| Mugiliformes | Mugilidae | *Mugil cephalus* Linnaeus, 1758 | Flathead grey mullet | LC |
| Mugiliformes | Mugilidae | *Rhinomugil corsula* (Hamilton, 1822) | Corsula mullet | LC |
| Acanthuriformes | Lobotidae | *Datnioides polota* (Hamilton, 1822) | Silver tiger perch | LC |
| Acanthuriformes | Leiognathidae | *Photopectoralis bindus* (Valenciennes, 1835) | Orangefin ponyfish | NE |
| Acanthuriformes | Leiognathidae | *Nuchequula blochii* (Valenciennes, 1835) | Twoblotch ponyfish | NE |
| Acanthuriformes | Leiognathidae | *Nuchequula gerreoides* (Bleeker, 1851) | Decorated ponyfish | NE |
| Acanthuriformes | Scatophagidae | *Scatophagus argus* (Linnaeus, 1766) | Spotted scat | LC |
| Tetraodontiformes | Tetraodontidae | *Lagocephalus spadiceus* (Richardson, 1845) | Half-smooth golden puffer | LC |
| Tetraodontiformes | Tetraodontidae | *Lagocephalus guentheri* Miranda Ribeiro, 1915 | Diamondback puffer* | LC |
| Centrarchiformes | Terapontidae | *Terapon theraps* Cuvier, 1829 | Largescaled terapon | LC |
| Centrarchiformes | Terapontidae | *Terapon jarbua* (Fabricius, 1775) | Tiger perch | LC |
| Perciformes | Ambassidae | *Parambassis lala* (Hamilton, 1822) | Hi-fin glassy perchlet* | NT |
| Perciformes | Ambassidae | *Parambassis ranga* (Hamilton, 1822) | Indian glassy fish | LC |
| Perciformes | Sillaginidae | *Sillaginopsis domina* (Cuvier, 1816) | Flathead sillago | NE |
| Perciformes | Sillaginidae | *Sillago sihama* (Fabricius, 1775) | Silver sillago | LC |
| Perciformes | Gerreidae | *Gerres macracanthus* Bleeker, 1854 | Long spined silverbiddy* | NE |
| Perciformes | Gerreidae | *Gerres setifer* (Hamilton, 1822) | Small Bengal silverbiddy | NE |
| Perciformes | Haemulidae | *Pomadasys maculatus* (Bloch, 1793) | Saddle grunt | LC |
| Perciformes | Sparidae | *Acanthopagrus berda* (Fabricius, 1775) | Goldsilk seabream | LC |
| Perciformes | Sparidae | *Acanthopagrus datnia* (Hamilton, 1822) | Bengal yellowfin seabream | DD |
| Perciformes | Sparidae | *Rhabdosargus sarba* (Gmelin, 1789) | Goldlined seabream | LC |
| Perciformes | Sciaenidae | *Otolithes ruber* (Bloch & Schneider, 1801) | Tigertooth croaker* | LC |

| Order | Family | Species | Common name | IUCN status |
|---|---|---|---|---|
| Perciformes | Sciaenidae | *Chrysochir aurea* (Richardson, 1846) | Reeves croaker | LC |
| Perciformes | Sciaenidae | *Pennahia aneus* (Bloch, 1793) | Donkey croaker* | LC |
| Perciformes | Sciaenidae | *Johnius dussumieri* (Cuvier, 1830) | Bearded croaker | LC |
| Perciformes | Sciaenidae | *Johnius borneensis* (Bleeker, 1851) | Sharpnose hammer croaker | LC |
| Perciformes | Sciaenidae | *Johnius belangerii* (Cuvier, 1830) | Belanger's croaker | LC |
| Perciformes | Sciaenidae | *Johnius carouna* (Cuvier, 1830) | Caroun croaker* | LC |
| Perciformes | Sciaenidae | *Johnius coitor* (Hamilton, 1822) | Coitor croaker | LC |
| Perciformes | Sciaenidae | *Otolithoides pama* (Hamilton, 1822) | Pama croaker | DD |
| Perciformes | Sciaenidae | *Panna microdon* (Bleeker, 1849) | Panna croaker | LC |
| Perciformes | Sciaenidae | *Macrospinosa cuja* (Hamilton, 1822) | Cuja croaker | DD |
| Perciformes | Sciaenidae | *Daysciaena albida* (Cuvier, 1830) | Bengal corvina | LC |
| Perciformes | Sciaenidae | *Pterotolithus maculatus* (Cuvier, 1830) | Blotch tiger-toothed croaker | LC |
| Perciformes | Mullidae | *Upeneus sulphureus* Cuvier, 1829 | Sulphur goatfish* | LC |
| Perciformes | Platycephalidae | *Grammoplites scaber* (Linnaeus, 1758) | Rough flathead | NE |
| Perciformes | Platycephalidae | *Platycephalus indicus* (Linnaeus, 1758) | Bartail flathead | DD |

## 3.2. Taxonomic Account of New Records of Fishes

We used the following abbreviations in this section: TL-Total length, SL-Standard length, BD-Body depth and ex-Examples/individuals. The materials examined section contains the number of individuals, the date of capture in DD-MM-YY format, the collection point and the registration number. The sizes provided are of the collected individuals.

1. *Sardinella longiceps* Valenciennes, 1847. Common name-Indian oil sardine (Plate I, 1).

Material examined: ex 2, 19-06-2018, Point 1, ZSI F 12905/2.

Description: Body moderately compressed; belly with a sharp keel of scutes 27-29, pre-pelvic-15-17, post-pelvic-12; pelvic fin with 1 unbranched and 8 branched rays; 13 dorsal fin rays; 14-15 anal fin rays; dense frontoparietal striae on top of head; a distinct black spot on posterior edge of gill cover.

Distribution: From the Gulf of Aden up to the Andaman Islands (Whitehead, 1985; Rajan et al., 2013).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-180-185 mm (SL).

2. *Sardinella fimbriata* (Valenciennes, 1847). Common name-Fringescale sardinella (Plate I, 2).

Material examined: ex 3, 18-06-2018, Point 1, ZSI F 12887/2.

Description: Belly with a sharp keel of 31-32 scutes; pre-pelvic-17-18, post-pelvic-14; pelvic fin with 1 unbranched and 7 branched rays; 14 dorsal fin rays; 15 anal fin rays; scales with well-developed posterior median extensions and discontinued striae; many frontoparietal striae on top of head; a black spot at dorsal fin origin.

Distribution: From Kuwait up to the eastern part of Papua New Guinea (Kailola, 1987; Abou-Seedo, 1992).

IUCN status: Least concern (LC).

Remarks: This fish has good fishery value. Size-123-137 mm (SL).

3. *Thryssa kammalensoides* Wongratana, 1983. Common name-Godavari thryssa (Plate I, 3).

Material examined: ex 2, 19-06-2018, Point 1, ZSI F 12901/2.

Description: Belly with 27 scutes; pre-pelvic-18, post-pelvic-9; 24-25 gill rakers on lower limb of first gill arch; serrae, not clumped together; maxilla reaching at least to edge of gill cover; 32 branched anal fin rays; a dark blotch on nape region extending to upper part of gill opening.

Distribution: Currently only known from Indian estuarine and coastal waters (Whitehead et al., 1988; Mishra and Krishnan, 1999).

IUCN status: Data deficient (DD).

Remarks: The fish has good fishery value. Size-108-114 mm (SL).

4. *Thryssa spinidens* (Jordan & Seale, 1925). Common name-Bengal thryssa (Plate I, 4).

Material examined: ex 2, 19-06-2018, Point 1, ZSI F 12705/2.

Description: Maxilla not reaching pectoral fin base; belly scutes 27; pre-pelvic-16, post-pelvic-11; 13 gill rakers on lower arm of first gill arch; teeth enlarged; anal fin with 3 branched and 40-41 unbranched rays; tip of snout located at level of upper rim of eye; no black blotch on upper part of gill opening.

Distribution: From India up to Thailand (Whitehead et al., 1988; Monkolprasit et al., 1997).

IUCN status: Data deficient (DD).

Remarks: The fish has good fishery value. Size-135-140 mm (SL).

5. *Scomberomorus lineolatus* (Cuvier, 1829). Common name-Streaked seerfish (Plate I, 5).

Material examined: 1 ex, 19-06-2018, Point 1, ZSI F 12875/2.

Description: Compressed body; 8 dorsal and anal finlets; 9 gill rakers on lower limb of first gill arch; second dorsal fin closer to caudal fin than snout; lateral line gradually bending downwards towards caudal keels; horizontal narrow black bars laterally.

Distribution: From India up to Java (Allen & Smith-Vaniz, 1994; Kapoor et al., 2002).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-190 mm (SL).

6. *Eupleurogrammus glossodon* (Bleeker, 1860). Common name-Longtooth hairtail (Plate I, 6).

Material examined: 1 ex, 19-06-2018, Point 1, ZSI F 12873/2.

Description: Body tapering, ribbon-like; subopercle lower margin convex; eyes close to dorsal profile; tip with a pair of fangs; pectoral fin extending beyond lateral line; tip of each jaw with black dermal flaps.

Distribution: From the Persian Gulf up to Thailand (Nakamura and Parin, 1993).

IUCN status: Not evaluated (NE).

Remarks: The fish has good fishery value. Size-110 mm (TL).

7. *Acentrogobius cyanomos* (Bleeker, 1849). Common name-Threadfin blue goby (Plate I, 7).

Material examined: 1 ex, 19-06-2018, Point 1, ZSI F 12735/2.

Description: Pelvic fins medially joined; cheek and opercle naked; scales cycloid on pectoral fin base and breast, ctenoid on rest of the body; first dorsal fin with 6 spines, second dorsal fin with 1 spine and 10 soft rays; pectoral fin with 18 rays; anal fin with 1 spine and 9 soft rays; longitudinal scale series 23; pre-dorsal scales 10; presence of numerous bright pale blue spots on body and fins.

Distribution: From India up to Indonesia (Kottelat et al., 1993; Rema Devi, 1993).

IUCN status: Least concern (LC).

Remarks: The fish has no significant fishery value. Occasionally collected in the aquarium fish trade for its colourful appearance. Size-80 mm (SL).

8. *Oxyurichthys microlepis* (Bleeker, 1849). Common name-Maned Goby (Plate I, 8).

Material examined: 1 ex, 18-06-2018, Point 1, ZSI F 12799/2.

Description: Pelvic fins medially joined by a simple frenum; nape with a narrow dermal crest; first dorsal fin with 6 spines; second dorsal fin with 1 spine and 12 soft rays; pectoral fin with 20 rays; anal fin with 1 spine and 13 soft rays; longitudinal scale series 42; pre-dorsal scales 14; a distinctive round black spot on upper portion of eye; many scales on nape and back have dense black-brown spots on them.

Distribution: From Pakistan to North-eastern Australia (Talwar and Jhingran, 1991; Pezold and Larson, 2015).

IUCN status: Least concern (LC).

Remarks: The fish has no significant fishery value. Occasionally collected in the aquarium fish trade for its colourful appearance and also used as baitfish. Size-82 mm (SL).

9. *Sphyraena jello* Cuvier, 1829. Common name-Pick-handle barracuda (Plate I, 9).

Material examined: 1 ex, 18-05-2018, Point 2, ZSI F 12878/2.

Description: Maxilla reaches just below anterior margin of eye; no gill rakers on first gill arch; first dorsal fin with 5 spines; second dorsal fin with 1 spine and 9 soft rays; anal fin with 2 spines and 8 soft rays; caudal fin forked; 138 pored lateral line scales.

Distribution: Entire Indo-West Pacific (Allen and Erdman, 2012).

IUCN status: Not evaluated (NE).

Remarks: The fish has good fishery value. Size-216 mm (SL).

10. *Solea ovata* Richardson, 1846. Common name-Ovate sole (Plate I, 10).

Material examined: ex 3, 29-05-2018, Point 2, ZSI F 12833/2.

Description: Body ovate; BD two times in TL; snout obtusely pointed with maxilla reaching midpoint of lower eye; rostral hook short; only 1 lateral line on eyed side and none on blind side; eyes separated by a scaly concave space; pectoral fin on ocular side about 1.8 times as long as one on blind side; scales ctenoid on both sides; caudal fin separated from dorsal and anal fin; 66-68 dorsal fin rays; 45-48 anal fin rays; eyed side brown with black blotches on body and fins.

Distribution: From India up to Indonesia (Munroe, 2001; Kapoor et al., 2002).

IUCN status: Least concern (LC).

Remarks: The fish has some fishery value. Size-58-63 mm (SL).

11. *Cynoglossus quadrilineatus* (Bleeker, 1851). Common name-Fourlined tonguesole (Plate I, 11).

Material examined: 1 ex, 27-04-2018, Point 1, ZSI F 12712/2.

Description: Body moderately elongated; rostral hook short; corner of mouth reaches beyond posterior of lower eye; 2 lateral lines on eyed side and 2 on blind side; 14 scale rows between lateral lines on eyed side; 110 dorsal fin rays; 83 anal fin rays; eyed side brown with an uneven black mark on gill cover.

Distribution: From Saudi Arabia up to Japan, Australia (Blaber, 1980; Masuda et al., 1984; Carpenter et al., 1997).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-183 mm (SL).

12. *Cynoglossus semifasciatus* Day, 1877. Common name-Bengal tonguesole (Plate I, 12).

Material examined: 1 ex, 26-05-2018, Point 2, ZSI F 12861/2.

Description: Body elongated; snout rounded; angle of mouth extending a little beyond vertical from eye; rostral hook short; 2 lateral lines on eyed side and none on blind side; mid-lateral line with 73 scales; 12 scale rows between two lateral lines; 102 dorsal fin rays; 77 anal fin rays; 10 caudal fin rays; eyed side reddish-brown with a few faint, uneven bands.

Distribution: From India, Sri Lanka and possibly Thailand (De Bruin et al., 1994; Monkolprasit et al., 1997; Mishra & Krishnan, 2003).

IUCN status: Data deficient (DD).

Remarks: The fish has good fishery value. Size-160 mm (SL).

13. *Cynoglossus macrolepidotus* (Bleeker, 1851). Common name-Largescale tonguesole (Plate I, 13).

Material examined: 1 ex, 19-06-2018, Point 1, ZSI F 12850/2.

Description: Body elongated; snout pointed; angle of mouth reaching beyond lower eye, about midway between gill opening and snout tip; rostral hook short; 2 lateral lines on eyed side and none on blind side; scales ctenoid on eyed side, cycloid on blind side; mid-lateral line with 59 scales; 8 scale rows between two lateral lines; 122 dorsal fin rays; 73 anal fin rays; 10 caudal fin rays; eyed side uniform brown in colouration.

Distribution: From India up to Indonesia (Mishra et al., 1999; Fricke et al., 2017).

IUCN status: Not evaluated (NE).

Remarks: The fish has good fishery value. Size-132 mm (SL).

14. *Lagocephalus guentheri* Miranda Ribeiro, 1915. Common name-Diamondback puffer (Plate I, 14).

Material examined: ex 3, 29-05-2018, Point 2, ZSI F 12787/2.

Description: Spinule patch on back, halfway through interorbital origin to dorsal fin base; 10-12 dorsal fin rays; 11-12 anal fin rays; caudal fin in fresh specimens with slight posterior extensions (appears as doubly emarginated), caudal fin tips white; dorsal half of body with broad dusky bands.

Distribution: From Saudi Arabia up to Japan (Matsuura et al., 2011; Bogorodsky and Randall, 2018).

IUCN status: Least concern (LC).

Remarks: Consumed locally in the Sundarbans (Mishra et al., 2018). Size-53-65 mm (SL).

15. *Parambassis lala* (Hamilton, 1822). Common name-Hi-fin glassy perchlet (Plate I, 15).

Material examined: 1 ex, 29-05-2018, Point 2, ZSI F 12918/2.

Description: Body deeply compressed; lower jaw longer than upper jaw; first dorsal fin with 6 spines, second dorsal fin with 1 spine and 12 soft rays; anal fin with 3 spines and 15 soft rays; caudal fin forked; body brightly coloured with red and yellow.

Distribution: Occurs primarily in freshwater ecosystems in India, Bangladesh and Myanmar (Talwar and Jhingran, 1991; Vidthayanon et al., 2005).

IUCN status: Near threatened (NT).

Remarks: The fish has no significant fishery value. Size-25 mm (SL).

16. *Gerres macracanthus* Bleeker, 1854. Common name-Longspined silverbiddy (Plate I, 16).

Material examined: 1 ex, 29-05-2018, Point 2, ZSI F 12888/2.

Description: Body elongated; BD 2.7 times in SL; dorsal fin with 9 spines and 10 soft rays; second dorsal spine filamentous; anal fin with 3 spines and 7 soft rays; 42 lateral line scales; 8 indistinct vertical bands on flanks.

Distribution: From the Red Sea up to New Guinea (Weber ad De Beaufort, 1931; Iwatsuki et al., 2013).

IUCN status: Not evaluated (NE).

Remarks: The fish has good fishery value. Size-67 mm (SL).

17. *Otolithes ruber* (Bloch and Schneider, 1801). Common name-Tigertooth croaker (Plate I, 17).

Material examined: ex 2, 29-05-2018, Point 2, ZSI F 12728/2.

Description: Body slender; mouth oblique; first dorsal fin with 10 spines; second dorsal fin with 1 spine and 26-28 soft rays; anal fin with 2 spines and 7 soft rays; caudal fin rhomboidal; 10 gill rakers on lower limb of first gill arch; big canine teeth on both jaws; swimbladder carrot-shaped, with 30-32 branching appendages on each side.

Distribution: From East Africa up to Australia (van der Elst, 1993; Hoese et al., 2006).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-112 mm (SL).

18. *Pennahia aneus* (Bloch, 1793). Common name-Donkey croaker (Plate I, 18).

Material examined: ex 2, 29-05-2018, Point 2, ZSI F 12903/2.

Description: Mouth large; teeth large and small in both jaws; 9 spines on first dorsal fin; second dorsal fin with 1 spine and 22 soft rays; anal fin with 2 spines and 7 soft rays; 11 gill rakers on lower limb of first gill arch; caudal fin truncate; swimbladder carrot-shaped, with 17 branched appendages along its sides.

Distribution: From the Persian Gulf up to Taiwan (Sasaki, 2001).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-71-109 mm (SL).

19. *Johnius carouna* (Cuvier, 1830). Common name-Caroun croaker (Plate I, 19).

Material examined: ex 3, 29-05-2018, Point 2, ZSI F 12900/2.

Description: Mouth small, inferior; first dorsal fin with 10 spines; second dorsal fin with 1 spine and 29-30 soft rays; anal fin with 2 spines and 7 soft rays; 14 gill rakers on lower limb of first gill arch; caudal fin rhomboidal; swimbladder hammer-shaped, with 14-15 branching appendages on each side.

Distribution: From India up to Southern China (Talwar, 1995; Sasaki, 2001).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-105-126 mm (SL).

20. *Upeneus sulphureus* Cuvier, 1829. Common name-Sulphur goatfish (Plate I, 20).

Material examined: ex 5, 18-06-2018, Point 1, ZSI F 12819/2.

Description: BD 3.2 times in SL; first dorsal fin with 8 spines; second dorsal fin with 1 spine and 7-8 soft rays; anal fin with 1 spine and 6 soft rays; scales on anal fin and second dorsal fin; barbels reach posterior margin of preopercle; two narrow yellow stripes in live and freshly dead specimens; no bars on caudal fin lobes.

Distribution: From East Africa up to Australia (Uiblein & Heemstra, 2010).

IUCN status: Least concern (LC).

Remarks: The fish has good fishery value. Size-59-79 mm (SL).

### 3.3. Environmental Parameters

Water quality parameters (Table 2) displayed strong evidence of tidal incursion, with considerable freshwater influence due to monsoonal discharge in the Sundarbans delta. We observed moderately high salinity (mean: 1.011-1.017) and moderately high dissolved oxygen (mean: 9.6-10.1). The average water pH was slightly alkaline and was relatively constant among the two sites, ranging between 7.4 and 8.2. We measured higher salinity at point 1.

### 3.4. Diversity Status

The values of Shannon Wiener index (H), evenness (E) and Simpson's diversity index (1-D) for both communities are shown in Figures 3-5.

Community 1 has a Shannon-Wiener index value of 3.94 and evenness of 0.830, while community 2 has a Shannon index of 3.72 and evenness of 0.832. The ENS calculated from the Shannon indices are 51 for community 1 and 41 for community 2, meaning community 1 is 1.24 times more diverse than community 2. Community 1 has a Simpson's diversity index of 0.979, while community

Table 2. Mean and standard deviation values of environmental parameters of the two collection points (April 2018-June 2018).

| Collection Point | Salinity | Dissolved oxygen (mg $L^{-1}$) | pH | Water temperature (˚C) | Secchi Depth (inches) |
|---|---|---|---|---|---|
| Point 1 | 1.017 ± 2.2 | 9.6 ± 5.7 | 8.2 ± 3.4 | 24.3 ± 1.3 | 36.1 ± 4.8 |
| Point 2 | 1.011 ± 1.7 | 10.1 ± 2.6 | 7.4 ± 1.4 | 25.5 ± 2.8 | 38.3 ± 1.6 |

2 has 0.973. The value of Sorenson's coefficient of community is 0.87.

## 4. Discussion

The Shannon-Wiener diversity measure comes from information theory (Rissanen, 1997). It measures the number of individuals observed for each species in a sample area. In this study, community 1 has a Shannon index of 3.94, suggesting that the richness and evenness of community 1 are more than that of community 2, which has a value of 3.72. However, these two values are just indices. To effectively compare species diversity, we calculated the effective number of species. We found that community 1 has a value of 51, which is 1.24 times more than the ENS of community 2, 41. The evenness values show that both communities are pretty even (community 1: 0.830, community 2: 0.832) with a slight difference.

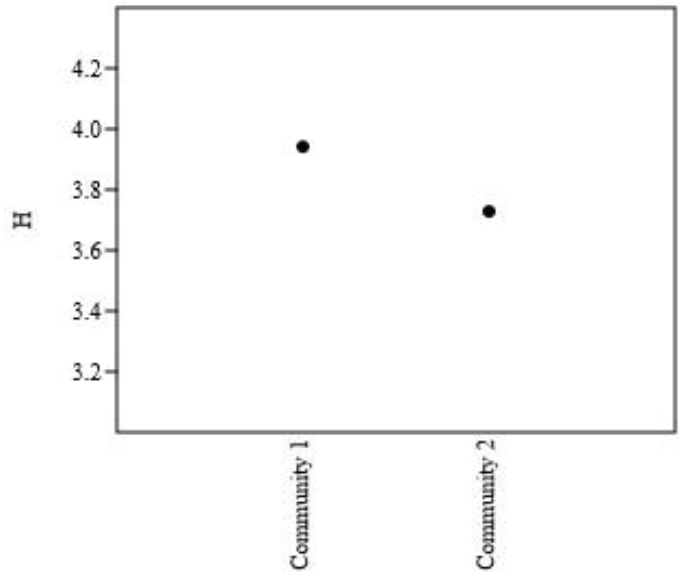


Figure 3. The Shannon-Wiener index (H) of community 1 = 3.94 and community 2 = 3.72.

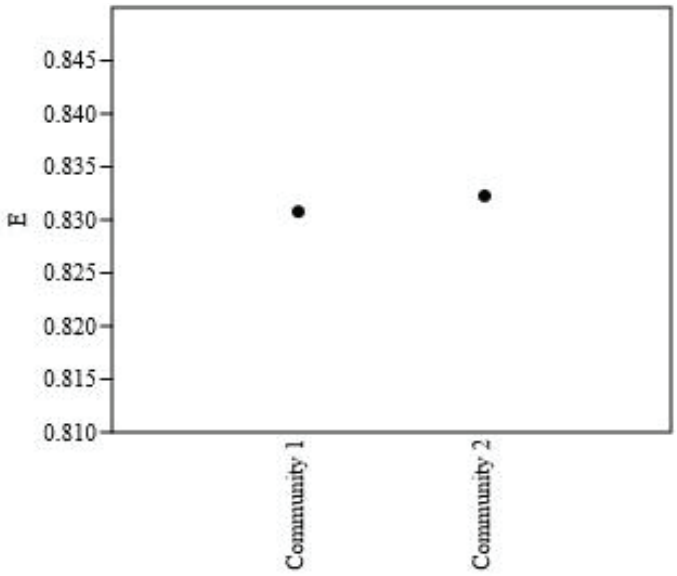


Figure 4. The evenness (E) of community 1 = 0.830 and community 2 = 0.832.

A modified scale of pollution represented in terms of species diversity shows a negative correlation between the Shannon index and pollution (Staub et al., 1970). According to its range, both communities in our study are only marginally polluted.

Simpson's index for community 1 is 0.979. It has a slightly greater value when compared to community 2, whose value is 0.973. However, the indices of both communities suggest decent species diversity at both points. The coefficient of community value of 0.87 signifies a good deal of similarity in species between two points (a value of 1 suggests a complete overlap of species between the communities).

There exists a significant correlation of mangrove forest attributes (natural, degraded and replanted) with estuarine fish and crustacean species diversity (Crona and Ronnback, 2005; Manson et al., 2005; Sandoval Londoño et al., 2020). Therefore, we hypothesize that fewer mangroves and the presence of anthropogenic pressures could be the reason community 2 has a relatively less number of species. Its location near the village of Amlamethi in Bally-I island could be why it has less mangrove cover and faces human-related pressures.

We have provided the respective IUCN statuses for all the fishes we have listed. In our collection, we found two fish species-*Harpadon nehereus* and *Parambassis lala,* belonging to the conservation category near threatened (NT). We also found two species-*Tenualosa toli*, *Oreochromis mossambicus* belonging to the vulnerable (VU) category. All four species face a risk of extinction in the wild. Others mainly fell into the least concern (LC), not evaluated (NE), and data deficient (DD) categories. One of the vulnerable fish, *Oreochromis mossambicus*, is an invasive species in India (Ganie et al., 2013). However, it faces extirpation in its native range (Zengeya et al., 2015).

We have provided only those assessments that are based globally. The basis of some categorizations in the IUCN Red List are regional assessments (e.g., *Eleutheronema tetradactylum* assessed to be endangered (Motomura et al., 2015), based on studies from the Persian Gulf). So, the applicability of such assessments for Indian Sundarbans remains to be ground-truthed. There is an urgent need to assess the status of the not evaluated fishes in the Indian Sundarbans, as they are collected regularly for human consumption and sale.

We recommend being mindful about the terms: Data deficient (DD) and Not evaluated (NE). One must never synonymize them with the category of Least Concern (LC). There is an equal threat of extinction for species that currently falls in the DD and NE categories. We have graphically represented the number of fishes and their respective conservation categories (Figure 6). All species reported in this study are economically significant and locally consumed, even Tetraodontiformes (Mishra et al., 2018).

Pneumatophores and prop roots of the mangrove trees, along with their fallen branches and leaves, make a complex habitat for a host of prey organisms, forming an important food source for many fish species (Verweij et al., 2006). Therefore, mangroves form a core fish habitat in tropical estuaries and lagoons (Blaber, 2007).

A total of 20 fish species were recorded for the first time from the Indian Sundarbans during this study. It effectively brings the total number of fish species recorded from the region to 378. Some of the newly documented fishes

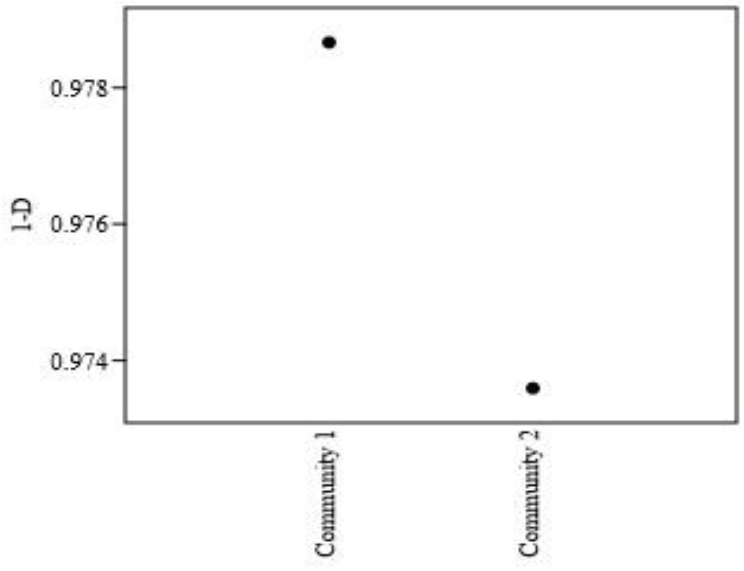


Figure 5. IUCN conservation status of the fishes collected during the study

are also first records from West Bengal, e.g., *Thryssa kammalensoides, Scomberomorus lineolatus, Lagocephalus guentheri,* and others

Salinity plays a significant role in the distribution of marine and brackish water fishes, and long term variations in salinity can affect fish species distribution (Cyrus and Blaber, 1992). In many studies, catch rates of abundant species correlated strongly with salinity patterns (Barletta et al., 2005; Lugendo et al., 2007). We recorded salinity only during sampling and not during other times. Such discrepancy disallows from accurately correlating salinity with fish distribution within the scope of this study. The need to collect environmental data consistently over a more prolonged period is necessary. We hypothesize tidal incursion to have a role to play in the distribution of the newly recorded fishes.

Abiotic factors like turbidity may also play a role in the presence of fish species absent earlier. Since turbidity is usually high in the mangrove region, it reduces the visual capacity of large predators. The shallow waters exclude large predatory fishes from entering them, helping smaller fish to take shelter and thrive in the creeks around mangroves (Cyrus and Blaber, 1987). The mean visible depth of both the collecting points was almost similar (point 1-36", point 2-38").

Another possible explanation of why we found these previously unreported fishes could be because they probably escaped the attention of science. It could be due to inadequate sampling or incorrect taxonomy. For example, a newly described Moray eel: *Gymnothorax pseudotile* Mohapatra, Smith, Ray, Mishra & Mohanty, 2017 was considered a marine fish until its recent report from the Indian Sundarbans (Chakraborty, et al. 2018). It probably got overlooked in previous surveys from the Indian Sundarbans.

The presence of *Thryssa kammalensoides* in the Sundarbans is intriguing as this species was previously only recorded from the coastal waters of the neighbouring state of Odisha, with a northern limit up to Chandipur in the Balasore district (Mishra and Krishnan, 1999).

We suspect foraging to be a reason behind the occurrence of *T. kammalensoides* in the region. Both the quantity and type of food found in mangrove areas are different from adjacent marine areas. Many of the microflora and fauna found in the sheltered mangroves are not present in offshore waters. Therefore, there is an increase in the diversity and quantity of food available to fishes in the mangroves (Robertson and Duke, 1990). The availability of *T. kammalensoides* in Sundarbans may be correlated to the availability of its food source.

We recorded almost all freshwater fish species from community 2. The mean value of salinity of community 2 is considerably less than that of community 1. The collection point was very close to an island with several freshwater outlets, and there was the added freshwater influx of the monsoons. We believe that those reasons could have allowed for the survival of freshwater fishes in the collection point.

Seasonal variations in nutrients affect the coexistence of many fish species (Huh andFigure Kitting, 1985). The first author noted a large number of small shrimps getting caught in each haul. There could be a relation between the high incidences of these crustaceans with observed fish species. Some fishes were found when the salinity

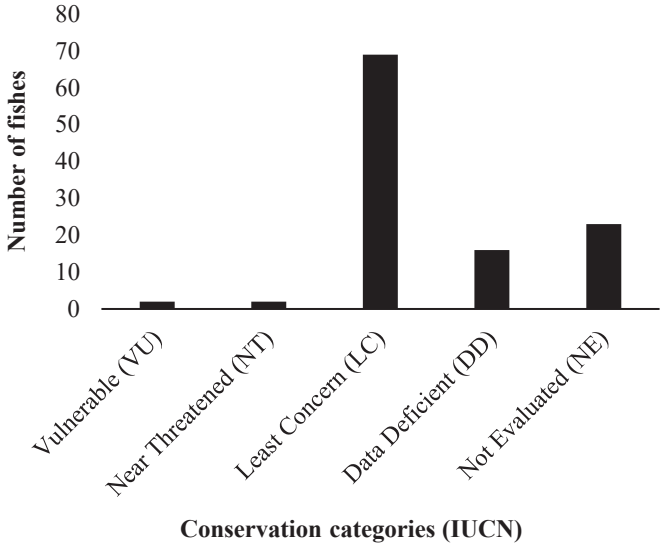


Figure 6. IUCN status of the fishes collected during the study (NE-22, DD-16, LC-70, NT-2, and VU-2).

of a point was considerably higher. For example, in community 2, the fishers caught the Pickhandle barracuda on a day when the salinity was-1.019. The environmental parameters provide some insights into the ecology of the fishes.

## 5. Conclusions

In this study, we found the fish composition from both communities to be moderately distinct from each other. The Shannon values indicate that both communities are high in species richness and evenness. No particular species dominate the communities. The true diversity values reveal that community 1 is 1.24 times as diverse in fish species as community 2. A high Simpson's index indicates that both communities are considerably diverse. All the values are indicative of the overall good health of the surrounding ecosystem.

We recorded a total of 20 fish species from the mangroves for the first time, bringing the total number of fishes recorded from the Indian Sundarbans to 378. Some are even new records from West Bengal, India. The Indian Sundarbans is a highly variable region, and its variability affects the ever-changing ichthyofauna residing in its brackish waters. The present study is a baseline study for only three months. We believe that long term monitoring to assess the distribution and abundance of the ichthyofaunal diversity of Sundarbans is crucial, especially the responses to climate change.

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## References

Abou-Seedo F.S., 1992, Abundance of fish caught by stake-traps (*hadra*) in the intertidal zone in Doha, Kuwait Bay. Journal of the University of Kuwait 19: 91-99.

Allen G.R. & Erdmann M.V., 2012, Reef fishes of the East Indies, volumes I-III. Tropical Reef Research, Perth: 1260.

Allen G.R. & Smith-Vaniz W.F., 1994, Fishes of the Cocos (Keeling) Islands. Atoll Research Bulletin 412: 1-21.

Andharia J., 2020, A Web of Vulnerabilities: Eco-fragility, Poor Livelihoods and Cyclones in Sundarban Region, India, [in:] Disaster Studies, J. Andharia (ed.), Springer, Singapore: 357-374. doi: https://doi.org/10.1007/978-981-32-9339-7_17

Barik J. & Chowdhury S., 2014, True Mangrove Species of Sundarbans Delta, West Bengal, Eastern India: A Revised Species List. Check List 10(2): 329-334. doi: https://doi.org/10.15560/10.2.329

Barletta M., Barletta-Bergen A., Saint-Paul U. & Hubold G., 2005, The role of salinity in structuring the fish assemblages in a tropical estuary. Journal of Fish Biology 66(1): 45-72. doi: https://doi.org/10.1111/j.0022-1112.2005.00582.x

Blaber S.J.M., 1980, Fish of Trinity Inlet system of north Queensland with notes on the ecology of fish faunas of tropical Indo-Pacific estuaries. Marine and Freshwater Research 31(2): 137-146.

Blaber S.J.M., 2007, Mangroves and fishes: issues of diversity, dependence, and dogma. Bulletin of Marine Science 80(3): 457-472.

Bogorodsky S.V. & Randall J.E., 2018, Endemic fishes of the Red Sea, [in:] Oceanographic and biological aspects of the Red Sea, N.M.A. Rasul & I.C.F. Stewart (eds.), Springer Oceanography, Basel: 239-265.

Brinda S., Srinivasan M., Balakrishnan S., 2010, Studies on diversity of finfish larvae in Vellar estuary, Southeast coast of India. World Journal of Fish and Marine Sciences 2(1): 44-50.

Carpenter K.E., Krupp F., Jones D.A. & Zajonz U., 1997, Species identification guide for fishery purposes. The living marine resources of Kuwait, eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. FAO, Rome: 239.

Chakraborty P., Saren S.C., Sengupta A. & Mishra S.S., 2018, Notes on the record of *Gymnothorax pseudotile* Mohapatra et al., 2017 (Muraenidae: Muraeninae) from the Sundarbans, West Bengal, India. Records of Zoological Survey of India 118(3): 318-321. doi: 10.26515/rzsi/v118/i3/2018/121639

Crona B.I. & Ronnback P., 2005, Use of replanted mangroves as nursery grounds by shrimp communities in Gazi Bay, Kenya. Estuarine Coastal and Shelf Science 65(3): 535-544. doi: https://doi.org/10.1016/j.ecss.2005.07.001

Cyrus D.P. & Blaber S.J.M., 1987, The influence of turbidity on juvenile marine fish in the estuaries of Natal, South Africa. Continental Shelf Research 7(11/12): 1411-1416. doi: https://doi.org/10.1016/0278-4343(87)90046-X

Cyrus D.P. & Blaber S.J.M., 1992, Turbidity and salinity in a tropical northern Australian estuary and their influence on fish distribution. Estuarine, Coastal and Shelf Science 35(6): 545-563. doi: https://doi.org/10.1016/S0272-7714(05)80038-1

Darwall W.R.T. & Vie´ J.C., 2005, Identifying important sites for conservation of freshwater biodiversity: extending the species-based approach. Fisheries Management and Ecology 12(5): 287-293. doi: https://doi.org/10.1111/j.1365-2400.2005.00449.x

De Bruin G.H.P., Russell B.C., Bogusch A., 1994, Species identification guide for fishery purposes. The marine fishery resources of Sri Lanka. FAO, Rome: 400.

Fricke R., Eschmeyer W.N., Van der Laan R., (eds.), 2021, ESCHMEYER'S CATALOG OF FISHES: GENERA, SPECIES, REFERENCES. California Academy of Sciences, San Francisco, CA, USA. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp [electronic version, Accessed 22 February 2021].

Fricke R., Golani D., Appelbaum-Golani B., 2017, *Cynoglossus crepida*, a new species of tongue sole from the Gulf of Aqaba, Red Sea (Teleostei: Cynoglossidae). Journal of the Ocean Science Foundation 25: 77-87.

FSI, 2019, India State of Forest Report. Forest Survey of India, Dehradun: 183.

Ganie M.A., Bhat M.D., Khan M.I., Parveen M., Balkhi M.H. & Malla M.A., 2013, Invasion of the Mozambique tilapia, *Oreochromis mossambicus* (Pisces: Cichlidae; Peters, 1852) in the Yamuna river, Uttar Pradesh, India. Journal of Ecology and the Natural Environment 5(10): 310-317.

Hammer Ø., Harper D.A.T., Ryan P.D., 2001, PAST: Paleontological statistics software package for education and data analysis. Palaeontologia electronica 4(1): 1-9.

Hoese D.F., Bray D.J., Paxton J.R. & Allen G.R., 2006, Fishes, [in:] Zoological Catalogue of Australia, volume 35, O.L. Beasley & A. Wells (eds.), ABRS & CSIRO Publishing, Australia: 1-2178.

Huh S.H. & Kitting C.L., 1985, Trophic relationships among concentrated populations of small fishes in seagrass meadows. Journal of Experimental Marine Biology and Ecology 92(1): 29-43. doi: https://doi.org/10.1016/0022-0981(85)90020-6

IUCN, 2021, *The IUCN Red List of Threatened Species. Version 2021-1.* https://www.iucnredlist.org Downloaded on [09 February 2021].

Iwatsuki Y., Jawad L.A., Tanaka F., Al-Busaidi H., Al-Mamry J.M. & Al-Kharusi L.H., 2013, Omani fishes collected in the vicinity of Mutrah, Gulf of Oman and Madrakah, southern Oman through 3 to 13 October 2010. Bulletin of the Faculty of Agriculture, University of Miyazaki 59: 29-41.

Kailola P.J., 1987, The fishes of Papua New Guinea. A revised and annotated checklist, volume I: Myxinidae to Synbranchidae. Research Bulletin No. 41. Department of Fisheries and Marine Resources, Port Moresby: 194.

Kapoor D., Dayal R., Ponniah A.G., 2002, Fish biodiversity of India. National Bureau of Fish Genetic Resources, Lucknow: 775.

Karr J.R., 1981, Assessment of biotic integrity using fish communities. Fisheries 6(6): 21-27. doi: https://doi.org/10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2

Kottelat M., Whitten A.J., Kartikasari S.N. & Wirjoatmodjo S., 1993, Freshwater fishes of Western Indonesia and Sulawesi. Periplus Editions, Hong Kong: 259.

Lugendo B.R., de Groene A., Cornelissen I., Pronker A., Nagelkerken I., van der velde G. & Mgaya Y.D., 2007, Spatial and temporal variation in fish community structure of a marine embayment in Zanzibar, Tanzania. Hydrobiologia 586(1):1-16.

Manson F.J., Loneragan N.R., Skilleter G.A. & Phinn S.R., 2005, An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions. Oceanography and Marine Biology-An Annual Review 43: 483-513.

Marzluff J.M. & Ewing K., 2008, Restoration of Fragmented Landscapes for the Conservation of Birds: A General Framework and Specific Recommendations for Urbanizing Landscapes, [in:] Urban Ecology, J.M. Marzluff et al. (eds.), Springer, Boston, MA: 739-755. doi: https://doi.org/10.1007/978-0-387-73412-5_48

Masuda H., Amaoka K., Araga C., Uyeno T. & Yoshino T., 1984, The Fishes of the Japanese Archipelago, volume 1. Tokai University Press, Tokyo: 437.

Matsuura K., Golani D., Bogorodsky S.V., 2011, The first record of *Lagocephalus guentheri* Miranda Ribeiro, 1915 from the Red Sea with notes on previous records of *L. lunaris* (Actinopterygii, Tetraodontiformes, Tetraodontidae). Bulletin of the National Museum of Nature and Science, Series A 37(3): 163-169.

Mishra S.S. & Krishnan S., 1999, On the occurrence of *Thryssa kammalensis* (Bleeker) and *Thryssa kammalensoides* Wongratana (Engraulididae: Pisces) from India. Records of Zoological Survey of India 97(3/4): 109-111.

Mishra S.S. & Krishnan S., 2003, Marine fishes of Pondicherry and Karaikal. Records of the Zoological Survey of India, Occasional Paper No. 216: 1-52.

Mishra S.S., Chakraborty P., Saren S.C. & Sengupta A., 2018, First record of *Lagocephalus guentheri* Miranda Riberio 1915 (Tetraodontiformes: Tetraodontidae) from the West Coast of India. Records of Zoological Survey of India 118(1): 91-96. doi: https://doi.org/10.26515/rzsi/v118/i1/2018/122386

Mishra S.S., Gopi K.C., 2017, Fish diversity of Indian Sundarbans and its resources and research prospects, [in:] Fauna of Sundarbans Biosphere Reserve, K. Chandra et al. (eds.), Zoological Survey of India, Kolkata: 107-127.

Mishra S., Gouda R., Nayak L. & Panigrahy R.C., 1999, A check list of the marine and estuarine fishes of south Orissa, east coast of India. Records of the Zoological Survey of India 97(3): 81-90.

Monkolprasit S., Sontirat S., Vimollohakarn S. & Songsirikul T., 1997, Checklist of Fishes in Thailand. Office of Environmental Policy and Planning, Bangkok: 353.

Motomura H., Matsuura K., Bishop J. & Kaymaram F., 2015, *Eleutheronema tetradactylum*. The IUCN Red List of Threatened Species 2015: e.T46087646A57168342. Downloaded on 09 April 2021.

Munroe T.A., 2001, Families Soleidae, [in:] Species identification guide for fishery purposes. The living marine resources of the western central Pacific, volume 6. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals, K.E. Carpenter & V.H. Niem (eds.), FAO, Rome: 3878-3889.

Nakamura I. & Parin N.V., 1993, FAO species catalogue. Snake mackerels and cutlassfishes of the world (Families Gempylidae and Trichiuridae). An annotated and illustrated catalogue of the snake mackerels, snoeks, escolars, gemfishes, sackfishes, domine, oilfish, cutlassfishes, scabbardfishes, hairtails, and frostfishes known to date. FAO Fisheries Synopsis 125(15): 1-136.

Padhy S.R., Bhattacharyya P., Dash P.K., Reddy C.S., Chakraborty A. & Pathak H., 2020, Seasonal fluctuation in three mode of greenhouse gases emission in relation to soil labile carbon pools in degraded mangrove, Sundarban, India. The Science of the total environment 705: 135909. doi: https://doi.org/10.1016/j.scitotenv.2019.135909

Pezold F.L. & Larson H.K., 2015, A revision of the fish genus *Oxyurichthys* (Gobioidei: Gobiidae) with descriptions of four new species. Zootaxa 3988(1): 1-95.

Rajan P.T., Sreeraj C.R., Immanuel T., 2013, Fishes of Andaman, Andaman and Nicobar Islands: a checklist. Journal of Andaman Science Association 18(1): 47-87.

Rema Devi K., 1993, Gobioids of Ennore Estuary and its vicinity. Records of the Zoological Survey of India 90(1/4): 161-189.

Rissanen J., 1997. Shannon-Wiener information and stochastic complexity, [in:] Proceedings of the Norbert Wiener centenary congress on Norbert Wiener centenary congress (NWCC '94), V. Mandrekar & P.R. Masani (eds.), AMS Press, Inc., New York: 331-341.

Robertson A.I. & Duke N.C., 1990, Mangrove fish communities in tropical Australia: spatial and temporal patterns in densities, biomass and community structure. Marine Biology 104: 369-379.

Sandoval Londoño L.A., Leal-Flórez J., Blanco-Libreros J.F., 2020, Linking mangroves and fish catch: a correlational study in the southern Caribbean Sea (Colombia). Bulletin of Marine Science 96(3): 415-429. doi: https://doi.org/10.5343/bms.2019.0022

Sarkar S.K. & Bhattacharya A.K., 2003, Conservation of biodiversity of the coastal resources of Sundarbans, Northeast India: an integrated approach through environmental education. Marine Pollution Bulletin 47(1/6): 260-264. doi: 10.1016/s0025-326x(02)00475-7

Sasaki K., 2001, Family Sciaenidae, [in:] Species identification guide for fishery purposes. The living marine resources of the western central Pacific, volume 6. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals, K.E. Carpenter & V.H. Niem (eds.), FAO, Rome: 2791-3380.

Smith-Vaniz W.F., 1999, Family Carangidae, [in:] Species identification guide for fishery purposes. The living marine resources of the western central Pacific, volume 4. Bony fishes part 2 (Mugilidae to Carangidae), K.E. Carpenter & V.H. Niem (eds.), FAO, Rome: 2659-2756.

Staub R., Appling J.W., Hofstetter A.M. & Haas I.J., 1970, The effects of industrial wastes of Memphis and Shelby County on primary planktonic producers. BioScience 20(16): 905-912.

Talwar P.K. & Jhingran A.G., 1991, Inland fishes of India and adjacent countries, volumes I-II. Oxford & IBH Publishing Co., New Delhi, Bombay, Calcutta: 1158.

Talwar P.K., 1995, Fauna of India and adjacent countries: Pisces, Perciformes: Sciaenidae. Zoological Survey of India, Kolkata: 144.

Uiblein F. & Heemstra P.C., 2010, A taxonomic review of the Western Indian Ocean goatfishes of the genus *Upeneus* (Family Mullidae), with descriptions of four new species. Smithiana Bulletin 11: 35-71.

Van der Elst R., 1993, A guide to the common sea fishes of southern Africa, 3rd ed. Struik Publishers, Cape Town: 398.

Van der Laan R., Fricke R., Eschmeyer W.N., (eds.), 2021, ESCHMEYER'S CATALOG OF FISHES: CLASSIFICATION. (http://www.calacademy.org/scientists/catalog-of-fishes-classification/). [electronic version, Accessed 12 February 2021].

Verweij M.C., Nagelkerken I., de Graaf D., Peeters M., Bakker E.J. & van der Velde G., 2006, Structure, food and shade attract juvenile coral reef fish to mangrove and seagrass habitats: a field experiment. Marine Ecology Progress Series 306: 257-268.

Vidthayanon C., Termvidchakorn A., Pe M., 2005, Inland fishes of Myanmar. Southeast Asian Fisheries Development Center, Bangkok: 160.

Weber M. & De Beaufort L.F., 1931, The fishes of the Indo-Australian Archipelago, volume VI. Perciformes: Serranidae, Theraponidae, Sillaginidae, Emmelichthyidae, Bathyclupeidae, Coryphaenidae, Carangidae, Rachycentridae, Pomatomidae, Lactariidae, Menidae, Leiognathidae, Mullidae. E.J. Brill Ltd., Leiden: 448.

Welcomme R.L., Winemiller K.O., Cowx I.G., 2006, Fish environmental guilds as a tool for assessment of ecological condition of rivers. River Research and Applications 22(3): 377-396. doi: https://doi.org/10.1002/rra.914

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, Part 1: Chirocentridae, Clupeidae and Pristigasteridae. FAO Fisheries Synopsis 125(7): 113-114.

Whitehead P.J.P., Nelson G.J., Wongratana T., 1988, 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, Part 2: Engraulididae. FAO Fisheries Synopsis 125(7/2): 305-579.

Zengeya T.A., Booth A.J., Chimimba C.T., 2015, Broad niche overlap between invasive Nile tilapia *Oreochromis niloticus* and indigenous congenerics in Southern Africa: Should we be concerned? Entropy 17(7): 4959-4973. doi: https://doi.org/10.3390/e17074959

## PLATE I

1. CLUPEIDAE *Sardinella longiceps*

2. CLUPEIDAE *Sardinella fimbriataw*

3. ENGRAULIDAE *Thryssa kammalensoides*

4. ENGRAULIDAE *Thryssa spinidens*

5. SCOMBRIDAE *Scomberomorus lineolatus*

6. TRICHIURIDAE *Eupleurogrammus glossodon*

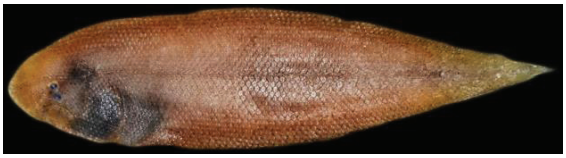
7. GOBIIDAE *Acentrogobius cyanomos*

8. GOBIIDAE *Oxyurichthys microlepis*

9. SPHYRAENIDAE *Sphyraena jello*

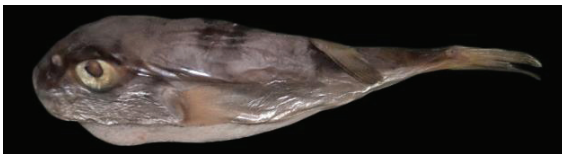
10. SOLEIDAE *Solea ovata*

11. CYNOGLOSSIDAE *Cynoglossus quadrilineatus*



12. CYNOGLOSSIDAE *Cynoglossus semifasciatus*

13. CYNOGLOSSIDAE *Cynoglossus macrolepidotus*



14. TETRAODONTIDAE *Lagocephalus guentheri*

15. AMBASSIDAE *Parambassis lala*

16. GERREIDAE *Gerres macracanthus*

17. SCIAENIDAE *Otolithes ruber*

18. SCIAENIDAE *Pennahia aneus*

19. SCIAENIDAE *Johnius carouna*

20. MULLIDAE *Upeneus sulphureus*