Fish distribution dynamics in the Aghanashini estuary of Uttara Kannada, west coast of India

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Fish diversity (77 species) in the Aghanashini River estuary of the Indian west coast is linked to variable salinity conditions and zones I, II and III for high, medium and low salinity respectively. Zone I, the junction between Arabian Sea and the estuary, had all species in yearly succession – due to freshwater conditions in monsoon to high salinity in pre-monsoon. The medium (zone II) and low (zone III) salinity mid and upstream portions had maximum of 67 and 39 fish species respectively. Maintenance of natural salinity regimes in estuary, among other ecological factors, is critical for its fish diversity.

Keywords: Aghanashini estuary, fish diversity, freshwater, osmo regulation, salinity.

ESTUARY, a tidally influenced transition zone between river and sea, is a unique ecosystem. The upstream limit to which the river turns brackish (to a minimum of 0.5 ppt) is considered the upper limit of the estuary. Sedimentary movements and deposits happen in the estuary due to constant intermingling of water from the land and the ocean[1,2]. Tropical estuaries with microhabitats like mangroves, mud flats, marshes, reed swamps, shell beds, etc. and varied salinity conditions are good places for fishery[3]. The vastness of the ocean notwithstanding, several marine fishes use estuaries as nurseries for their young or feeding grounds for sub-adults and adults. Root entanglement of mangroves provides security for many fishes from predation and fishing by humans[4–6]. Estuary is often dominated by euryhaline and to lesser extent by stenohaline fishes tolerant of variable and narrow ranges of salinity respectively[7]. Estuaries today are heavily exploited and are among the most threatened ecosystems. The present study on fish diversity and distribution in relation to environmental factors, particularly salinity, in the Aghanashini River estuary, is a pioneering one for Karnataka.

The 121 km long, west-flowing Aghanashini River from central Western Ghats of southwest India joins the Arabian Sea forming an estuary of about 48 sq. km (lat. 14.3910–14.5850 N, long. 74.3040–74.5160 E) in the Kumta taluk of Uttara Kannada district (Figure 1). The study period (June 2011–May 2012) was divided into three quarters, monsoon (June–September), post-monsoon (October–January) and pre-monsoon (February–May). As a preliminary step pre-monsoon high-tide salinity was measured, at 2 km intervals, and the estuary was divided into three salinity zones: 'high' (>20 ppt), 'medium' (10–20 ppt) and 'low' (<10 ppt). Catches by fishermen were monitored for one year. Monthly monitoring of environmental parameters like salinity, dissolved oxygen (DO), pH, air and water temperature during high tides, was carried out in three stations – Aghanashini, Kodkani and Divgi – representing high, medium and low salinity zones respectively. Fish specimens collected from five consecutive cast-net hauls from each zone, month-wise, by fishermen were identified using taxonomic keys[8–12]. Similarity of fish assemblages on temporal scale from salinity zones was measured using Bray–Curtis index[13]. Fish distribution related to environmental variables was obtained using canonical correspondence analysis (CCA)[14].

Altogether 77 fish species from 47 families (Table 1) were recorded. Of them, 17% was basically marine, 57% marine–estuarine and 24% from wide ranging habitats, sharing even freshwater (Figure 2). The pearl-spot (*Etroplus suratensis*) was the only true estuarine species. The Asian swamp-eel (*Monopterus albus*) that shifts between freshwater and estuary was another exception. Zone I, Aghanashini, was the richest with all 77 species recorded in the course of the study. Some fishes, notably mangrove snappers, sea bass, ponyfish, perchlet, mullets, eels, etc.

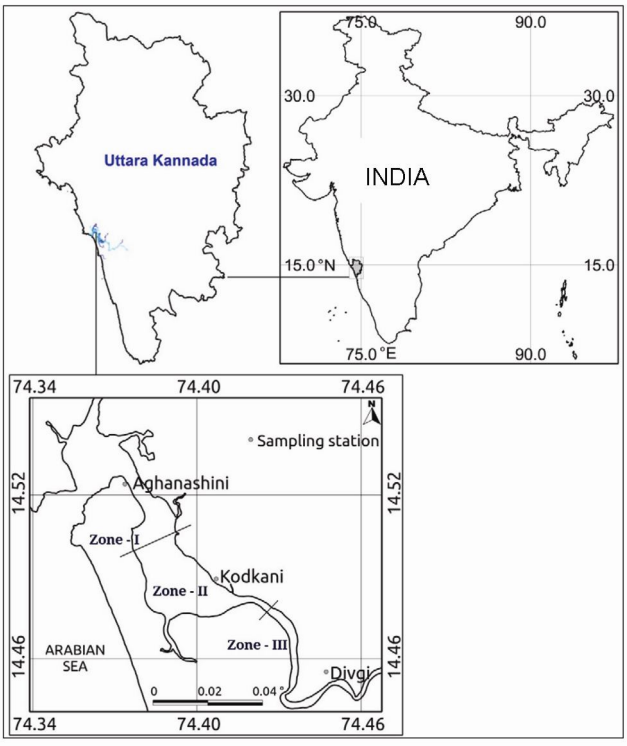

Figure 1. Aghanashini estuary with sampling stations.

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Table 1. Checklist of Ichthyofauna observed in Aghanashini estuary (categorization based on www.fishbase.org, accessed on 19 January 2014)

Code used	Family	Scientific name	Common name	Local name (Kannada)
Marine				
3	Carangidae	*Carangoides praeustus*	Brownback trevally	Haluguruku
4	Scombridae	*Rastrelliger kanagurta*	Indian Mackerel	Bangade
5	Nemipteridae	*Nemipterus japonicus*	Japanese thread fin bream	Rane menu
6	Serranidae	*Cephalopholis boenak*	Blue lined coral cod	Gobrya, Kallumurge
7	Bothidae	*Crossorhombus azureus*	Blue spotted flounder	Masur leppe
8	Paralichthyidae	*Pseudorhombus javanicus*	Javan flounder	Nengu
9	Scombridae	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	Iswana
10	Stromatidae	*Pampus argenteus*	Silver pomfret	Bili manji
32	Rhinobatidae	*Glaucostegus halavi*	Halavi ray	Balagende torke
42	Siganidae	*Siganus argenteus*	Streamlined spinefoot	Baana
77	Scaridae	*Parrot fish*	–	–
68	Batrachoididae	*Colletteichthys dussumieri*	Flat toad fish	Gonke, Goke
76	Serranidae	*Ephinephelus bleekeri*	Bleeker's reef cod	Gobrya
Marine, estuarine				
1	Clupeidae	*Sardinella fimbriata*	Fringescale sardinella	Pedi
2	Engraulidae	*Stolephorus indicus*	Indian anchovy	Belanji
12	Carangidae	*Carangoids chrysophrys*	Brownback trevally	Haluguruku
13	Ariidae	*Arius arius*	Threadfin sea catfish	Bili sady
14	Siganidae	*Siganus vermiculatus*	Vermiculated spinefoot	Baana, Padiyar
15	Tetraodontidae	*Arothron stellatus*	Starry blow fish	Chonja
16	Engraulidae	*Stolephorus commersonnii*	Commerson's anchovy	Dodda danashi
17	Platycephalidae	*Grammoplites scaber*	Rough flathead	Vadati
18	Sillaginidae	*Sillago sihama*	Silver sillago	Nogla
19	Sciaenidae	*Otolithes ruber*	Tigertooth croaker	Banagu, Dodi
20	Sphyraenidae	*Sphyraena barracuda*	Great barracuda	Onakaandi
21	Lactariidae	*Lactarius lactarius*	False trevally	Samdale
22	Belonidae	*Strongylura leiura*	Banded needle fish	Burkaandi
23	Carangidae	*Megalaspis cordyla*	Torpedo trevally	Guruku
24	Carcharhinidae	*Scoliodon laticaudus*	Shark	Sora
25	Platacidae	*Drepane punctata*	Spotted sickle fish	Chandaka
26	Carangidae	*Caranx ignobilis*	Giant kingfish	Guruku
27	Dasyatidae	*Himantura bleekeri*	Bleeker's whip ray	Hola
28	Clupeidae	*Opisthopterus tardoore*	Tardoore	Pachage
29	Leiognathidae	*Leiognathus splendens*	Blacktip ponyfih	Guruku
30	Lobotidae	*Lobotes surinamensis*	Tripletail	Pavade
31	Engraulidae	*Thryssa mystax*	Moustached thryssa	Vaintali
33	Leiognathidae	*Secutor insidiator*	Pugnose ponyfish	Guruku
35	Trichiuridae	*Trichiurus lepturus*	Large head hairtail	Barik hamle
38	Sphyraenidae	*Sphyraena obtusata*	Obtuse barracuda	Hallin kaandi
40	Cynoglossidae	*Cynoglossus macrostomus*	Malabar sole	Leppe
41	Platacidae	*Platax orbicularis*	Orbicular bat fish	Manji
43	Engraulidae	*Thryssa malabarica*	Malabar thryssa	Vaintali
45	Engraulidae	*Thryssa setirostris*	Long jaw thryssa	Vaintali
46	Carangidae	*Atule mate*	Yellowtail scad	Guruku
47	Pempheridae	*Pempheris moluca*	Mollucan sweeper	Ramachi
48	Pomadasyidae	*Pomadasys maculatus*	Saddle grunt	Guruku
50	Ariidae	*Arius Caelatus*	Engraved sea catfish	Gonde Sady
51	Stromatidae	*Parastromateus niger*	Black pomfret	Kari manji
52	Sciaenidae	*Chrysochir aureus*	Reeve's croaker	Mooru hallin banagu
53	Lutjanidae	*Lutjanus johni*	John's snapper	Hottekemsa
54	Lutjanidae	*Lutjanus ruselli*	Russell's snapper	Kemsa
34	Soleidae	*Synaptura commersonnii*	Commerson's sole	Leppe
36	Sciaenidae	*Johnius belangeri*	Belanger's croaker	Banagu
74	Hemiramphidae	*Hemirhaphus far*	Black barred half beak	Toli
37	Triacanthidae	*Tricanthus biaculeatus*	Short-nosed tripod fish	Kuduremeenu, kadbale
39	Cynoglossidae	*Paraplagusia biliniata*	Double lined tongue sole	Leppe
44	Gobiidae	*Trypauchen vegina*	Burrowing goby	Bombale
Estuarine				
56	Cichilidae	*Etroplus suratensis*	Pearl spot	Kagalse

(*Contd*)

Table 1. (*Contd*)

Code used	Family	Scientific name	Common name	Local name (Kannada)
Estuarine freshwater				
58	Synbranchidae	*Monopterus albus*	Asian swamp eel	Kolav
Marine, estuarine, freshwater				
11	Scatophagidae	*Scatophagus argus*	Spotted scat	Hulka
55	Lutjanidae	*Lutjanus argentimaculatus*	Mangrove red snapper	Eri
57	Gobiidae	*Glossogobius giuris*	Tank goby	Bili Mandli
59	Gobiidae	*Acentrogobius griseus*	Grey goby	Kari mandli
61	Mugilidae	*Mugil cephalus*	Flathead grey mullet	Madle
62	Mugilidae	*Liza parsia*	Gold spot mullet	Madle
63	Polynemidae	*Eleutheronema tetradactylum*	Four finger threadfin	Raws, Ramachi
64	Teraponidae	*Terapon jarbua*	Cresent pearch	Kumbari, Garge
60	Gerridae	*Gerres filamentosus*	Threadfin silver biddy	Girbaingi
65	Gerridae	*Gerres limbatus*	Saddleback silver biddy	Mundbaingi
66	Leiognathidae	*Secutor ruconius*	Deep pugnose ponyfish	Guruku
67	Centropomidae	*Lates calcarifer*	Barramundi, Seabass	Kurude
69	Ambassidae	*Ambassis ambassis*	Commersons glassy perchlet	Burante
70	Cynoglossidae	*Cynoglossus punticeps*	Spotted tongue sole	Leppe
71	Ophichthidae	*Pisoodonophis cancrivorus*	Snake eel	Aragotka
73	Ophichthidae	*Lamnostoma polyophthalma*	Ocellated sand-eel	Hemalga
72	Apogonidae	*Apogon hyalosoma*	Humpbacked cardinal fish	Burante
75	Clupeidae	*Tenualosa ilisha*	River shad	Malati pedi
Uncertain habitat				
49	Scorpinidae	*Scorpeana haplodactylus*	–	–

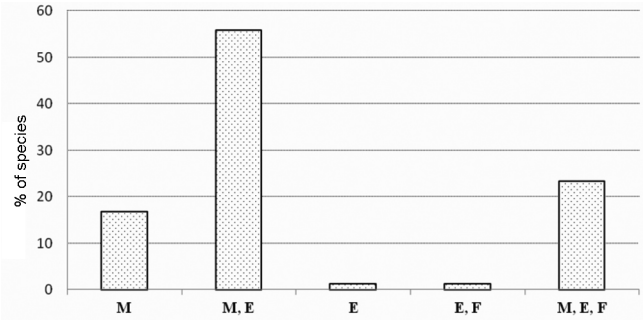

Figure 2. Habitat combinations of estuarine fishes of Aghanashini (based on www.fishbase.org accessed on 19 January 2014). M, Marine; M, E, Marine, estuarine; E, Estuarine; E, F, Estuarine, freshwater; M, E, F, Marine, estuarine, freshwater.

inhabited here throughout monsoon to pre-monsoon. The marine–estuarine group, mainly anchovis, croakers, barracudas, snappers, sillagos, black pomfrets, soles, etc. kept away from zone I during monsoon. Such euryhaline fishes entered the zone from the sea only from post-monsoon with rising salinity. The stenohaline marine fishes, notably mackerels, silver pomfrets and cods appeared in Aghanashini when salinity levels peaked in the pre-monsoon months. The mid-estuarine zone II (Kodkani) had 67 species, most of them euryhaline. Stenohaline marine fish avoided this medium-salinity zone. Only 39 species occurred in zone III (Divgi), the interphase with freshwater. They were mostly a subset of zone II and moved freely between the sea and the estuary; some even entered freshwater. Exclusive freshwater species were absent in the estuary even during the rainy season.

The families Carangidae and Engraulidae had five species each; Sciaenidae had four species; Clupeidae, Cynoglossidae, Gobiidae, Leiognathidae and Lutjanidae had three species each. Eleven families were represented by 2 species, while 28 had only 1 each. A comparable study from Ponnani estuary in Kerala had 112 species from 53 families[15]. Carangidae with eight, Leiognathidae with seven and Engraulidae with six species each followed. From Kodungallur–Azhikode estuary of Kerala, 63 fishes of 37 families were reported. Mugilidae had five and Engraulidae, Carangidae, Cyprinidae, Cichilidae and Gerridae had three each[16]. From Yedayanthittu estuary in Tamil Nadu, 75 species of 37 families were reported[17].

Monthly variations in environmental parameters like salinity, pH, DO, water and air temperatures of the three zones are depicted in Figure 3 *a–c* respectively. Heavy rains (2500–5000 mm), in the catchment areas, caused salinity drop to nil or very low; from marginal rise in September to zone-wise peaks were attained in March–May. Similar pattern was observed in the Naaf estuary of Bangladesh, by Chowdhury *et al.*[18], when July rainfall (1159 mm) caused salinity to decline to 0–8.6 ppt.

Aghanashini estuary had maximum DO (6.32 mg/l) during monsoon to early post-monsoon. It was similar in Vellar, Tamil Nadu[19]. Pre-monsoon saw highest water temperature in Aghanashini (31.5°C) and lowest (25.6°C) during monsoon. Water temperature was lower than air temperature, which was higher in October, April and May.

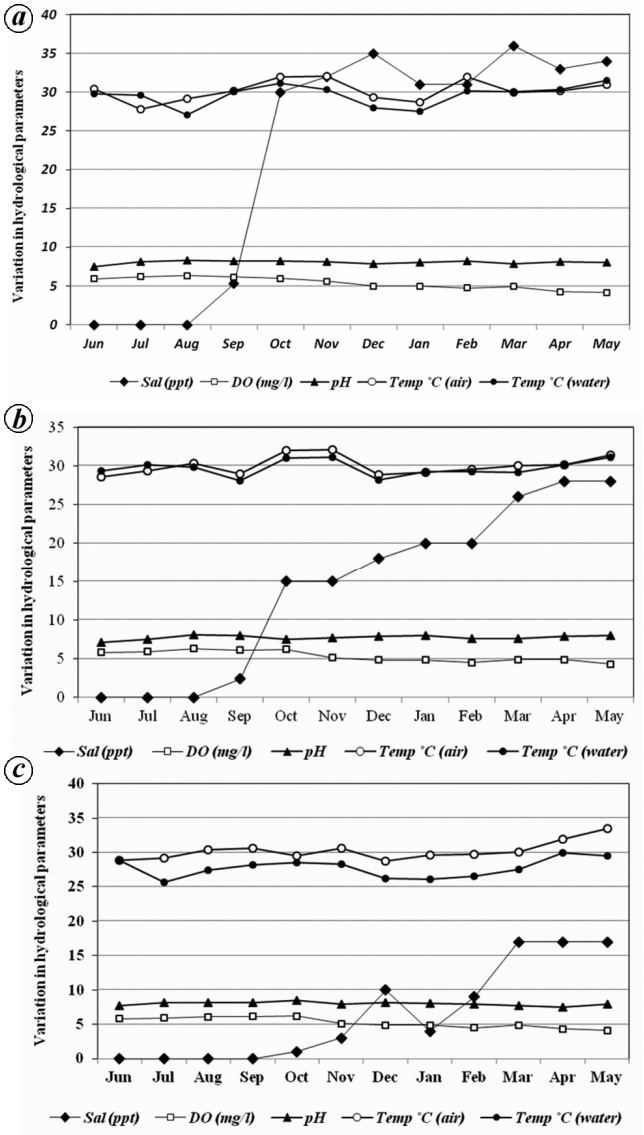

Figure 3. Hydrological parameters observed at (***a***) zone I (Aghanashini), (***b***) zone II (Kodkani) and (***c***) zone III (Divgi) during June 2011–May 2012.

When 77 species and 5 environmental variables from Aghanashini estuary were selected for CCA analysis (Figure 4), the first two components had eigenvalues, $\lambda 1 = 0.119$, $\lambda 2 = 0.051$. Axis 1 accounted for 55.32% of the cumulative percentage of variance in species abundance with environmental parameters and was positively correlated with salinity, water and air temperatures and negatively correlated with DO and pH. Axis 2 explained 24.1% variance and was positively correlated with salinity, pH and air temperature, and negatively with DO and water temperature. CCA showed most fishes exhibiting positive correlation with salinity. Few like *Strongylura leiura*, *Hemirhampus far* and parrot fish showed negative correlation with salinity as these occurred mainly during monsoon.

Bray–Curtis analysis of monthly fish assemblage distinguished two (A and B) major groups (Figure 5). Cluster A was grouped into all the seasons of zone III (Divgi) and three months (October, November and December) of zone II (Kodkani). In this group fishes such as *Sillago sihama*, *Otolithes ruber*, *Lutjanus johni*, *Lutjanus ruselli*, *Lutjanus argentimaculatus*, *Etroplus suratensis*, *Glossogobius giuris*, *Gerres filamentosus*, *Mugil cephalus*, *Terapon jarbua* were shared between zones II and III. These are among well-known indicators of highly variable estuarine salinity conditions. Cluster B consists of two sub-groups, namely cluster B_1 and B_2; B_1 is further sub-divided into B_1-I and B_1-II. B_1-I clustered with post-monsoon season of zone I (Aghanashini) and premonsoon season of zone II. Clustering of this nature reveals that many estuarine fishes have their own preferable salinity regimes necessitating constant movement of fishes within the estuary in adjustment with dynamic salinity conditions depending on mixing of fresh and salt waters. The cluster B_1-II shows that the fish assemblages are 92% similar and closely related to the pre-monsoon (April and May) of zone I. Predominantly marine fishes like *Rastrelliger kanagurta*, *Scomberomorus commerson* and *Pampus argenteus* get into this high-salinity (34 ppt) assemblage. However, George *et al.*[20] had reported mackerels (*R. kanagurta)* from Netravati estuary of Mangalore during January in lesser salinity (14.10–23.50 ppt).

Estuarine life is more challenging than marine mainly because of fluctuating salinity. Fishes of specific salinity ranges keep shifting positions within their respective ranges. The osmoregulation mechanism in fishes and species-specific operating ranges in relation to salinity are of great interest to fish physiologists[21,22]. Through osmoregulation the fish maintains an internal balance of salt and water within the cells when there is difference in salinity between internal and external conditions. Various cellular-level mechanisms exist safeguarding fishes from high salinity and fluctuations in salinity[21–25].

The estuarine–freshwater fish Seabass (*Lates calcarifer*) requires greater depths (10–15 m), hardly available in the estuary, and higher salinity conditions (30–32 ppt) for gonadial maturity, making it migrate from the river into the sea for spawning during monsoon. The spawning happens in September and the larvae move into the estuary for further development[26].

The Aghanashini study has notable similarity with works in the Caete River estuary[27] of Brazil. Both the basins have hot and humid weather, five to six rainy months and annual rainfall exceeding 2500 mm. In both seasonal salinity fluctuations appeared to be the main factor that structured fish assemblage in the entire estuarine system. At least 85% of the 82 species captured by the artisanal fishers of the adjoining Brazilian coast required estuarine conditions to complete their life cycle. While the study reveals that 74 of the 77 species recorded from Aghanashini used sea as a common habitat, the estuary

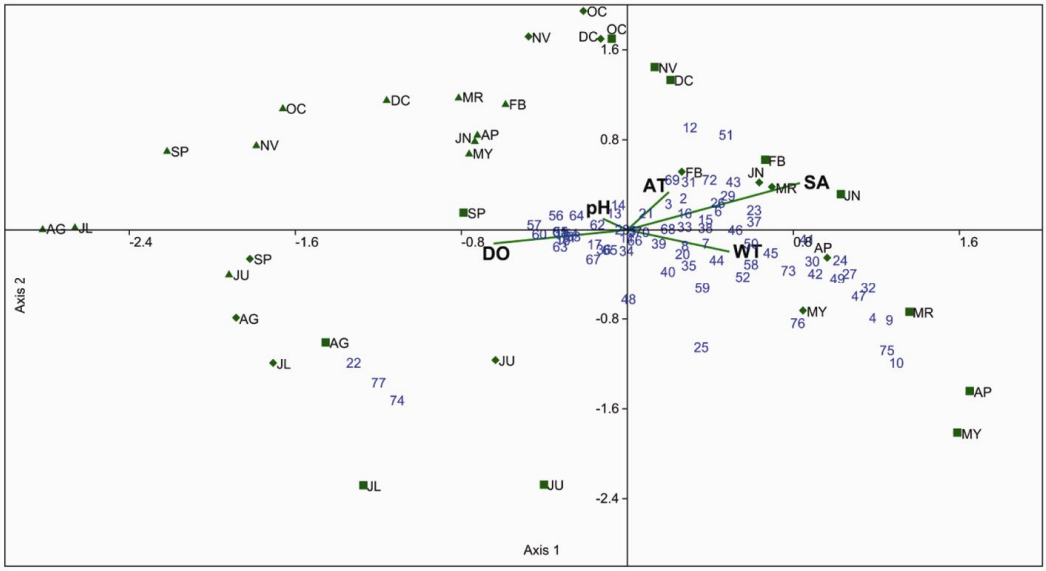

Figure 4. Canonical correspondence analysis of Aghanashini estuary on fish species numbers and month-wise environmental parameters. JN, January; FB, February; MR, March; AP, April; MY, May; JU, June; JL, July; AU, August; SP, September; OC, October; NV, November; DC, December. Square indicates zone I with corresponding month; diamond indicates zone II with corresponding month and triangle indicates zone III with corresponding month. Numbers = Fish species; Line = Environmental parameters.

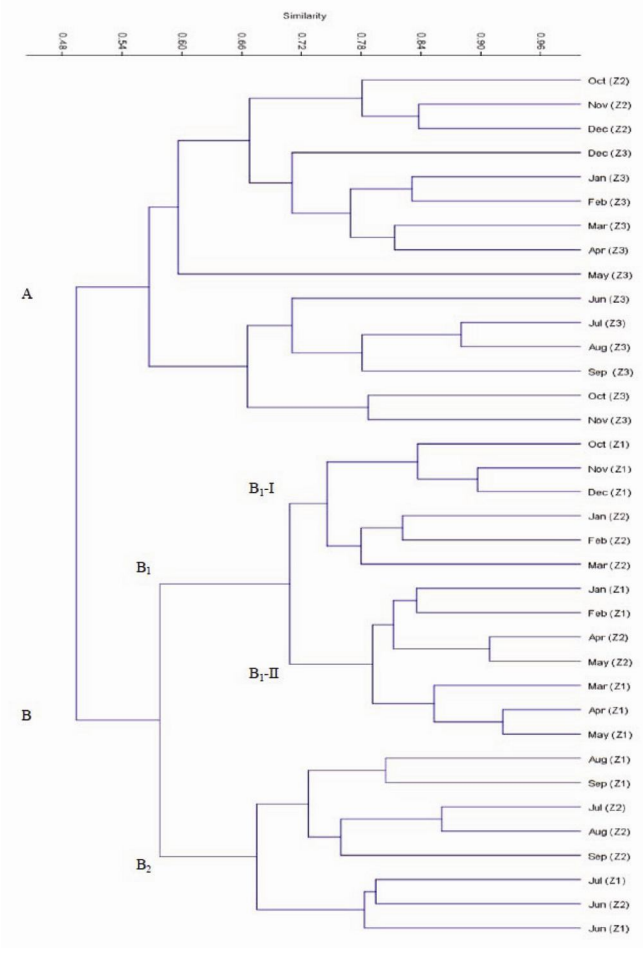

Figure 5. Bray–Curtis clustering of fish species in Aghanashini estuary.

plays a significant role in their lives highlighting the importance of its conservation.

Tropical estuaries in their natural states are rich in fisheries. Of the prominent environmental parameters considered in the study, salinity was the most decisive in fish distribution. The estuary as such had hardly any exclusive fish, with minor exceptions. Zone I closest to the sea had highest diversity as it experienced lowest salinity during monsoon and highest during pre-monsoon, facilitating seasonal fish succession from low- to high-salinity species; many euryhaline fishes with wider salinity tolerance range occupied the zone throughout the year. There is also need to protect estuarine microhabitats like mangroves, sedge areas, mud-flats, shell-beds, etc. for healthy assemblage of fishes. As regards salinity many estuaries of the west coast are seriously affected by execution of hydro-electric projects, the water releases from which adversely affect salinity regimes with adverse consequences on fish diversity and fisheries itself. Fishery collapse has happened in the Sharavathi estuary of Uttara Kannada, which has only 29 fin fish species, unlike 77 in Aghanashini, attributed to year-round salinity drop due to constant freshwater releases from upstream hydro-electric projects[28]. River diversion from the Western Ghats, with scanty consideration for environment, particularly estuarine ecology, is a burning topic today.

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