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# Temporal pattern of fish production in a microtidal tropical estuary in the south-west coast of India

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## ABSTRACT

The status of fisheries and seasonal variation in fish diversity in the Kodungallur-Azhikode Estuary (KAE) were investigated. Total annual average fish production in the estuary declined significantly to 908.6 t with average yield of 5.4 kg ha$^{-1}$ day$^{-1}$, when compared to earlier study; where 2747 t was reported. During the present study, 60 species of finfishes (belonging to 34 finfish families), 6 species of penaeid shrimps, 2 species of palaemonid prawns, 2 species of crabs (4 crustacean families), 6 species of bivalves and 2 species of edible oysters (3 molluscan families) were noticed. Finfishes were the major group that contributed 69.62% of total fishery in the estuary and crustaceans (23.47%), bivalves (6.84%) and oysters (0.07%) also formed good fishery. Many of the fish species in the estuary were observed as threatened (*Horabagrus brachysoma, Channa striatus, Channa marulius, Clarias batrachus, Heteropneustes fossilis* and *Wallago attu*). The major fishing gears employed in the estuary were gillnets, cast nets, stake nets, scoop nets, ring nets, traps and Chinese dip nets. Gillnets contributed 45% of the total fish catch. Gillnets also showed highest catch per unit effort (CPUE) of 6.91 kg h$^{-1}$ followed by cast nets (1.85 kg h$^{-1}$), Chinese dip nets (3.20 kg h$^{-1}$), stake nets (3.05 kg h$^{-1}$), ring nets (1.27 kg h$^{-1}$), hooks and lines (1.35 kg h$^{-1}$) and scoop nets (0.92 kg h$^{-1}$). The study implies that temporal changes in fish landing pattern of the KAE was mainly due to environmental variability, habitat modification and fish migration; under the influence of south-west monsoon and anthropogenic activities in the KAE. Results of the study suggest that spatio-temporal variations in the fish community structure could be an indicator for anthropogenic stress and it should be considered for restoration programmes.

Keywords: Conservation, CPUE, Fish landings, Kodungallur-Azhikode Estuary (KAE), Tropical estuary

## Introduction

Estuarine fisheries, characterised by economically and biologically important resources, provide food and income. However, decline in fish stocks as a result of overfishing, insufficient management and habitat degradation, reduces the chances of its sustainability (Bijoy Nandan, 2008). India produces an average of 4.6 million t of fish annually from inland water bodies (Sugunan, 2010). The average yield of estuarine fish production in India was estimated to vary from 45 to 75 kg ha$^{-1}$ (Jhingran, 1991; Sugunan, 2010). Major backwaters of Kerala, forming the crux of the coastal wetlands, house over 200 resident and migratory fish as well as shellfish species. Fishing activities in these water bodies provide livelihood for about 2,00,000 fishers and full time employment to over 50,000 fishermen (Bijoy Nandan, 2008). Various estuarine wetland systems spreading over three lakh ha form an important component of the inland fisheries resources of India (Kurup and Harikrishnan, 2000; Sugunan, 2010) and recruitment of fishes from estuaries also strongly drive marine population dynamics (Elliott and Taylor, 1989). Nitrogen load resulting from human activities as well as low dissolved oxygen concentrations have dramatically increased since the 1950's in many of the estuaries and coastal waters worldwide (Diaz and Rosenberg, 1995; Diaz, 2001; Boesch, 2002; Seitzinger *et al*., 2002). In many cases, fishing has contributed to declining abundance of species that spend all or part of their life cycle in estuaries (Secor and Waldman, 1999; Lotze *et al.,* 2006).

The inter-dependence of the adjoining marine and estuarine zones in completion of the life cycle of finfish and shell fish species is indispensible (Jhingran, 1982, Chao *et al.,* 1982, 1986; Muelbert and Weiss, 1991; Vieira and Castello, 1997). Estuarine fishes can be divided into two broad categories according to where they spawn: in estuarine systems or the sea; the former group is referred to as estuarine and the latter, as marine. The life cycle of many marine species usually involves a juvenile period that is predominantly estuarine and an adult stage that is primarily marine (Wallace, 1975a). Although some species may attain sexual maturity within the estuarine environment, spawning always occurs in the sea (Wallace, 1975b) where the relatively stable marine environment is more suitable for the survival of the egg, embryonic and larval stages. A major factor influencing the composition of ichthyoplankton in estuaries is temperature, which is often linked to latitude. Species diversity generally declines from the subtropical systems in the north-east to the cool temperate systems in the south-west (Whitfield, 1994). The Vembanad backwater has been extensively studied for the composition, distribution and gearwise catch of major fishery (Shetty, 1965; Kurup, 1982; Kurup and Samuel, 1985, 1987; Anon., 2001; Bijoy Nandan, 2007; Harikrishnan *et al.*, 2011). Annual average fish production in the Vembanad Lake and other backwaters of Kerala was estimated at 14000- 17000 t (Sugunan, 2010). Kodungallur-Azhikode Estuary (KAE) is a northern extremity of Vembanad wetland ecosystem, which is permanently connected to Lakshadweep Sea at Munambam, and forms an ideal habitat for several species of finfishes and shellfishes (Anon, 2001).

A comprehensive study on the fish diversity and abundance in relation to hydrographic variations in the Kodungallur-Azhikode Estuary (KAE) was lacking; The main reasons for limited number of studies on estuarine fish community changes are: (1) complexity, linked to the high variability at different temporal and spatial scales, and (2) lack of reference conditions on the previous, pre-perturbation situation or a comparable pristine ecosystem. This paper discusses the diversity and abundance of fishes in relation to environmental quality in the KAE.

## Materials and methods

The present study (July 2009-June 2010) scrutinised the status of fisheries and seasonal variations in the fish diversity in the Kodungallur-Azhikode Estuary (KAE). KAE is a northern extremity of Vembanad wetland ecosystem (10°11'-10°12' N and 76°10'-76°13' E) having an area of 700 ha (Fig.1). Tidal variations in the estuarine region displayed microtidal range (Martin *et al.,* 2010) with maximum during spring tide (90 cm). The KAE is fed by the tributaries of Periyar River and it has remained open to

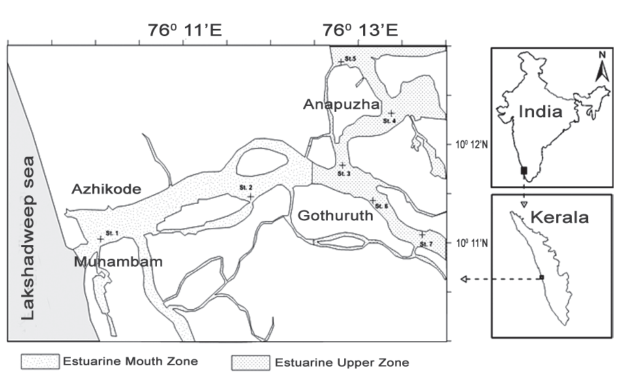


Fig.1. Location of the sampling sites in the Kodungallur-Azhikode Estuary (KAE)

tidal flushing from the sea at Munambam. Landing centre based direct data collection method and catch yield (Guptha *et al.,* 1997; FAO, 2002) was adopted for the fish landing estimation. The estuary was classified into two zones, estuarine mouth zone (EMZ) and estuarine upper zone (EUZ), based on general morphology and environmental characteristics to study the zonewise variation of fish catch. Data on catch composition, and gearwise catch (%) were collected weekly from July 2009 to June 2010. Azhikode, Anapuzha and Krishnankotta were the major fish landing centers of the estuary. The total catch in the landing center were sorted into finfish, shrimp, prawn, crab, molluscs and other groups. After sorting and counting, representative samples were preserved in 10% formalin for taxonomic studies in the laboratory. Catch per unit effort (CPUE) was defined as the catch obtained in one tow of the net operated once per site, and was expressed as kg $hr^{-1}$. The CPUE was computed for monthly and annual values and used as index of relative abundance (FAO, 2002). Species-wise identification was done following standard methods (Day, 1889; Talwar and Jhingran, 1991; Jayaram, 1999; Munro, 2000) and Fish Base (www.fishbase.org). Seven stations were selected within the two zones for monthly sampling of water quality parameters and primary productivity. Water transparency was measured by Secchi disk in the field. Dissolved oxygen (DO) was estimated according to Winkler's method (Grasshoff *et al.*, 1983) and pH using Systronics pH meter (No. 335; accuracy ± 0.01). For the estimation of Chlorophyll-*a* (Chl-*a*), acetone extraction method was employed (Parsons *et al.,* 1984). Primary productivity was estimated by *in situ* incubation method using the light and dark bottle oxygen method (Strickland and Parsons, 1972). Temperature of water samples were measured with a centigrade thermometer, conductivity by Systronics digital potentiometer (Model No. 318), turbidity by Systronics water analyser (Model No. 317) and salinity by Systronics water analyser (Model No. 317) calibrated with standard seawater (APHA, 2005). Carbon-di-oxide, alkalinity, hardness and biological oxygen demand (BOD) were determined by standard procedures (APHA, 2005). Samples for nutrients such as DIN (ammonia-nitrogen + nitrite-nitrogen + nitrate- nitrogen), DIP (dissolved inorganic phosphate) and DISi (dissolved inorganic silicate) were analysed following standard methods (Strickland and Parsons, 1972; Grasshoff *et al.*, 1983). Two way analysis of variance (ANOVA) was applied to calculate the monthwise variation in hydrographic and biological parameters and linear regression analysis for fish catch was also performed (SPSS 16v.).

## Results

Distinct variations of hydrographic state in the estuary were observed during the present study. Annual mean water column temperature in the KAE was comparatively normal (28.9 °C) and showed a clear vertical stratification especially during post-monsoon season. Temporal variation was also noticed in the water column and was lowest during south-west monsoon (27.5 °C) compared to pre-monsoon (30.4 °C) and post-monsoon (28.7 °C) seasons. Water temperature showed significant variation between months ($p<0.01$). Transparency values were generally low (0.6 m) in KAE particularly during monsoon season and it was negatively correlated with BOD values ($p<0.05$) ($r = -0.158$). In fact, high turbidity values were observed in KAE with an average of 9.8 NTU with peak concentration during south-west monsoon (20.2 NTU). Highest mean turbidity value was observed at the mouth of the estuary (EMZ) represented by station 1 (13.1 NTU). A discernible spatio-temporal variation was also observed in the pH values and it was generally on an alkaline side (7.4). However, the peak monsoon was marked by heavy rains, pH values tended to fall in all the stations of KAE (6.9). Higher pH values were observed in stations EMZ (station 1; 7.5) when compared to the station in EUZ (station 7; 7.2). Mean dissolved oxygen (DO) content of 5.1 mg $l^{-1}$ was noticed in the KAE and monsoon period showed highest concentration (5.8 mg $l^{-1}$) as compared to post-monsoon period (5 mg $l^{-1}$) and pre-monsoon period (5 mg $l^{-1}$). A noticeable trend was observed in the DO regime in the estuary, wherein surface water DO (5.6 mg $l^{-1}$) displayed comparatively higher values than that of bottom waters (4.7 mg $l^{-1}$). DO levels showed significant variations between months ($p<0.01$). Carbon-di-oxide ($CO_2$) values displayed highest mean in station 5 (7.1 mg $l^{-1}$) and minimum in station 7 (5.3 mg $l^{-1}$); temporarily the values were high during post-monsoon (6.9 mg $l^{-1}$) as compared to monsoon (6 mg $l^{-1}$) and pre-monsoon (6.3 mg $l^{-1}$) in KAE. A remarkably high $CO_2$ value of 14 mg $l^{-1}$ was recorded in the bottom water in station 2 (EMZ) during September and also comparatively high values were observed in most of the stations particularly in stations 1 (7 ± 3 mg $l^{-1}$) and 5 (7.1mg $l^{-1}$). Carbon-di-oxide levels showed significant variation between months ($p<0.01$) .

The average biological oxygen demand (BOD) during the present study was 2.6 mg $l^{-1}$; and it was high in station 1 (3.1 mg $l^{-1}$). Among the seasons, it was high during monsoon (3.1 mg $l^{-1}$) as compared to the post- monsoon (2.2 mg $l^{-1}$) and pre-monsoon (2.3 mg $l^{-1}$) periods. Relatively high alkalinity was observed during pre-monsoon period (43.7 mg $l^{-1}$), when compared to the monsoon (24.4 mg $l^{-1}$) and post-monsoon (36.9 mg $l^{-1}$) seasons. Highest mean alkalinity value was recorded at station 1 (40.3 mg $l^{-1}$). Alkalinity showed significant variation between months ($p<0.01$). Average salinity of the estuary indicated mesohaline nature. The maximum average salinity was recorded at mouth region (station1; 18.9 psu) and minimum at EUZ (station 7; 10.2 ± 8.6 psu). Clear vertical stratification and seasonality were observed in salinity pattern. The salinity values showed a definite trend, where it decreased from estuarine mouth to head. During monsoon (June to September) salinity values were comparatively low (5.4 psu); however, salinity enormously increased (21.6 psu) during post-monsoon (October to January). However, salinity tended to decrease (16.1 psu) during pre-monsoon (February-May), as a result of commencement of south-west monsoon. Significant variations ($p<0.01$) were observed in salinity levels between months. Tides in the KAE are semidiurnal, with amplitude of 1 m during spring tide and 60 cm during neap tides and average rainfall in the area was 310 cm (Revichandran and Abraham, 1998). During the present study, average macronutrient concentration observed in the KAE was 15.0 ± 12.1 µmol $l^{-1}$ for dissolved inorganic nitrogen (DIN), 49.1 ± 28.7 µmol $l^{-1}$ for dissolved inorganic silicate (DISi), and 1 ± 1.3 µmol $l^{-1}$ for dissolved inorganic phosphate (DIP). Among the three major macronutrients, DIP concentrations were comparatively low in the KAE. The average nitrate-nitrogen ($NO_3$-N) of KAE water was 10.2 µmol $l^{-1}$. The average $NO_3$-N values ranged from 7.9 ± 9.9 µmol $l^{-1}$ in station 2 (EMZ) to 13.6 µmol $l^{-1}$ in station 7 (EUZ). Comparatively high $NO_3$-N was observed during monsoon period (19.1 ± 19.4 µmol $l^{-1}$), whereas relatively low $NO_3$-N content was observed during post-monsoon (7.4 ± 3.6 µmol $l^{-1}$) and pre-monsoon periods (3.8 ± 3.3 µmol $l^{-1}$). Macronutrient levels also showed significant monthly variations ($p<0.01$) . The average Chl-*a* for the seven stations of KAE was 6.42 mg $m^{-3}$ and varied from 5.07 mg $m^{-3}$ in station 2 (EMZ) to 7.80 mg $m^{-3}$ in station 5 (Fig. 2a and b). Peak value of Chl-*a* was observed during pre-monsoon period (10.89 mg $m^{-3}$) and decreased to an average of 5.16 mg $m^{-3}$ during the monsoon season. Chl-*a* showed significant variation between months (p<0,01). The GPP showed an average of 1580 mg C $m^{-3}d^{-1}$ and NPP was 790 mg C $m^{-3}d^{-1}$ during the study period. Highest GPP was observed during pre-monsoon (1785 mg C $m^{-3}d^{-1}$) followed by post-monsoon (1589 mg C $m^{-3}d^{-1}$) and monsoon (1517 mg C $m^{-3}d^{-1}$). Generally, increased GPP was noticed in the stations of EMZ (station 1; 1625 mg C $m^{-3}d^{-1}$, station 2; 1750 mg C $m^{-3}d^{-1}$ and station 3; 1750 mg C $m^{-3}d^{-1}$). Highest NPP was observed during post-monsoon (1035 mg C $m^{-3}d^{-1}$) followed by monsoon (828 mg C $m^{-3}d^{-1}$) and pre-monsoon (585 mg C $m^{-3}d^{-1}$). Relatively high mean NPP values were observed in station 3 (921mg C $m^{-3}$ $d^{-1}$) whereas station 6 showed comparatively low average NPP values (588 mg C $m^{-3}d^{-1}$).

Fish landing pattern in the estuary was tremendously distorted during monsoon due to various stress factors induced by heavy river discharge. Many of the marine fish species in the estuary declined during monsoon due to

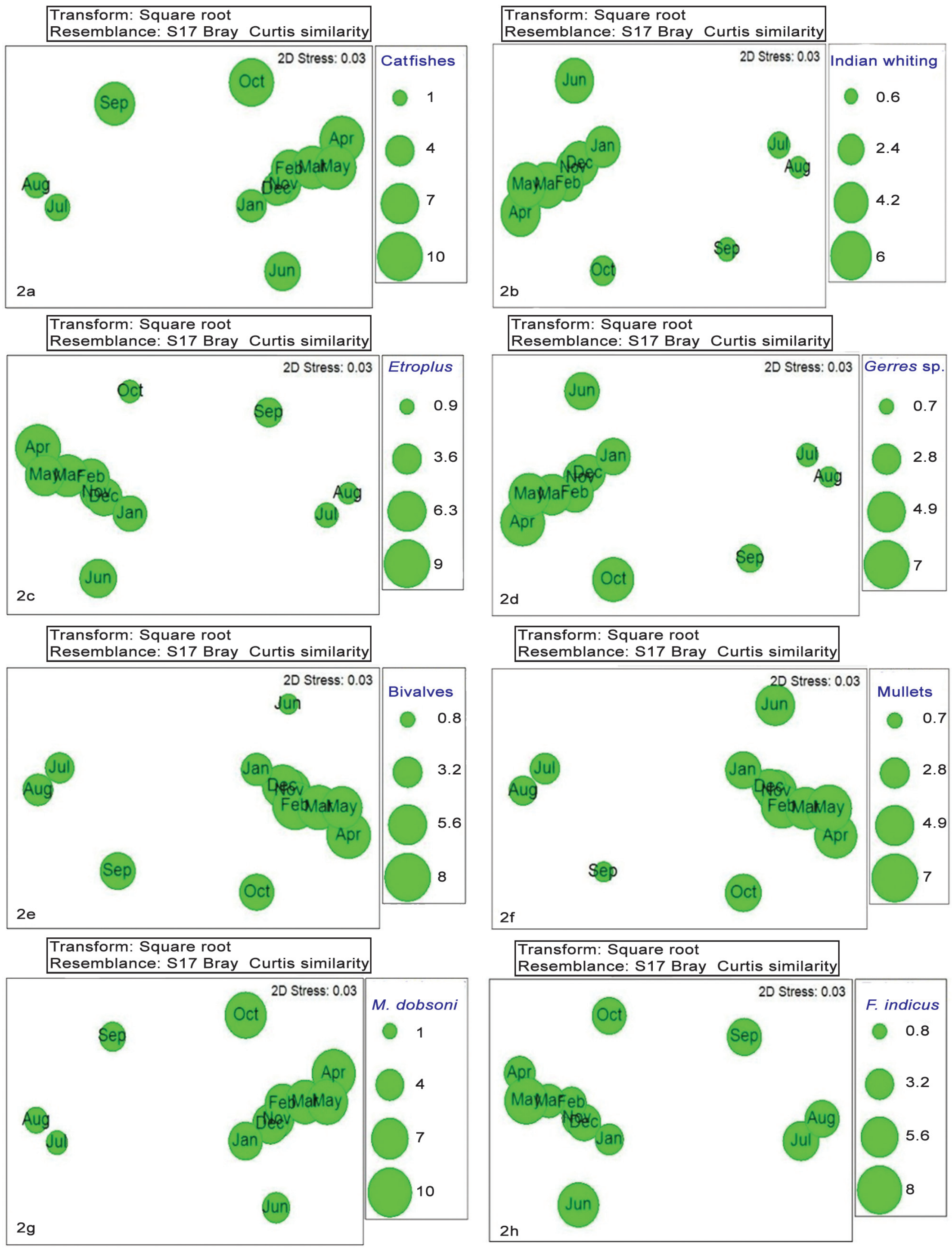


Fig. 2 (a - h). Bubble plot showing monthly variations in landings of the major fish groups

sudden changes in salinity, temperature and other physico-chemical and biological conditions in the estuary. Shrimp catch slightly increased during monsoon. The average fish production was estimated at 908.6 t during the present study and consisted of 60 species of finfishes (34 families), 6 species of penaeid shrimps, 2 species of palaemonid prawns, 2 species of crabs (under 4 families) and 6 species of bivalves including 2 species of edible oysters (under 3 families). Finfishes contributed 69.62% to total fishery of KAE; catfish (8.46%), *Etroplus maculatus* (5.69%), *Etroplus suratensis* (6.43%), mullets (5.65%) and *Sillago sihama* (4.95%) were the major finfish groups.

Table 1. Occurrence and distribution pattern of finfish species in the Kodungallur-Azhikode Estuary

| Family | Species | Habitat | Migration | Environment |
|---|---|---|---|---|
| Anguillidae | *Anguilla bengalensis*** | F, E, M | Catadromous | Benthopelagic |
| Belonidae | *Strongylura strongylura**** | E, M | - | Pelagic-neritic |
| Hemiramphidae | *Rhynchorhamphus georgii**** | E, M | - | Pelagic-neritic |
| Clupeidae | *Sardinella gibbosa** | M | - | Reef-associated |
| | *Sardinella longiceps** | M | Oceanodromous | Pelagic-neritic |
| Engraulidae | *Stolephorus commersonnii*** | E, M | Anadromous | Pelagic-neritic |
| | *Thryssa dussumieri*** | E, M | Amphidromous | Pelagic-neritic |
| | *Thryssa malabarica*** | E, M | Amphidromous | Pelagic-neritic |
| Cyprinidae | *Puntius amphibius*** | F, E | - | Benthopelagic |
| | *Puntius filamentosus*** | F | - | - |
| | *Puntius sarana*** | F, E | Potamodromous | Benthopelagic |
| Elopidae | *Elops machnata*** | E, M | Oceanodromous | Pelagic-neritic |
| Megalopidae | *Megalops cyprinoides**** | F, E, M | Amphidromous | Benthopelagic |
| Chanidae | *Chanos chanos**** | F, E, M | Amphidromous | Benthopelagic |
| Mugilidae | *Lisa macrolepis*** | F, E, M | Catadromous | Demersal |
| | *Lisa parsia**** | F, E, M | Catadromous | Demersal |
| | *Mugil cephalus**** | F, E, M | Catadromous | Benthopelagic |
| | *Valamugil cunnesius*** | F, E, M | Catadromous | Demersal |
| | *Valamugil speigleri*** | F, E, M | Catadromous | Demersal |
| Ambassidae | *Ambassis ambassis**** | F, E, M | Oceanodromous | Demersal |
| Carangidae | *Carangoides malabaricus*** | M | Amphidromous | Reef-associated |
| | *Caranx sexfasciatus *** | F, E, M | Amphidromous | Reef-associated |
| | *Trachinotus blochii ** | E, M | - | Reef-associated |
| Channidae | *Channa marulius ** | F | Potamodromous | Benthopelagic |
| | *Channa striata ** | F, E | Potamodromous | Benthopelagic |
| Cichlidae | *Etroplus maculatus**** | E,M | Amphidromous | Benthopelagic |
| | *Etroplus suratensis**** | E | - | Benthopelagic |
| | *Oreochromis mossambicus**** | F,E | Amphidromous | Benthopelagic |
| Eleotridae | *Bunaka gyrinoides** | F, E, M | Amphidromous | Demersal |
| | *Butis butis** | F, E, M | Amphidromous | Demersal |
| | *Eleotris fusca** | F, E, M | Amphidromous | Demersal |
| Gereidae | *Gerres erythrourus**** | F, E, M | Amphidromous | Demersal |
| | *Gerres filamentosus**** | E, M | Oceanodromous | Reef-associated |
| | *Gerres setifer*** | E, M | Amphidromous | Benthopelagic |
| Gobiidae | *Gobiopsis macrostoma*** | E, M | Amphidromous | Demersal |
| | *Taenioides buchanani** | E, M | Amphidromous | Demersal |
| | *Taenioides cirratus** | F, E, M | Amphidromous | Demersal |
| Siganidae | *Siganus canaliculatus* | E, M | Oceanodromous | Reef-associated |
| Tripauchenidae | *Trypauchen vagina**** | E, M | Amphidromous | Demersal |
| Latidae | *Lates calcarifer*** | F, E, M | Catadromous | Demersal |
| Leiognathidae | *Eubleekeria splendens**** | E, M | Amphidromous | Demersal |
| | *Leiognathus berbis*** | E, M | - | Demersal |
| | *Photopectoralis bindus**** | E, M | Amphidromous | Demersal |
| Lethrinidae | *Lethrinus lentjan*** | E, M | Non-migratory | Reef-associated |
| Lutjanidae | *Lutjanus malabaricus*** | M | - | Reef-associated |
| Mullidae | *Upeneus sulphureus*** | E, M | Oceanodromous | Demersal |
| | *Upeneus vittatus*** | E, M | - | Reef-associated |
| Nandidae | *Pristolepis fasciata* | F | Potamodromous | Demersal |
| Scatophagidae | *Scatophagus argus**** | E, M | Amphidromous | Reef-associated |
| Sciaenidae | *Johnius belangerii**** | E, M | Amphidromous | Demersal |
| | *Otolithoides biauritus**** | M | Amphidromous | Demersal |
| Sillaginidae | *Sillogo sihama**** | E, M | Amphidromous | Reef-associated |
| Terapontidae | *Terapon jarbua*** | F, E, M | Catadromous | Demersal |
| Cynoglossidae | *Cynoglossus macrostomus*** | E, M | Non-migratory | Benthopelagic |
| Paralichthyidae | *Pseudorhombus arsius*** | E, M | Oceanodromous | Demersal |
| Platycephalidae | *Platycephalus indicus**** | E, M | Oceanodromous | Reef-associated |

| | | | | |
|---|---|---|---|---|
| Ariidae | *Arius subrostratus**** | E,M | Non-migratory | Demersal |
| | *Plicofollis dussumieri**** | F, M, E | - | Demersal |
| Bagridae | *Horabagrus brachysoma** | F, E | Amphidromous | Demersal |
| | *Mystus gulio*** | E, M | Anadromous | Demersal |
| Clariidae | *Clarias batrachus ** | F, E | Potamodromous | Demersal |
| Heteropneustidae | *Heteropneustes fossilis ** | F, E | - | Demersal |
| SiIuridae | *Wallago attu** | F, E | Potamodromous | Demersal |

***Common **Abundant *Rare F- Freshwater, E-Estuarine, M-Marine

Among catfishes *Arius dussumieri* and *A.subrostratus* were the major species observed in the present study. Crustaceans contributed an average of 23.47% to total landing with *Metapenaeus dobsoni* (8.01%), *Fenneropenaeus indicus* (6.22%), *Metapenaeus monoceros* (4.52%), *Penaeus monodon* (1.45%), *Macrobrachium rosenbergii* (1.43%) and crabs (1.83%) being the major species/groups. Clams (6.84%) and oysters (0.07%) also contributed to fishery of KAE and the major clam species were *Villorita cyprinoides, Paphia malabarica* and *Meretrix casta,* whereas *Crassostrea madrasensis* and *Saccostrea cucullata* were the oysters noticed in the KAE. Monthly landings showed prominent variations as revealed by the bubble plots, which were drawn based on relative abundance of dominant groups of shell fishes and finfishes (Fig. 2 c-h).

Overall similarity of 71.26% was observed in the monthly total fish landings of the KAE with highest similarity observed between December and February months; with an apparent cluster formed between the months of monsoon and post-monsoon season (Fig. 3).

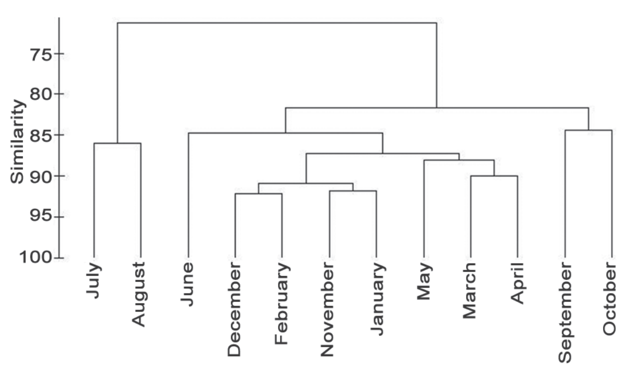


Fig. 3. Monthly similarity of total fish landings in Kodungallur-Azhikode Estuary

Seasonal mean fish catch in KAE was highest during pre-monsoon (397.9 t) followed by post-monsoon (311.5 t) and south-west monsoon period (199.2 t). Monsoon season was dominated by cat fishes (19.9 t), *E. suratensis* (13.2 t), mullets (11.7 t) and *C. chanos* (2.9 t). *F. indicus* (21.4 t) and *M. dobsoni* (12.5 t) were the major species of shrimps, which supported monsoon fishery of KAE (Fig. 2). Fishery in the post-monsoon season was formed by cat fishes (24.6 t), *Gerres* sp. (18.5 t), *E. maculatus* (17.9 t), *E. suratensis* (17.5 t), mullets (15.9 t), *Sillago* sp. (16.1 t), *Ambassis* sp. (15.3 t) and *C. chanos* (14.2 t). *M. dobsoni* (27.5 t) and *F. indicus* (16.4 t) was dominant in post-monsoon fishery. Clupeids and carangids also appeared in the fish catch during pre-monsoon; 16.2 t and 3 t respectively. Among a complex array of fishing gears being operated in the KAE, gillnets contributed 45% of the total fish catch followed by Chinese dip nets (18.31%), stake nets (19.96), cast net (7.15%), ring nets (4.19%), scoop nets (3.39) and hook and lines (2%). Gillnets also showed highest CPUE of 6.91 kg h$^{-1}$ followed by cast nets (1.85 kg h$^{-1}$), Chinese dip nets (3.20 kg h$^{-1}$), stake nets (3.05 kg h$^{-1}$), ring nets (1.27 kg h$^{-1}$), hook and lines (1.35 kg h$^{-1}$) and scoop nets (0.92 kg h$^{-1}$).

Table 2. Occurrence and distribution pattern of shellfish species in the Kodungallur-Azhikode Estuary

| Family | Species |
|---|---|
| Penaeidae | *Fenneropenaeus indicus**** |
| | *Penaeus monodon**** |
| | *Penaeus semisulcatus*** |
| | *Metapenaeus monoceros*** |
| | *Metapenaeus dobsoni**** |
| | *Metapenaeus affinis*** |
| Palaemonidae | *Macrobrachium rosenbergii**** |
| Squillidae | *Oratosquilla nepa*** |
| Portunidae | *Scylla serrata**** |
| | *Scylla tranquebarica*** |
| Corbiculidae | *Villorita cyprinoides**** |
| Veneridae | *Paphia malabarica**** |
| | *Meretrix casta**** |
| | *Meretrix meretrix**** |
| Ostreidae | *Crassostrea madrasensis**** |
| | *Saccostrea cucullata* * |

***common **abundant * rare
F- Freshwater, E - Estuarine, M - Marine

## Discussion

The application of ecological aspects is indispensable to achieve goals in conservation and restoration programmes. The present study investigated the variation in fish production and species composition in KAE in relation to the prevailing environmental changes. Environmental conditions have direct relationship with growth, reproduction, abundance and distribution of fishes and they were mainly temperature, salinity, dissolved oxygen, nutrients, pollutants, water current, tide and turbidity of water column (Vivekanandan and Sivakami, 2007). Fish assemblages in estuaries are largely structured by abiotic gradients (Kupschius and Tremain, 2001) that include salinity (Wagner, 1999; Martino and Able, 2003), temperature (Maes *et al*., 2004) and dissolved oxygen (Weisberg *et al.,* 1996; Eby and Crowder, 2004). In typical drowned river valley estuarine systems, environmental gradients are often steep due to the large watershed to surface area ratio and associated freshwater influence. This can cause dramatic shifts in salinity and temperature that estuarine organisms must either adapt to, or avoid (Vernberg, 1982; Jayachandran and Bijoy Nandan, 2012). Similarly, a significant seasonal variation was observed in the fishery of KAE during the present study. South-west monsoon and associated river discharge would have ultimately resulted in the decline in distribution and abundance of fish community with finfishes avoiding stressful conditions by migration and most of the sessile organisms like molluscs succumbing to sudden environmental changes. Increased primary production was observed during pre-monsoon period in the KAE. According to Day *et al.* (1989), high rate of coastal primary productivity, which suggest high availability of pelagic and/ or benthic prey; this prey availability could be one of the reason for observed maximum fish production in the KAE during pre-monsoon. Similar trend was also reported from the same estuary by Harkrishnan *et al.* (2011) during 2005- 2007 period. Whereas, fish production in the estuarine mouth zone (EMZ) decreased to 348.5 t during the present study as compared to earlier studies (Harkrishnan *et al*., 2011) where 369 t (2005-2006) and 424.8 t (2006-2007) were recorded. Total fish production in the estuary also declined to 908.6 t, when compared to the earlier studies (Anon., 2001) where 2747 t was observed. Average fish catch yield in the KAE (5.4 kg ha $day^{-1}$) was well below the average yield of estuarine fish production in India where it was 45 to 75 kg $ha^{-1}$ (Jhingran, 1991; Sugunan, 2010). However, compared to the total annual average fish production in the whole Vembanad wetland and other backwaters of Kerala (14000-17000 t; Sugunan, 2010) fish production in KAE was moderately good. Both fisheries exploitation and increased nutrient loading strongly affect finfish and shellfish abundance and production in estuaries (Breitburg *et al*., 2009). Turbidity level enormously increased particularly during monsoon which could be attributed to high influx of silt content, agricultural runoff, sewages and other allochthonous organic matters (Jayachandran and Bijoy Nandan, 2012). Clam production in KAE drastically reduced from earlier reports and it could be due to increased turbidity level and bottom disturbances by intense sand and clam mining and these stresses could have affected larval settlement pattern. Similar situation was also reported from the southern part of Vembanad Lake (Menon *et al.,* 2000). However, high turbidity level in the estuarine environment generally lead to increased partitioning of resources and shelter from predators (Day *et al.,* 1989). Heavy freshwater discharge from the rivers during monsoon result in depletion of oxygen content by the degradation of organic matter accumulated in the basin of the estuary. The combined effect of eutrophication and overexploitation of fishes simultaneously increase algal production, degrade habitat and remove fish and shellfish biomass (Breitburg *et al*., 2009). Clam population structure in the KAE also exhibited changes on a temporal scale. Omnivorous fishes in the estuary increased during post-monsoon due to organic enrichment and high level of habitat diversity in the estuary. In contrast, nutrient enrichment can reduce sustainable harvest by reducing the growth, survival and reproduction of target species where negative effect of eutrophication exists (Breitburg *et al*., 2009). Seasonal mean fish catch in the KAE significantly reduced during monsoon period, could be due to various stressors in the ecosystem and the maximum catch was recorded during pre-monsoon period. The observed reduction in the fish landing during south-west monsoon was not only due to environmental stress but also due to decreased fishing days; marked by heavy rains. In this ever changing environment, salinity has an important role, not only in determining the distribution of fishes within an estuary, but also in the abundance and diversity of ichthyofauna. Salinity was comparatively high during pre-monsoon months and it substantially reduced during south-west monsoon and the salinity variation in the water column could have resulted in the reduction of total fish landings. On the other hand, some fishes got attracted to estuary during monsoon due to physiological/behavioral attraction to river discharge and precipitation owing to preference to lower salinity for part or whole of life cycle (Day *et al.,* 1989). Significant positive relation between fish productivity and water temperature ($r = 0.738$, $p<0.01$) as well as significant positive correlation between pH ($r = 0.561$, $p<0.574$) and Chl-*a* ($r = 0.561$, $p<0.05$) were observed. Significant negative correlation was noticed between fish production and BOD level in the estuary ($r = -0.688$, $p < 0.05$). Linear regression analysis indicated that 50% of the variance in fish landing can be predicted from the Chl-*a*, water temperature and salinity variations combined. The model of Chl-*a*, water temperature and salinity significantly predicts the fish landing ($p<0.05$).

Mass fish surfacing and few mortality were also observed in the EMZ of KAE during fall of south-west monsoon by the influence of depleted oxygen content due to degradation of accumulated organic matter during the monsoon river discharge and sudden increase of salinity. Gillnet was the most widely used gear in the estuary which contributed 53.04% to the total fishery; and exhibited highest CPUE among the several types of fishing gears employed in the estuary (6.91 kg $h^{-1}$). Estuarine mouth zone (EMZ) contributed mainly marine and true estuarine fish species and estuarine upper zone (EUZ) contributed mainly freshwater and true estuarine species. The present study noticed a significant reduction in the fish production from the earlier studies (Anon. 2001 and Harikrishnan *et al.,* 2011) in the same estuary. Significant intra-annual variation in fish productivity was also observed during the study. This seasonality in fish catch in the estuary indicated that monsoon induced sudden changes in the water quality and supported low biological population and communities, while less disturbed seasons supported maximum fish stock and variety of species. The drastic reduction in annual fish landing in the estuary could be due to habitat degradation caused by intense sand mining, aquaculture, pollution, artificial breaching, urban encroachment and harbour development. Unfriendly fishing practices, size and recruitment overfishing and associated factors were the major reason for fish diversity loss in the KAE. Anthropogenic activities, overfishing and various types of pollutants from different point and non-point sources have a crucial role in the habitat degradation (Jayachandran and Bijoy Nandan, 2012).

Understanding the variation in estuarine fish production as well as icthyoplankton diversity is important for management of fisheries; partly owing to their biological importance as nursery areas for many commercial fish species. Juvenile estuarine fish populations are strongly affected by climatic variability, which may affect fish production potential through changes in either growth or abundance (Martin and Michael, 2002). KAE is an important ecological buffer for many of the marine fish species as a location for breeding and larval development. However, KAE appears to be potentially critical for dampening climate variability induced stock fluctuations whcih recalls the importance of sustainable management of fisheries; particularly during recruitment of fish stock and this in turn highlights the importance of estuaries. The declining fish stocks in the estuary could be attributed to inadequate fishery resource management which leads to mortality of juveniles and removal of broodstock during reproductive seasons. The large scale seasonal variability on environmental parameters implies that seasonal variation can have important role on fish abundance in the estuary. However, climatic variations can affect the natural fish stocks and these variations would affect the fishery environment and ecosystem as a whole. Therefore, its restoration deserves highest priority in conservation programs and in mitigation efforts.

Understanding the variation in estuarine fish production and diversity is important for management of fisheries. Estuaries act as feeding, rearing, breeding, spawning and larval development area for biologically and economically important marine and freshwater fish species. However, increased exploitation of estuarine resources by recreational as well as subsistence fishermen, and also by other human activities like sand mining, waste discharge *etc.* could have affected fish population dynamics in the estuary. Whole ecosystem approach is required to protect our ecosystems rather than measures to conserve individual species. The main implication should be the change of paradigm with a new approach for conservation actions and introduction of multidisciplinary research aiming at co-ordinated management.

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