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Distribution of mudskippers in the mudflats of Muthupet, Southeast coast of India

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Abstract
The relationship between mudskipper abundace and physico-chemical parametrs of Muthupet mangrove forest was studied during April 2012- March 2013. In the present study, impact of different enviornmental parameters on mudskipper population was investigated. The mudskippers population varied from place to place depending upon the enviornmental parameters. The parametrs such as clay, DO, TOC, pH, and soil moisture was found to have significant relationship with the mudskipper distribution. The estuarine and mangrove area was found more diverse then the riverine and marine areas. The genus periophthalmus was found dominant over other genus.

Keywords: Mudskippers, physico-chemical parametrs, population density, PCA and Muthupet.

Introduction
Mudskippers (Gobiidae: Oxudercinae) the only fishes which are known to burrow and reside in the intertidal mudflats or mangrove swamps of the Indo-West Pacific region. [1] There are about 40 species belonging to the genera namely *Periophthalmus*, *Boleophthalmus*, *Periopthalmodon*, *Scartelaos* and etc. In India occurrence of *Boleophthalmus boddarti* (Pallas), *B. dussumieri* (Valenciennes), *Periophthalmus variablis* (Pallas), *Periophthalmodon schlosseri* (Pallas) and *Scartelaos viridis* (Hamilton) are reported from various coastal places. [2-4] Mudskippers are on the verge of declining trend and are threatened to a combination of anthropogenic and natural calamities like tsunami. Rema Devi [5] listed a few species of mudskippers of India as Endangered (*B. dussumieri and S. viridis*) and Vulnerable (*B. boddarti* and *Ps. koelreuteri*) which is based on the habitat loss and other pollution status.
Muthupet mangrove wetland of Vedaranyam area is located (Lat.10˚46'N Long.79˚ 51'E) in the southernmost tip of the Cauvery delta, the total area of the lagoon is 13.32 km^2 and it has a volume of 9.6 x 106 m^3 (as estimated for Nov-Dec 2003). It is a part of a large coastal wetland complex called the great Vedaranyam Swamp. This area has a gentle slope towards Palk Strait of Bay of Bengal. The distributaries of Cauvery viz., Paminiyar, Koriyar, Kandaparichanar, Kilaithangiyar and Marakkakoraiyar discharge their water into the wetlands and form a large lagoon before reaching the sea. It is highly productive and rich in fishes, prawns, crabs, hermit crabs and bivalves. The seasonal climate in study area may be conveniently categorized into postmonsoon (January-March), summer (April- June), premonsoon (July-September) and monsoon (October-December). Muthupet mangrove is bounded by vast industrial activities like aquaculture, fishing, agriculture and tourism which add their effluents. The present study is a pathfinder to analyze the anthropogenic and natural changes in the hydrological and sediment parameters and their relationship with abundance and distribution of mudskippers. These data may serve as benchmark for future researches and development of appropriate management action plans.

2. Materials and methods
2.1. Physico- chemical analysis
On seasonal basis the water samples were collected in pre-cleaned polypropylene containers. Sediment samples were collected using corer and transferred to clean polythene bags and transported to the laboratory. The samples were air-dried and the plant root and other debris were removed and stored for further analysis. The physical parameters like pH, temperature and salinity were measured i*n-situ* in field condition. The temperature was measured with a mercury thermometer having ±0.02 °C accuracy and the pH of water was measured by a

calibrated pH pen (pH ep-3 model). Salinity was estimated using a Hand Refractometer (Erma Company, Japan). The DO was immediately fixed and brought to the laboratory for further analysis. For the analysis of soil textural composition and pH, the air-dried sediment samples were used as such. The estimation of total organic carbon in sediment was performed by adopting the method of El Wakeel and Riley [6].

2.2. Collection of Mudskippers

The mudskippers were seasonally collected from 4 different areas in the Muthupet mangroves by intensive field work and also with the help of local fishermen. Scoop net was used for the collection of mudskippers, the collected mudskipper specimens were preserved in 10% formalin buffer solution. The specimens were identified based on their Morpho - Meristic characteristics. Seasonal changes in the abundance of mudskippers at the study site were recorded during April 2012- March 2013 using a similar technique to the visual survey formulated by Chan [7]. The observations were made within a 200 m radius at each sampling stations. Two transect lines each 100 m^2, were established at the study site. One was laid perpendicular to the shore and other at angle to the shore. Along transects, 1 m^2 quadrates constructed of PVC pipes were fixed permanently at every 10 m interval. Field visit and observations were carried out in morning low tide. The Principle component analysis was done with PAST- version 1.89. The identification of the Mudskipper was done following Polgar, Murdy [1, 8]

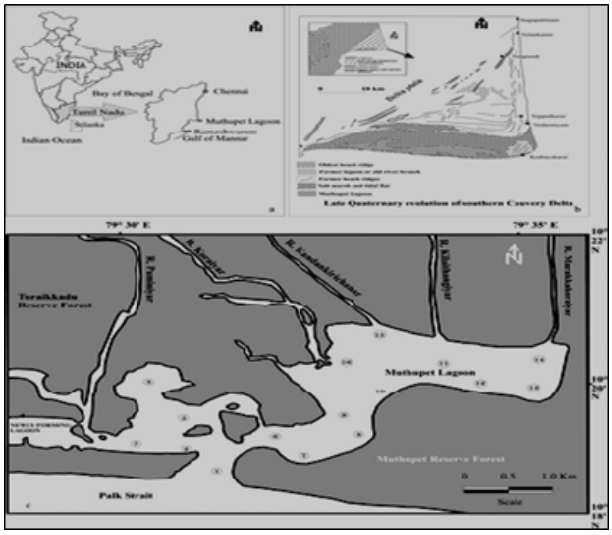

Fig 1: Map showing the study area

3. Results

3.1. Enviornmental Parameters

The air temperature and water temperature ranged from 25.9 ^{0}C to 37.3 ^{0}C and 23.5 to 35.3 ^{0}C respectively. Both air temperature and water temperature was recorded maximum during summer (April - June 2012) and the minimum values were recorded during monsoon (October - December 2013). The salinity of the water varied greatly throughout the year, it ranged from 24.4 psu to 34.4 psu. Maximum salinity was recorded during summer and the minimum salinity was reported during monsoon. The water pH varied significantly and the maximum value (8.17) was recorded during summer and the minimum (7.67) was reported during monsoon. The dissolved oxygen content in water varied from 3.8 mg/l to 5.17 mg/l.

The soil parameters also showed significant variation throughout the year, the soil pH ranged from 7.87 to 8.2. The maximum value was recorded during summer and the minimum during monsoon. The total organic content (mgC/g) also showed wide fluctuation, the least value (4.8 mgC/g) was found during premonsoon and most (5.4 mgC/g) during summer. The soil moisture was found maximum (40.2%) during monsoon and minimum (50.79%) during summer. The soil texture of Muthpet area frequently varied, the sand contents upper limit (38.4%) was found in summer and lower limit (30.14%) in monsoon similarly the silt values varied 25.2% to 31.5%. The clay content was found higher (44.7%) during postmonsoon and lower (29.9%) during summer.

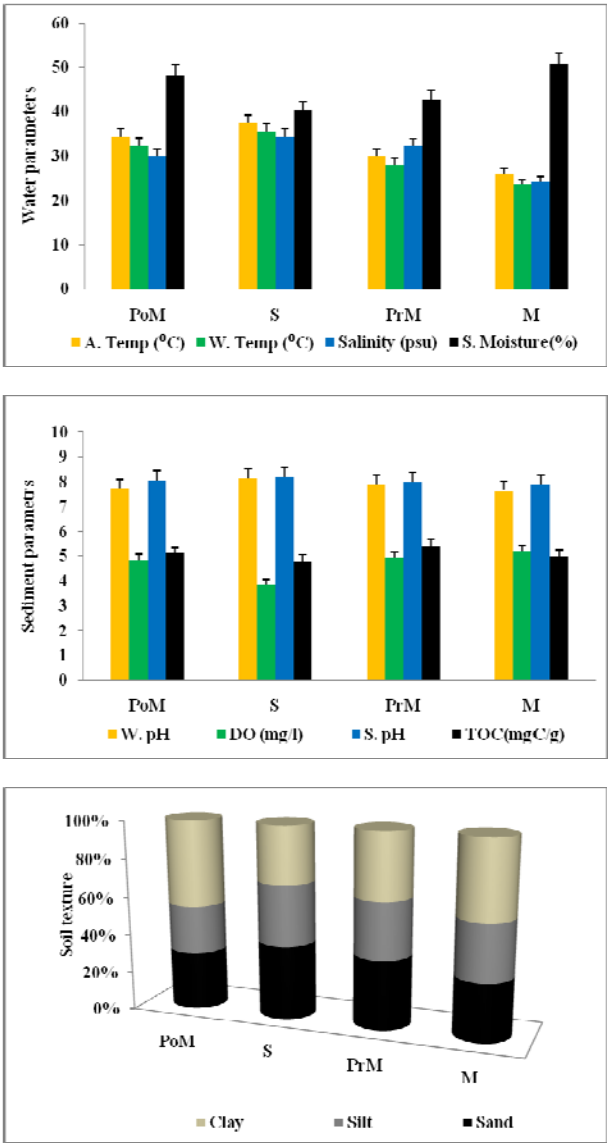

Fig 2: Water and sediment parameters recorded from the Muthupet mangroves

3.2. Biological entities

3.2.1 Species composition of mudskipper

In the present study, 5 mudskipper species belonging to the 3 different genera was recorded from the Muthupet mangroves:

1. *Boleophthalmus*
2. *Periophthalmodon*
3. *Periophthalmus*

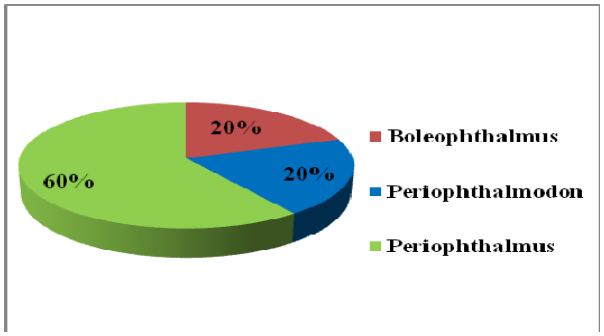

Fig 3: Species composition of mudskippers in Muthupet mangroves

Table 1: Distribution of mudskippers in five different stations of Muthupet mangroves

Mudskippers	Riverine	Estuarine	Mangrove	Marine
Genus *Boleophthalmus*				
Boleophthalmus boddarti	++	++	+	+
Genus *Periophthalmodon*				
Periophthalmodon schlosseri	*	+	++	*
Genus Periophthalmus				
P. chrysospilos	+	+	++	*
P. novemradiatus	+	++	+	+
P. variabilis	*	++	++	+

+: Present *: Absent ++: Abundant

Of the 5 species recorded, *Periophthalmus* genus was found to be the largest group in the collection with 3 species. *Boleophthalmus* and *Periophthalmodon* were found to be the next dominant group with 1 species each.

Among the genus *Periophthalmus*, *Periophthalmus variablis* and *P. novemradiatus* were found to be the common species in the samples collected in various stations. Among other genus, *Boleophthalmus boddarti* and *Periophthalmodon schlosseri* showed consistency in their occurrence in the samples collected from five different stations of Sundarbans.

3.2.2. Station wise distribution of mudskippers

In station I (Riverine area), a total of 2 species of mudskippers were recorded. Among them there were 1 species of *Periophthalmus* and 1 species of *Boleophthalmus*. In station II (Estuarine area), all the 5 species of mudskippers were recorded. Among them there were 3 species of *Periophthalmus*, 1 species of *Boleophthalmus* and *Periophthalmodon*. In station III (Mangrove), a total of 5 species of mudskippers were recorded. Among them there were 3 species of *Periophthalmus*, 1 species of *Boleophthalmus* and *Periophthalmodon*. In station IV (Marine), a total of 3 species of mudskippers were recorded. Among them there were 2 species of *Periophthalmus* and 1 species *Boleophthalmus*

Among mudskipper species viz., *Periophthalmus variablis, P. novemradiatus, and Boleopohthalmus boddarti* were found to occur in all the stations throughout the year and among stations, the Mangrove and Estuarine were the most populated stations. The Riverine area was moderately populated whereas the marine area were least populated.

3.2.3. Seasonwise occurrence of mudskippers

During postmonsoon the maximum (5) species was recorded in station III and the minimum (3) was recorded in station IV. The station I and II was recorded with 3 and 4 species respectively. During summer the highest (4) number species was recorded in station III and the minimum (2) was recorded in station I. In premonsoon the most number of species (4) was recorded in station II and the least (2) was recorded in station IV. During monsoon the maximum number of species (5) was recorded in station III and minimum (3) in station III.

3.2.4. Population density of mudskippers

The results of population density recorded in all the five stations are shown in Fig. 23. In station I, the density of mudskippers varied between 50 and 83 organisms per 100 square meters. The maximum was during postmonsoon, 2014 and minimum during summer, 2013. At station II, the population density of mudskippers varied from 80 to 109 animals per 100 square meters. The maximum density was recorded during postmonsoon, 2013 and minimum in premonsoon, 2014. With respect to station III, the density of mudskippers per 100 square meter fluctuated from 49 to 100 animals. The minimum was noticed during monsoon, 2014 and maximum in postmonsoon, 2013. In station IV, the density of organisms per 100 square meters was from 15 to 30 organisms. The minimum was witnessed during premonsoon, 2014 and maximum during postmonsoon, 2013.

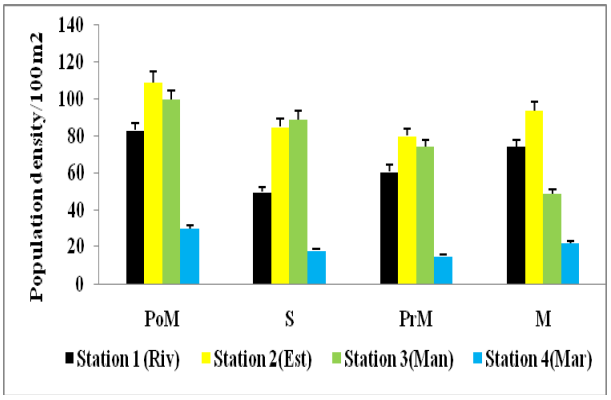

Fig 4: Seasonal variation in population density of mudskippers recorded in all 4 stations

3.2.5. Percentage composition of mudskippers

The percentage composition of mudskippers is depicted in Fig. 5 for all the four stations. In station I, *Periophthalmus* were found to be the dominant group by constituting 66.66% of the mudskipper recorded. *Boleophthalmus* formed the second dominant group with a percentage occurrence of 33.33%. At station II also *Periophthalmus* topped with a percentage incidence of 50% of the total mudskippers enumerated. *Boleophthalmus and Periophthalmodon* ranked second with a percentage of 25%. With respect to station III, *Periophthalmus* occupied the top place with a percentage of 75%. *Boleophthalmus and Periophthalmodon* constituted 12.5% to the total mudskippers collected. In station IV, *Periophthalmus* continued to be the dominant group and constituted 66.66% of the mudskipper recorded. *Boleophthalmus* formed the second dominant group with a percentage occurrence of 33.33%.

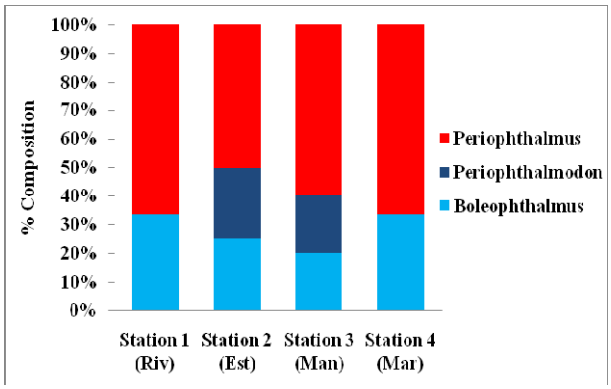

Fig 5: Percentage composition of Mudskippers recorded in stations I – IV during the study period.

3.3. Principal Component Analysis (PCA)

In order to ascertain the relationships between the environmental variables, species and seasons was done by PCA. The plot showed that the parameters such as atmospheric temperature, water temperature and salinity are significantly influenced by summer season in estuarine waters. It was also observed that silt and sand are the important parameters that are significantly influenced by premonsoon season. The parameters such as DO, TOC, soil pH and water pH are the important factors that are significantly influenced by postmonsoon season in estuarine waters. While the parameters like salinity and clay were positively correlated with the influence of monsoon (Fig. 6). The mudskippers were found maximum during postmonsoon because of favorable environmental conditions.

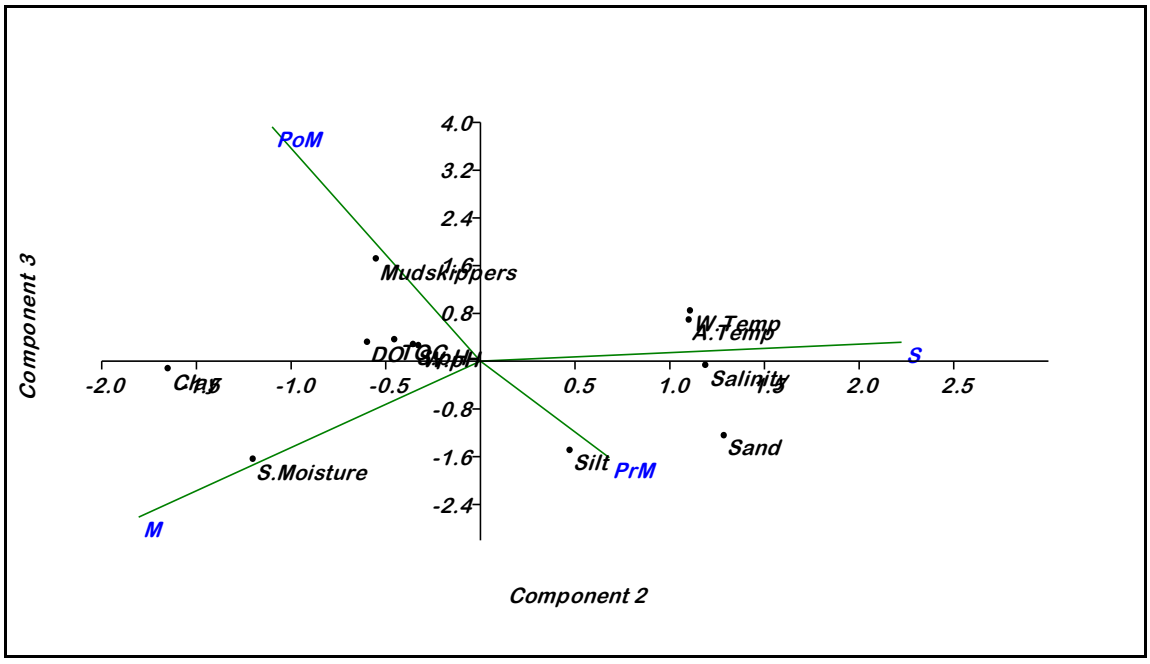

Fig 6: Principal Component analysis between the environmental variables and mudskipper species density in Muthupet mangroves

Discussion

This study gave baseline information about the assemblages of mudskipper species in different regions of Muthupet mangroves. The present results revealed that Physico-chemical variables play a leading role in the assemblage of mudskippers in all 4 stations of Muthupet mangrove forests. Clay content followed by dissolved oxygen TOC and pH were the major factors influencing the spatial patterns of mudskippers assemblage. Chaudhuri *et al*. [9] found a similar distributional pattern with intertidal mangrove fishes of Indian Sundarbans. Jaffar *et al*. [10] reported environmental parameters have profound influence on the abundance of dominant mudskippers. In the present study, atmospheric temperature and surface water temperature fluctuated from 25.9 ^{0}C to 37.3 ^{0}C and 23.5 to 35.3 ^{0}C respectively. The maximum was recorded during summer and minimum during monsoon. The minimum value of salinity 24.4 psu was recorded during monsoon and the maximum was 34.4 psu during summer. The DO ranged from 3.8 ml/l in summer to 5.17 ml/l in monsoon similarly, the water pH varied from 7. 67 (monsoon) to 8.17 (summer)

The soil pH ranged from 7.87 to 8.2. The maximum value was recorded during summer and the minimum during monsoon. The least value of TOC (4.8 mgC/g) was found during premonsoon and most (5.4 mgC/g) during summer. The soil moisture was found maximum (40.2%) during monsoon and minimum (50.79%) during summer. the sand contents upper limit (38.4%) was found in summer and lower limit (30.14%) in monsoon similarly the silt values varied 25.2% to 31.5%. The clay content was found higher (44.7%) during postmonsoon and lower (29.9%) during summer. The environmental parameters recorded in the present study were found to similar to Chaudhuri *et al*. and Kundu *et al*., [9, 11] who recorded the same set of results from this same study area.

The preferred environment of a species is determined by many biotic and abiotic parameters, such as prey abundance or predator avoidance, temperature, salinity, bottom type etc. [12-14] The geographical distribution of a species can depend on the density of the population and so may change between years, [15] in some cases it is considered to be age or size dependent. [16, 17, 14] The density of fish may vary within the surveyed area since gradients can occur related to environmental parameters like water depth, salinity, temperature etc. [18] In the present study, the highest part of variability of mudskipper assemblages was evaluated by Principal Component Analysis (PCA) and it explained the

species composition in different geographical regions.

The present study emphasized that clay content, soil moisture, TOC, DO and salinity were the most important factors controlling the temporal variation of mudskippers in the intertidal estuarine system of Muthupet mangroves. By applying Principal Component Analysis, as much as 13.26 to 42.96% of the variations in fish abundance were explained by these five environmental variables. PCA can discriminate environmental factors affecting fish assemblage at species level. It is a good tool to comprehend the spatial distribution in estuarine ecosystem if the species and environment matrix data are suitable.

Coastal-estuarine habitats are being used extensively as nursery grounds by marine species and also as nesting ground by euryhaline coastal and estuarine species. Kundu [11] reported that the fish assemblage in mudflat environments of Sundarban mangroves during low tide was dominated by the mudskippers, *Periophthalmus novemradiatus* (61-80%) and *Boleophthalmus boddarti* (13.54- 25.5%). In the present study also the *Periophthalmus* species outnumbered (50-75%) the other mudskippers. The *Boleophthalmus* was recorded as second dominant (12.5-33.3%). In the present study a total of 5 oxudercine gobiies were recorded from the 4 intertidal stations of Muthupet mangroves during low tide. The diversity of intertidal mudflat fishes was recorded maximum during the postmonsoon season. The similar observations were supported by the studies of Pintu and Puchihewa [19] from Sri Lanka similarly Morrison [20] reported same set of results in an Australian estuary.

Conclusions

In this study, seasonal, spatial and inter-annular variation were approached to record the mudskippers assemblage in intertidal mudflats. The mudskippers were recorded maximum during the postmonsoon season and similarly the estuarine and mangrove area (Station 2 and 3) were found as most diverse. The present study illustrated the importance of intertidal mudflat habitat of Muthupet mangroves for the mudskippers assemblage. Further studies about the intertidal mudflats and their relationship with mudskipper assemblage are important to understand the adaptation of this group of fishes in mudflat environment.

Conflict of Interest Statement

We declare that the present work has no conflict of interest.

Acknowledgments

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