Available online at: www.mbai.org.in doi:10.6024/jmbai.2021.63.1.2165-16

Diversity of Mudskippers along the selective mudflats of mangroves of east coast of India

V. Ravi*, G. Mahadevan and R. Bharathi
Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai-608502, Tamil Nadu, India.

*Correspondence e-mail: ravi.velayudham@gmail.com

Received : 05 Sep 2020 Accepted : 09 Apr 2021 Published : 15 Apr 2021

Original Article

Abstract

Mudskippers (Oxudercidae) a highly evolved group of fishes, are distributed exclusively in the mudflats of estuary and mangroves of Indo-West Pacific region. The distributional record of Indian mudskippers is rare and hence the present study was aimed to study the species diversity and assemblage of mudskippers in the mudflats environments of five major mangroves of east coast of India especially a selective part for sampling along the Sundarbans, Bhitarkanika, Coringa, Pichavaram and Muthupettai. The samples of mudskippers were collected from the mudflats by scoop net and handpicking methods. Mudskipper specimens were identified and preserved. Diversity indices were calculated for statistical analysis. The results revealed that, of the 17 species recorded, the genus *Periophthalmus* was the dominant group with 6 species, while the genus *Boleophthalmus, Scartelaos* and *Parapocryptes* were the next dominant group with 2 species each. Among the five stations for sampling of fishes, station (1) (Sundarbans) dominated with 17 species of mudskippers followed by station 2 (Bhitarkanika) (9 species), station 4 (Pichavaram) (7 species), station 5 (Muthupettai) (6 species) and station 3 (Coringa) (5 species). The species richness Margalef index (d) ranged between 7.966 (Station 1) and 14.826 (Station 3). Similarly, the species evenness (Pielou's evenness index) varied from 0.765 (station 5) to 0.974 (station 2). The species diversity index (Shannon diversity index) varied from 0.568 (Station 3) to 1.146 (station 1). Monitoring of species diversity and the endemic nature of mudskippers helps to understand the health of the ecosystem as they act as ecological indicators of mudflats in estuaries and mangroves.

Keywords*: Mudskippers, diversity, mudflats, mangroves, India*

Introduction

Mudskippers (Oxudercidae) inhabit the mudflats of estuary and mangroves of Indo-Pacific region. Studies on the distribution of mudskippers were reviewed by Murdy (1989), Clayton (1993) and Parenti and Jaafar (2017). They comprise predominantly of five genera (*Boleophthalmus, Periophthalmus, Periophthalmodon, Pseudapocryptes* and *Scartelaos*) which are air-breathing and amphibious (Ishimatsu *et al.,* 2007) using the bucco-pharyngeal- opercular cavity as a respiratory organ (Aguilar *et al.,* 2000). They build burrows to a depth range of 25 to 150 cm (Ravi *et al.,* 2004) for sheltering to raise their

young ones and also for escaping from predators (Stebbins and Kalk, 1961). Their burrows are always water–filled up to the brim even during low tides. Mudskippers have greater population density on tidal mudflats of estuary and mangroves (Edun *et al.,* 2010). Sasekumar and Chong (1998) described that the vegetation enhances this fish population as they provide organic matter and detritus as a food source. Mudskippers feed mainly on diatoms (Ravi, 2013) and crustacean appendages, polychaetes and insect parts (Bob-Manuel, 2011) during low tide. Mudskippers are known for their remarkable behavior like skipping, rolling, digging, confronting, partial swimming, partly climbing on pneumatophores and mangrove trees during low tide and they also have the capacity on zonal recovery or direction-finding ability (Berti *et al.,* 1992). Mudskipper species of *Boleophthalmus pectinirostris* and *Pseudapocryptes elongatus* have a high potential for coastal aquaculture (Hong *et al.,* 2007; Minh *et al.,* 2010) and consequently the number of intensive farms of mudskippers are increasing along coastal areas (Minh *et al.,* 2010). Mudskipper fishery is carried out on *P. elongatus* in Mekong Delta, Vietnam (Minh *et al.,* 2010) and *B. boddarti* in Namkhana region (Sundarbans mangroves), India (Ravi *et al.,* 2013) and their nutritional values were described by Banerjee *et al.* (1997); Andem and Ekpo (2014). Mangroves act as shelter for a variety of living organisms (Macnae, 1968; Kathiresan and Bingham, 2001). Studies on mudskippers distribution on mangrove environment were carried out by Jung and Lee, 1994; Daud *et al.,* 2005; Lawson, 2011; Ravi, 2013; Udoh *et al.,* 2013; Mahadevan and Ravi, 2015; Su and Lim, 2016; and Budi *et al.,* 2018. The distributional record of Indian mudskippers are rare (Ravi *et al.,* 2013; Mahadevan and Ravi, 2015; Das and Palita, 2015) and hence the present study was aimed to study the species diversity and assemblage of mudskippers in the mudflats environments of five major mangroves of east coast of India especially a selective part for sampling along the Sundarbans, Bhitarkanika, Coringa, Pichavaram and Muthupettai.

Material and methods

Study areas and sampling of Mudskippers

Fishes (mudskippers) were identified (Murdy, 1989; Polgar *et al.*, 2010) and then preserved in 10% formalin buffer solution. Samples of mudskipper species were collected from 5 stations namely the mangroves of Sundarbans (Station 1), Bhitarkanika (Station 2), Coringa (Station 3), Pichavaram (Station 4) and Muthupettai (Station 5) (Fig.1) through intensive field work (January 2013- December 2015) in the mudflats during low tide. The details of description of the study areas are given below:

Station 1. Sundarbans mangrove forests: Sundarbans is one among the world's largest delta consisting 10,200 sq. km of mangrove forest, spread over India (4200 sq. km of Reserved Forest) and Bangladesh (6000 sq. km approx. of Reserved Forest). Indian Sundarbans is bound to be supported on the west by river Muriganga and on the east by rivers Harinbhahga and Raimangal. There are other major rivers such as Saptamukhi, Thakuran, Matla and Goasaba flowing through this eco-system.

Lothian Island of the western Sundarbans is a small island of approximately 38 sq. km area, which extends from 88°18'10"E to 88°21'30"E longitude and 21° 32'50"N to 21°42' 30"N latitude. The island is regularly inundated by diurnal tide up to a certain distance from the northern coast. Mangrove species are found distributed (Joshi and Ghose, 2003) in the Lothian Island such as *Acanthus ilicifolius, Aegialitis rotundifolia, Aegiceras corniculatum, Avicennia alba, Avicennia marina, Avicennia officinalis, Ceriops decandra, Dalbergia spinosa, Derris trifoliate* and *Excoecaria agallocha.* In the present study, the survey of mudskippers was made at low tide during the study period along the mudflats near Bhagabatpur and Surendar Nagar area. The mudflat is located on the northern bank of the river. Many boats land along the vast mudflats and mangroves.

Station 2. Bhitarkanika mangrove forests: Bhitarkanika mangrove forest covers an area of 650 km² in the river delta of the Brahmani

Fig. 1. Map showing the study areas

and Baitarani rivers of Odisha State. Next to the Sundarbans, Bhitarkanika (20°4′-20°8′ N; 86°45′-87°50′ E) is the second largest viable mangrove eco-system in India harbouring more than 70 species of mangrove and its associates. The survey of mudskippers was carried out in two stations in the mudflats of Bhitarkanika mangrove forests in the present study,

Station 3. Coringa mangrove forests: Coringa mangrove (Lat. 16°44′ to 16°53′N and Long. 82°14′ to 82°22′E) is located south of Kakinada Bay, Andhra Pradesh State, India. Coringa mangroves receive freshwater from Coringa and Gaderu rivers, distributaries of Gautami Godavari River and neritic waters from Kakinada Bay. Numerous creeks and canals traverse this ecosystem.

Station 4. Pichavaram mangrove forests: Pichavaram mangrove (Lat.11°27′N; Long.79°47′E) is situated amidst the Vellar Estuary in the north and the Coleroon Estuary in the south in Tamil Nadu. It is a repository of rare, endemic and endangered species of mangroves. Mudflats selected for the present study lie at Muzhukkuthurai (Lat. 11°27′20N; 79°47′00E). During low tide, the mudflats are exposed and the numerous mudskipper's burrows, crabs, gastropod (*Telescopum telescopim*) can be seen. The buffer zone is covered with thick Casuarina plantation.

Station 5. Muthupettai mangrove forests: Muthupettai mangrove forests (Lat.10°18′N; Long. 79°49′E) are found as lagoon environments. It is situated on the southern part of Cauvery deltaic region along the southeast coast of India. Mangroves spread to an area of about 6800 ha. in which *A. marina* is the single dominant mangrove species accounting for about 95% of the vegetative cover. Other mangroves include *Aegiceras coniculatum, Excoecaria agallocha, Lumnitzera racemosa* and *Acanthus ilicifolius.* Mudflats of this forest are vast spread to an area of about 4 km length. This mudflat is of special category since it is directly exposed to the open sea (Bay of Bengal). Mudskippers are quite actively involved in feeding and exhibiting several behaviors.

Statistical analysis

The biodiversity indices (Shannon and Weiner, 1949; Margalef, 1968; Pielou, 1966) were used to evaluate relative abundance and evenness of species diversity. For Cluster analysis, Bray-Curtis similarity was performed to assess natural grouping of mudskippers (Bray and Curtis, 1957).

Diversity index: In the present study, **α**- diversity was used, which is the diversity of species within a community or habitat. The diversity index was calculated by using the Shannon – Wiener (1949) diversity index.

Diversity index $= H = -\sum Pi \ln Pi$

where $Pi = S / N$

S = number of individuals of one species; N = total number of all individuals in the sample; In = logarithm to base e

Species richness: Margalef's index was carried out as a simple measure of species richness (Margalef, 1958).

Margalef's index $= (S - 1) / \ln N$

Where, S = total number of species; N = total number of individuals in the sample; In = natural logarithm

Species evenness: Species evenness was calculated following the Pielou's Evenness Index (e) was used (Pielou, 1966).

$e = H / \ln S$

where, H = Shannon – Wiener diversity index; S = total number of species in the sample

Results

Distribution of Mudskippers in the study areas

The distribution of mudskippers, especially the total number of species, genus and abundant species are given in (Table 1 and Fig.1-3). Of the 17 species recorded, the genus *Periophthalmus* was found to be the dominant group with 6 species while the genus *Boleophthalmus, Scartelaos* and *Parapocryptes,* were the next dominant group with 2 species each. The genera *Apocryptes, Apocryptodon, Oxuderces, Pseudapocryptes* and *Periophthalmodon* had only one species each.

New records of the mudskippers were noticed in the study areas such as *Scartelaos histophorus* (Stations 1 and 2), *S. gigas* (Station 1), *Pseudapocryptes elongatus* (Stations 1 and 2), *Periophthalmus* (*Ps*) *argentilineatus* (Station 1), *Ps. chrysospilos* (Stations 1,4, 5), *Ps. novemradiatus* (Stations 1-5), *Ps. variabilis* (Stations 1-5), *Ps. walailakae* (Station 1 and 4) and *Ps. waltoni* (Station 1).

The station (1) dominated with 17 species of mudskippers followed by station 2 (9 species), station 4 (7 species), station 5 (6 species) and station 3 (5 species). The genus- wise composition of mudskippers were found high in station (1) with 9 different genera, followed by 7 genera in station 2. The other stations had 3 genera each in stations 3, 4 and 5 respectively.

Table 1. Distribution of mudskippers in the study areas

Species name	Sundarbans (St 1)	Bhitarkanika (St 2)	Coringa (St 3)	Pichavaram (St 4)	Muthupet (St 5)
Phylum Chordata					
Subclass Vertebrata					
Class Actinopterygii					
Order Gobiiformes					
Family Oxudercidae					
Subfamily Oxudercinae					
Tribe Oxudercini					
Parapocryptes rictuosus	+	-	-	-	-
Parapocryptes serperaster	+	+	-	-	-
Apocryptodon madurensis	+	-	-	-	-
Oxuderces dentatus	+	-	-	-	-
Tribe Periophthalmini					
Apocryptes bato	+	+	-	-	-
Pseudapocryptes elongatus	++	++	-	-	-
Scartelaos gigas	+	-	-	-	-
Scartelaos histophorus	+	+			
Boleopthalmus boddarti	++	++	++	++	++
Boleopthalmus dussumieri	++	+	+	+	++
Periophthalmodon schlosseri	++	+	+	+	+
Periophthalmus argentilineatus	+	-	-	-	-
Periophthalmus chrysospilos	+	-	-	+	+
Periophthalmus novemradiatus	++	++	+	+	+
Periophthalmus variabilis	++	+	+	+	+
Periophthalmus walailakae	+	-	-	+	-
Periophthalmus waltoni	+	-	-	-	-
Total species recorded	17	9	5	7	6

+ present; ++ abundant ;–absent/not recorded

Species abundance was estimated based on the dominance by the structure of population in the study areas. In station (1), 6 species were found as abundant species followed by 3 species in station 2; 2 species in station 5; 1 species each in stations 3 and 4 respectively in the study areas. It could be observed that the mudskipper *B. boddarti* was the single most dominant and abundant species, which was uniformly distributed in all the stations. Similarly, the mudskippers such as *B. dussumieri, P. schlosseri, P. novemradiatus* and *P. variabilis* were also found commonly in the study areas. On the contrary, certain species like *P. rictuosus, Apocryptodon madurensis, Oxuderces dentatus, S. gigas, P. argentilineatus, P. chrysospilos* and *P. waltoni* was recorded only in station 1 (Sundarbans).

Biodiversity indices of the mudskippers calculated

The species richness ranged between 7.966 and 14.826. Minimum value was found in Station 1 and maximum was noticed in Station 3. Similarly, species evenness for the study areas is presented in Table 2 and Fig. 2. The species evenness varied from 0.765 to 0.974 in stations 5 and 2 respectively. Species diversity index differed from 0.568 to 1.146 in stations 3 and 1 respectively (Table 2 and Figs.2 and 3).

Analysis of Cluster (Bray-Curtis similarity measure)

Transformation of data effectively limits the distortion by outlying values on the Bray-Curtis similarity measure, which represents an effective method of using cluster analysis in distinguishing biotopes of mudskippers. Similarity was studied through Bray-Curtis Cluster Analysis and they are shown in Fig.3. Stations, Pichavaram and Muthupet formed grouping with highest level of similarity (84%), followed by next level of similarity in Coringa with Pichavaram (62%) and Muthupet (54%). The next level of similarity in Bhitarkanika was with Coringa (55.8%), Pichavaram

Table 2. Biodiversity indices for the study areas

Stations	Total no. of species (S)	Total no. of individuals (N)	Margaleff M Base 10. (Richness)	Pielou's J' (Evenness)	Shannon H' Log Base 10. (diversity)
Sundarbans (St 1)	17	102	7.966	0.931	1.146
Bhitarkanika (St2)	9	31	10.728	0.974	0.88
Coringa (St3)	5	12	14.826	0.944	0.568
Pichavaram (St4)	7	17	13.003	0.835	0.705
Muthupet (St5	6	21	12.101	0.765	0.595

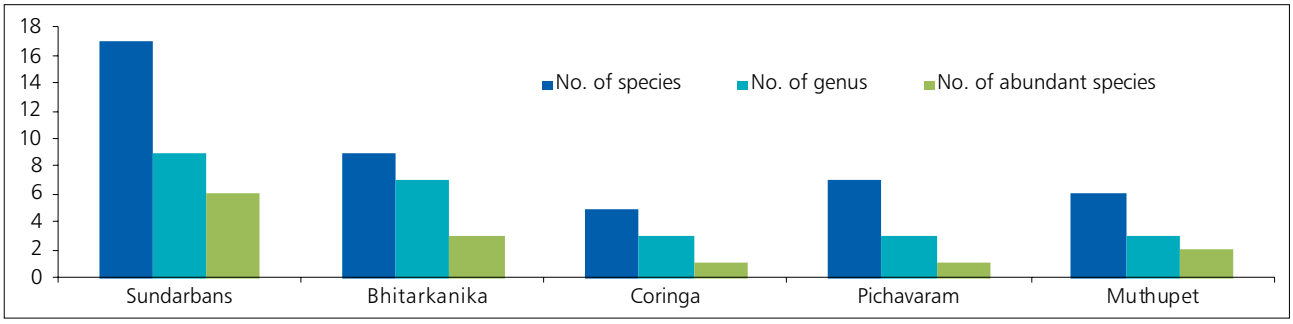

Fig. 2. Total number of mudskippers recorded in the study area

(41%) and Muthupet (38%). Sundarbans linked to the above groups at lowest level of similarity (Fig.3). The genus level of dominance is displayed in Fig.4. The results showed that, among the genera, *Apocryptes* (82%), *Apocryptodon* (80%), formed grouping with highest level of similarity, followed by *Parapocryptes* (89%), *Oxuderces* (94%), *Pseudapocryptes* (90%), *Scartelaso* (90%) and *Periophthalmodon* (65%). *Periopthalmus* and *Boleophthalmus* linked to the above groups at lowest level of similarity (Fig.4).

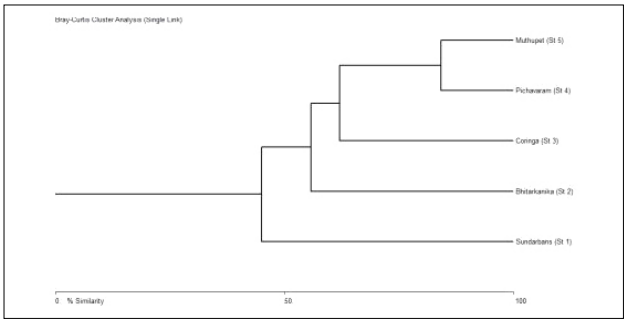

Fig. 3. Biodiversity indices (Cluster analysis) for the mudskippers in the study areas

Discussion

Intertidal habitats receive special attention to establish their value for the species that use them at different stages of their life cycle (Franca *et al.,* 2008), juveniles of several fish species (Vinagre *et al.,* 2006), feeding ground by large populations of resident and migratory birds (Moreira, 1999) and as a nursery area by many fish species (Cabral, 2000). Mudflats are unique intertidal habitat harboring high productivity in comparison with subtidal areas (Elliot and Dewailly, 1995) as they constitute a high abundance and diversity of fauna, including infauna, epifauna, as well as fauna that periodically enter it during high tide (Laegdsgaard and Johnson 2001; Chong *et al.* 1990). Mudskippers live on intertidal mudflats and are exposed to a daily regime of alternating terrestrial and aquatic environments (Clayton, 1993). Among Actinopterygians, the divergent adaptation in the functional morphology is extreme in mudskippers. The pectoral fins of mudskippers are used for their primary mode of locomotion on land and pectoral fins in conjunction with the axial musculature and caudal fin to move in water (Pace and Gibb, 2009).

In the present study, totally 17 species of mudskippers were recorded in the study areas. The genus *Periophthalmus* was found to be the dominant group with 6 species while the genera *Boleophthalmus, Scartelaos* and *Parapocryptes,* were the next dominant group with 2 species each. The genera *Apocryptes, Apocryptodon, Oxuderces, Pseudapocryptes* and *Periophthalmodon* were found to have only one species each.

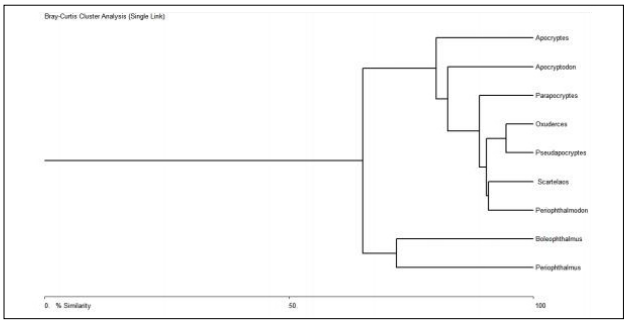

Fig. 4. Biodiversity indices (Cluster analysis) for the mudskipper genera

Among the stations studied, Sundarbans mangroves (the station, 1) dominated with 17 species of mudskippers followed by 9 species in Bhitarkanika mangroves (station 2), 7 species in Pichavaram mangroves (station 4), 6 species in Muthupet mangroves (station 5) and 5 species in Coringa mangroves (station 3). The genus-wise composition of mudskippers was high in station (1) with 9 different genera, followed by 7 genera in station 2. The other stations had 3 genera each in station 3, 4 and 5 respectively. The abundant species were estimated based on the dominance by the structure of population in the study areas. Consequently, 6 species were found in station (1) as abundant species followed by 3 species in station 2; 2 species in station 5; 1 species each in stations 3 and 4 respectively in the study areas. Thus, it could be observed that the mudskipper *B. boddarti* was the single most dominant and abundant species, which was uniformly distributed in all the stations. Similarly, the mudskippers *B. dussumieri, P. schlosseri, P. novemradiatus* and *P. variabilis* were also found commonly in the study areas. On the contrary, species like *P. rictuosus, A. madurensis, O. dentatus, S. gigas, P. argentilineatus, P. chrysospilos* and *P, waltoni* were found recorded only in station 1 (Sundarbans). The family Oxudercidae (Order Gobiiformes) contain about 86 genera and about 598 species (Nelson *et al.,* 2016). The mudskipper species is widely distributed in Indo-West Pacific region (Murdy, 1989; Clayton, 1993). Three species of mudskippers were reported from Tamil Nadu (Rema Devi, 1992), whereas Venkateswarlu *et al.* (1998) mentioned seven species of mudskippers from Mahanadi estuarine region. Similarly Koumans (1953) described eight species with three new records (*Periophthalmus chrysospilos, P. malaccensis* and *Pseudopocryptes borneansis*) while Berry (1972) noticed five species with one new record, *Periophthalmus argentilineatus*. Larson *et al.* (2008) described a total of 149 gobioid species including mudskippers from Singapore. New records of mudskippers are also described. Takita *et al.* (1999) reported eight species with a new record *Boleopthalmus dussumeiri*. Khaironizam and Rashid (2003) listed 13 species adding on four new records *Periophthalmus spilotus*, *P. walailakae, Periophthalmodon septemradiatus* and *Parapocryptes serperaster*, representing seven genera. Most recently, Parenti and Jaafar (2017) recognized forty-three valid species of oxudercine gobies classified in ten genera. Ansari *et al.* (2014) described that the mudskippers are recognized as potential bio-indicator in environmental monitoring and assessments of coastal waters and tropical or subtropical soft bottom intertidal systems. Mudskippers are strongly associated with mangrove ecosystems and tropical mudflats (Ansari *et al*., 2014). In the present study, Sundarbans mangroves support high density and abundance of mudskippers as it has a vast area of potential mudflats. However the clayey dominated periphery/bunds of the riverine system of Sundarbans face damage through soil erosion during floods, which replace the soft muddy area where mudskippers inhabit.

Mudflats of coastal regions are inhabited by mudskippers and thus mudflats act not only as feeding ground but also as breeding and nursery ground. Mudskippers diversity helps to understand the health of coastal regions, hence needs adequate conservation of the resource. Hence conservationists, government and non-governmental agencies have a major role to play in creating public awareness and support for the conservation of mudskipper species in the study areas.

Acknowledgements

The authors are thankful to Dean and Director, CAS in Marine Biology, Annamalai University for the facilities provided and also grateful to the Ministry of Environment, Forests and Climate Change, New Delhi for the financial support.

References

Aguilar, N. M., A. Ishimatsu, K. Ogawa and K. H. Khoo. 2000. Aerial ventilatory responses of the mudskipper, *Periophthalmodon schlosseri*, to altered aerial and aquatic respiratory gas concentrations, *Comp. Biochem. Physiol.*, 127A: 285-92.

Ansari, Abid, A., Subrata Trivedi, Shalini Saggu and Hasibur Rehman. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. *J. Entomol. Zool. Stud.*, 2(6): 22-33.

Andem, A. B. and P. B. Ekpo. 2014. Proximate and mineral compositions of Mudskipper Fish (*Periophthalmus babarus*) in the mangrove swamp of Calabar River, southern Nigeria. *International Journal of Science and Technology*, 72(2): 72-76.

Banerjee, D., D. Pal, T. K. Patra, S. Misra and A. Ghosh. 1997. Lipids and fatty acids of air breathing fish *Boleophthalmus boddareti. Food. Chem.*, 60: 303-309.

Berry, A. J. 1972. The natural history of West Malaysian mangrove faunas. *Malayan Nature Journal*, 25: 135-162.

Berti, R., L. Chelazzi, I. Colombini and A. Ercollni. 1992. Direction-finding ability in a mudskipper from the delta of the Tana River Kenya. *Tropical. J. Zool.,* 5: 219-228.

Bob-Manuel, F. G. 2011. Food and feeding ecology of the mudskipper *Periopthalmus koelreuteri* (Pallas) Gobiidae at Rumuolumeni Creek, Niger Delta, Nigeria. *Agriculture and Biology Journal of North America*, 2(6): 897-901.

Bray, J. R. and J. C. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.,* 27:325-349.

Budi, A. S., Tetri Widiyania and Agung Budiharjo. 2018. Daily behavior of the Mudskippers at Wonorejo mangrove forest Surabaya. In: Inventing Prosperous Future through biological research and tropical biodiversity management AIP *Conf. Proc.* 2002, Page 020003-1-020003-6; doi.org/10.1063/1.5050099.

Cabral, H. N. 2000. Comparative feeding ecology of sympatric *Solea solea* and *Solea senegalensis*, within the nursery areas of the Tagus Estuary. *Portugal. J. Fish Biol.*, 57: 1550-1562.

Chong, V. C., A. Sasekumar, M. U. C. Leh and R. D'Cruz. 1990. The fish and prawn communities of a Malaysian coastal mangrove system, with comparisons to adjacent mud flats and inshore waters. *Est. Coast. Shelf. Sci.,* 31: 703-722.

Clayton, D. A. 1993. Mudskippers, *Oceanography and Marine Biology Annual Review,* 31:507-577.

Das, Mishra and Sharat K. Palita, 2015. Record of six species of Mudskippers (Gobiidae: Oxudercinae) from the mangroves of Bhitarkanika, Odisha, east coast of India, *Indian J. Geo-Marine Sci.*, 44(9): 1294-1301.

Daud, K., Mehdi Mohammadi, Siti Shapor Siraj and Mohamad Pauzi Zakaria, 2005. Morphometric analysis of Malaysian Oxudercine Goby, *Boleophthalmus boddarti* (Pallas, 1770). *Pertanika, J. Trop. Agric. Sci.*, 28(2):121-134.

Edun, O. M., O. A. Akinrotimi, A. Uka and K. N. Owhonda. 2010. Patterns of mudskipper consumption in selected fishing communities of rivers state, *J. Agricult. Social,* (JASR) 10(2): 100-108.

Elliott, M. and F. Dewailly. 1995. The structure and components of European estuarine fish assemblages. *J. Aquat. Ecol.,* 29: 397-417.

França, Susana, Miguel A. Pardal, and Henrique N. Cabral. 2008. Mudflat nekton assemblage in the Tagus Estuary (Portugal): distribution and feeding patterns. *Scientia Marina*, 72(3): 591-602.

Hong, W., S. Chen, Q. Zhang and Q. Wang. 2007. Reproductive ecology of the mudskipper *Boleophthalmus pectinirostris. Acta. Oceanol. Sinica*., 26(4):72-81.

Ishimatsu, A, Y. Yoshida, N. Itoki, T. Takeda, H. J. Lee and J. B. Graham. 2007. Mudskippers brood their egg in air but submerge them for hatching, *J. Exp. Biol.,* 210: 3946-54.

Joshi, H. and M. Ghose. 2003. Forest structure and species distribution along soil salinity and pH gradient in mangrove swamps of the Sundarbans. *Trop. Ecol.*, 44 (2): 197-206.

Jung, T. C, and S. C. Lee. 1994. Genetic variation of the Chinese Mudskipper, *Periophthalmus cantonensis* (Osbeck, 1762) (Pisces; Perciformes, Gobiidae) from Taiwan, *Zool. Stud.,* 33(1): 34-43.

Kathiresan, K. and B. L. Bingham. 2001. Biology of mangrove and mangrove ecosystems. *Adv. Mar. Biol.,* 40:.81-251.

Khaironizam, M. Z. and Y. Norma-Rashid. 2003 First record of the mudskipper, *Periophthalmodon septemradiatus* (Hamilton) (Teleostei: Gobiidae) from Peninsular Malaysia, *Raffles Bull. Zool.,* 51(1): 97-100.

Koumans, F. P. 1953. The fishes of the Indo-Australian Archipelago X. (Leiden: E.J. Brill) 423pp

Laegdsgaard, P. and C. Johnson. 2001. Why do juvenile fish utilize mangrove habitats? *J. Exp. Mar. Biol. Ecol.*, 257: 229-253.

Larson, Helen K., Zeehan Jaafar and Kelvin K. P. Lim, 2008. An updated checklist of the gobioid fishes of Singapore. *Raffles Bull. Zool. Suppl.,* 34: 744-757.

Lawson, E. O. 2011. Testicular maturation and reproductive cycle in mudskipper, *Periophthalmus papilio* (Bloch and Schneider 1801) from Lagos Lagoon, Nigeria. *J. American. Sci.,* 7(1): 48-59.

Macnae, W. 1968. A general account of a fauna and flora of mangrove swamps and forest in the Indo-Pacific region. *Adv. Mar. Biol.,* 6: 73-270.

Mahadevan, G. and V. Ravi. 2015. Distribution of mudskippers in the mudflats of Muthupet, southeast coast of India. *Internat. J. Fish. Aquat. Stud*., 3(2): 268-272.

Margalef, R. 1968. Perspectives in Ecological Theory. Chicago II. University of Chicago Press,Chicago. 111 pp.

Minh, Truong H., Wenresti G. Gallardo and Nguyen T. Phuong, 2010. Fishery and aquaculture of juvenile Mudskipper *Pseudapocryptes elongatus* (Cuvier, 1816) in the coastal zone of Mekong Delta, Vietnam. *Asian. Fish. Sci.*, 23: 224-239.

Moreira, F. 1999. On the use by birds on intertidal areas of the Tagus Estuary: implications for management. *Aquat. Ecol*., 33: 301-309.

Murdy E. O. 1989. A taxonomic revision and cladistic analysis of the Oxudercine gobies (Gobiidae: Oxudercinae). *Rec. Australian Mus. Suppl*., 11:1-93.

Nelson, J. S., T. C. Grande and M. V. H. Wilson. 2016. Fishes of the World. Fifth edition. Hoboken, New Jersey: John Wiley & Sons, 707 pp.

Pace, C. M. and A. C. Gibb. 2009. Mudskipper pectoral fin kinematics in aquatic and terrestrial environments. *J. Exp. Biol.*, 212: 2279-2286.

Parenti, Lynne R. and Zeehan Jaafar. 2017. The natural distribution of mudskippers. *In*: Jaafar Z, Murdy EO, Fishes Out of Water: Biology and Ecology of Mudskippers. In: CRC Press, USA.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. *J. Theoret. Biol.*, 13: 131-144.

Polgar, G., A. Sacchetti and P. Galli. 2010. Differentiation and adaptive radiation of amphibious gobies (Gobiidae: Oxudercinae) in semi-terrestrial habitats. *J. Fish Biol.*, 77: 1645-1664.

Ravi, V. 2013. Food and Feeding Habits of the Mudskipper, *Boleophthalmus boddarti* (Pallas, 1770) from Pichavaram Mangroves, southeast coast of India. *Inter. J. Mar. Sci.,* 3(12): 98-104.

Ravi, V., G. Mahadevan and R. Bharathi. 2013. Mudskipper fishery at Namkhana Region- Sundarbans mangrove forests, India. *Fish. Chimes,* 33(4): 42- 44.

Ravi, V., S. Rajagopal, S. Ajmal Khan and T. Balasubramanian. 2004. On the classification of burrows of the mudskipper, *Boleophthalmus boddarti* (Pallas) (Gobiidae: Oxudercinae) in the Pichavaram mangroves, southeast coast of India. *Journal of the Annamalai University*, Science, Platinum Jubilee Special Issue, p. 235-239.

Rema Devi, K. 1942. Gobioids of Ennore estuary and its vicinity, *Rec. Zool. Surv. India*, 90(14): 161-189.

Sasekumar, A. and V. C. Chong. 1998. Faunal diversity in Malaysian mangroves. *Global Ecology and Biogeography Letters,* 7(1): 57-60.

Shannon, C. E. and W. Weiner. 1949. The Mathematical Theory of Communication. Urbana, IL: University of Illinois Press, Urbana. 117 pp.

Stebbins, R. C. and M. Kalk. 1961. Observations on the natural history of the mudskipper, *Periophthalmus sobrinus. Copeia*: p. 18-27.

Su, T. L. and Shirley S. L. Lim. 2016. Niche partitioning in two syntopic mudskipper species (Teleostei: Gobiidae: Oxudercinae) in a Singapore mangrove. *Raffles Bull. Zool*., 64: 220-228.

Takita, T. Agusnimar and A. B. Ali 1999. Distribution and habitat requirements of oxudercine gobies (Gobiidae: Oxudercinae) along the Straits of Malacca *Ichthyol. Res.*, 46: 131-138.

Venkateswarlu, T., K. Rema Devi, T. J. Indra and J. G. Pattnayak. 1998. Fishes in: Fauna of Mahanadi Estuary Orissa, VIII, Zoological Survey of India, Calcutta, p. 23-114.

Vinagre, C., S. França and H. N. Cabral. 2006. Diel and semilunar patterns in the use of an intertidal mudflat by juveniles of Senegal sole, *Solea senegalensis. Est. Coast. Shelf Sci.*, 69(1-2): 246-254.

Udoh, J. P., I. Brownson I. M. T. Udo and C. Ofor. 2013. Population dynamics of mudskipper, *Periophthalmus barbarus* (Linneaus 1766) (Teleostei: Gobiidae) in the artisanal fishery of Imo River Estuary, Southeast, Nigeria. *J. Fish. Aquacult.*, 4(3): 148-153.