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Research Article

DISTRIBUTION OF MUDSKIPPERS IN THE MUDFLATS OF HATHAB COAST, GUJARAT, INDIA

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ABSTRACT
Mudskippers (Gobiidae: Oxudercinae) which are known to burrow and reside in the intertidal mudflats or mangrove swamps of the Indo-West Pacific region. Two species of Mudskippers were recorded from Hathab coast namely *Boleophthalmus dussumeiri*, and *Scartelaos histophorus*. Within the study area, the highest population density of *B. dussumeiri* were recorded which is followed by *S. histophorus*. Populations of mudskippers were highest during winter due to more thickness of mud layer, which reduced during the summer and monsoon with reduction of mud layer. Moreover, here mudskipper distribution varies from upper intertidal zone to lower intertidal zone. The parameters such as mud layer depth, sediment composition, pH, Temperature and salinity to have the significant relationship with the mudskipper distribution.

Keywords: *Mudskipper Distribution, Mud Reduction, Sediment Composition, Physico-Chemical Parameter, Hathab Coast*

INTRODUCTION
Mudskippers belong to subfamily Oxudercinae and family Gobiidae (Murdy, 1989); therefore, the members of this group commonly known as 'Gobi fishes' or 'Walking Gobies'. The Gobi fishes are fully amphibious and can crawl on land with their pectoral fin (Harris, 1960; Swanson and Gibb, 2004). As being amphibious organisms, these are exclusively adapted by means of their ecology, physiology and biochemistry to the intertidal habitats (Clayton, 1993; Graham, 1997), therefore, they usually found active during low tide. They live more comfortably in muddy coasts or soft bottom habitats (Randall, 1995) due to their burrowing mode of life (Patzner *et al.,* 2011) and found actively jumping, feeding and interacting with other members of same group and others on mudflats. Each mudskipper forms its own deep burrow where it hides during the high tides and at any disturbance. Many mudskippers are territorial and exhibit courtship display (Clayton and Vaughan, 1982, 1986; Patzner *et al.,* 2011). Mudskippers studied by researchers for several means like their behaviour and environmental biology and Eco physiology (Clayton, 1993; Bridges, 1988; King and Udo, 1996, 1997). Their breeding habits studied by Etim *et al.,* (2002) while studies on their orientation and distribution done by Bertini *et al.,* (1992, 1994). Their reproductive biology explained by Udo (2002) from Nigerian river.
There are only two genera *Boleophthalmus*, Valenciennes, 1837 and *Scartelaos*, Swainson, 1839 found on west coast of the southern tip of Indian coastline and from there extend as far western side as the Arabian Gulfs (Patzner *et al.,* 2011; Murdy, 1989; Froese and Pauly, 2017). These genera extend as far north as western Japan.
Many ouxidercines are endemic to relatively limited geographic areas. *B. dussumeiri* and *S. histophorus* are intertidal mudskippers (Martin and Bridges, 1999). These mudskipper species found on variety of habitats along an intertidal area like, estuarine areas, marshy areas, mangrove swamps, and on tidal mud flats and sand flats (Polgar and Crosa, 2009, Clayton and Vaughan, 1988; Man and Hodgkiss, 1996) and it has been reported at tidal zones in freshwater habitat (Rainboth, 1996). These both omnivores, feeds on benthic algae, harpacticoids, chromodorids, epibenthic diatoms, cynobactaria, zooplanktons, small invertebrates (Nematodes, Copepods, Ostracopods, Crustaceans), and Teleost fish eggs (Khoo, 1966; Clayton, 1993; Martin and Bridges, 1999; Patzner *et al.,* 2011) with typical grazing behaviour side-to-side head movement.

Gujarat has longest shoreline of 1600 km, which contribute highest 24% to the Indian coastline. Gujarat coastline divided into, Gulf of Kachchh at north-west side and Gulf of Khambhat at southeast side and a Saurashtra coast. Gulf of Khambhat bears 2588km^2 mudflat and enrich by plentiful inlets of Arabian Sea and rivers, which drains heavy load of sediment into the gulf areas (Ramnathan *et al.*, 2002).
Present study reveals distribution of mudskippers, *B. dussumeiri*, and *S. histophorus* in single site and relationship between their distribution and sediment composition along with their ecological status in mudflats of Hathab coast, Gujarat, India.

MATERIALS AND METHODS

Study Area

Hathab is located 28 KM from Bhavnagar city. It is situated between 21°34'02"N to72°IS·45"E. Hathab is famous tourist spot and known as Golden Sea beach which having sandy as well as muddy coastal characteristics (Figure 1).

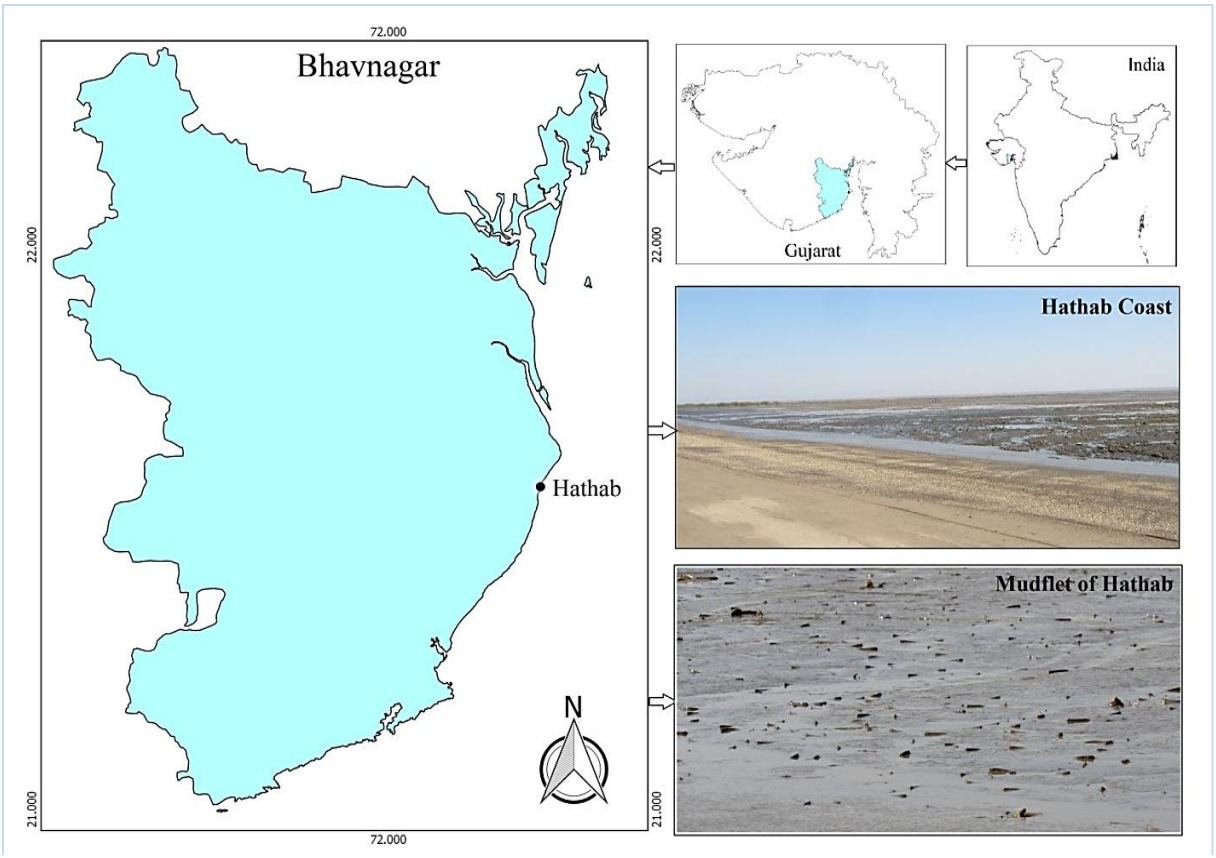

Figure 1: Study Area, Hathab Coast

This research work carried out during a period of a year, from December 2014 to November 2015. Sampling station visited on monthly basis, population assessment has done by using quadrate (1m^2) data from three zones of intertidal area. The thickness of mud layer measured in centimeter at the sampling site. The Mudskipper purchased from local fisherman and bought to the laboratory. Identification has done by using literature provided by Murdy (1989). A Physico-chemical parameters like temperature, pH, and salinity of seawater of selected site measured by using standard protocols and help of equipment. Sediment samples collected from the study area and carried to the laboratory for further analysis. Sediment samples were ground to the fine powder and dried on the hot plate at 110 °C to constant weight for an hour (Ravi, 2011).

RESULTS AND DISCUSSION

The muddy habitat of Hathab coast is suitable for burrowing activity to Mudskipper. The mud drained towards the lower intertidal zone during monsoon season, so sufficient mud is not available for mudskipper in an upper intertidal zone, where only a few random patches of mud found in the upper intertidal zone. During study two kinds of mudskippers were found namely *Boleophthalmus dussumeiri,* and *Scartelaos histophorus* (Figure 2).

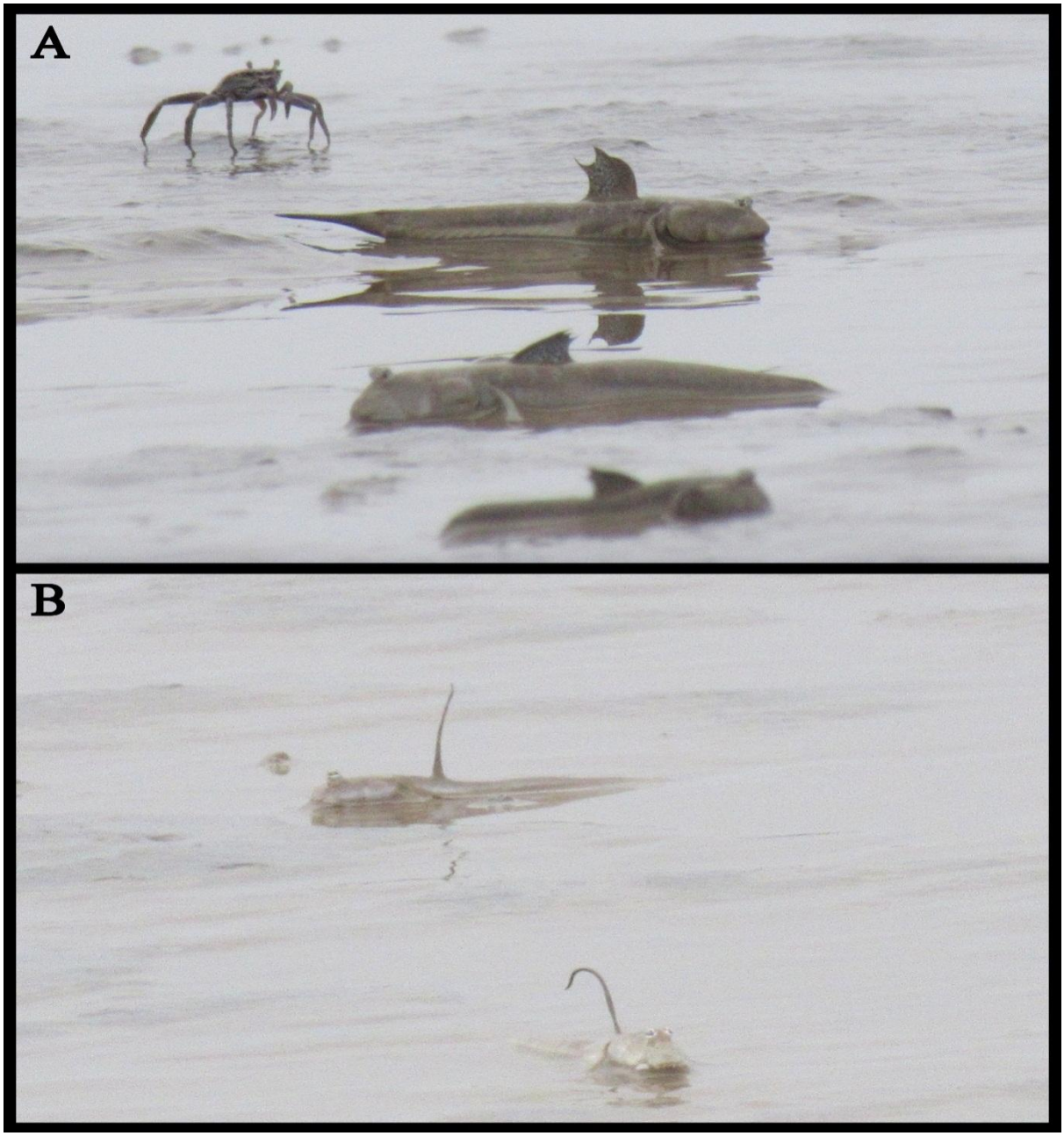

Figure 2: Mudskipper Diversity in Hathab, A. *B. dussumeiri* and B. *S. histophorus*

Thickness of Mud Layer

The thickness of mud layer varied seasonally as shown in graph (Figure 3). It was found that in winter, the mud layer was very thick, in summer, it decreased. Whereas, during monsoon the thickness of the

mud layer dramatically decreased. In the middle of the monsoon, the mud layer in the upper intertidal zone completely eroded and there was no more mud available for the mudskipper. During the study, it also found that due to wave and current action the erosion of mud layer found. The thickness of mud layer was highest in the lower intertidal zone.

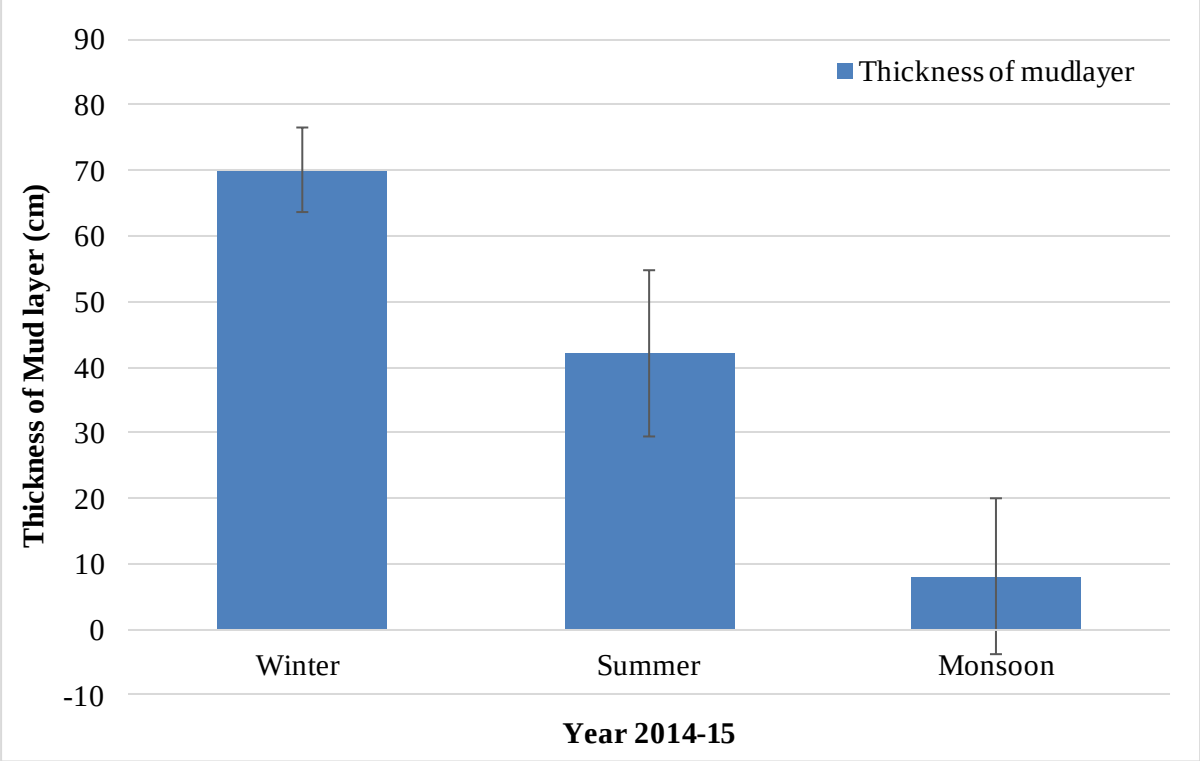

Figure 3: Seasonal Change in Thickness of Mud Layer

Sediment Composition

The sediment analysis shows a vast difference from upper intertidal zone to lower intertidal zone. The percentage of clay was Maximum during winter, which was Minimum during monsoon as mud eroded. The silt content is Maximum during winter, which also decreases during monsoon. In addition, the sand content was fluctuating in entire intertidal zone throughout the year (Table 1). Clay, silt and sand percentage range gives an information about the sediment composition in intertidal zone. This difference plays significant role in mudskipper distribution.

Table 1: Sediment Composition

Sediment Composition									
Season	**Upper Intertidal Zone**			**Middle Intertidal Zone**			**Lower Intertidal Zone**		
	Clay %	**Silt %**	**Sand %**	**Clay %**	**Silt %**	**Sand %**	**Clay %**	**Silt %**	**Sand %**
Winter	34-60	10-12	20-34	34-48	19-24	25-28	50-68	20-23	28-43
Summer	48-59	15-19	33-53	36-48	18-23	25-30	48-60	17-21	20-34
Monsoon	0-18	20-23	68-80	40-56	20-28	34-38	48-60	14-15	34-58

Mudskipper Population and Distribution

The study shows that the density of mudskipper was highest during winter 7 to 12 individuals/m^2 due to more thickness of mud layer in the entire intertidal zone. It is slight decrease with the decrease in the mud layer in summer 5 to 9 individuals/ m^2 and during the monsoon, 0 to 2 individuals/m^2. The population of

mudskipper was highly decreased per quadrate due to the decrease in the thickness of mud layer in upper and middle intertidal zone. The soil (mud) played an important role in mudskipper density as it provides shelter to the mudskipper for burrowing. The mudskipper density and mud layer thickness has great relation (R^2 = .905) was found (figure 4). In monsoon season in the upper intertidal zone was completely eroded, due to that, there was no mud available for burrowing for the mudskipper. Simultaneously, the eroded mud somewhat accumulated at the lower intertidal zone. This is the reason that is why the mudskippers were migrating in the lower intertidal zone during monsoon season. In addition, the population of the mudskipper recorded somewhat high in the lower intertidal zone during monsoon in compare to middle and upper intertidal zone. Moreover, the distribution of Mudskipper was not clearly zone vise, as the particular spices of Mudskipper was not distributed in particular zone (upper, Middle, and lower intertidal) but it is depend on sediment composition of the zone. So, both the spices of the Mudskippers ware distributed throughout the intertidal zone. The sediment analysis shows that where the clay, silt and the sand percentage range from near about 34% to 48%, 10% to 20 %, and 15% to 24% respectively, this place occupied by the mudskipper *B. dussumeiri*. Whereas, the clay, silt and sand percentage ranges from 50% to 68%, 15% to 20%, and 14% to 23% respectively this place occupied by *S. histophorus*. In some occasions, both spices of mudskipper found within the same habitat. Here, clay is the major key factor for burrowing activity for the mudskipper because the mudskipper *B. dussumeiri* preferred somewhat hard mud than the *S.histophorus*.

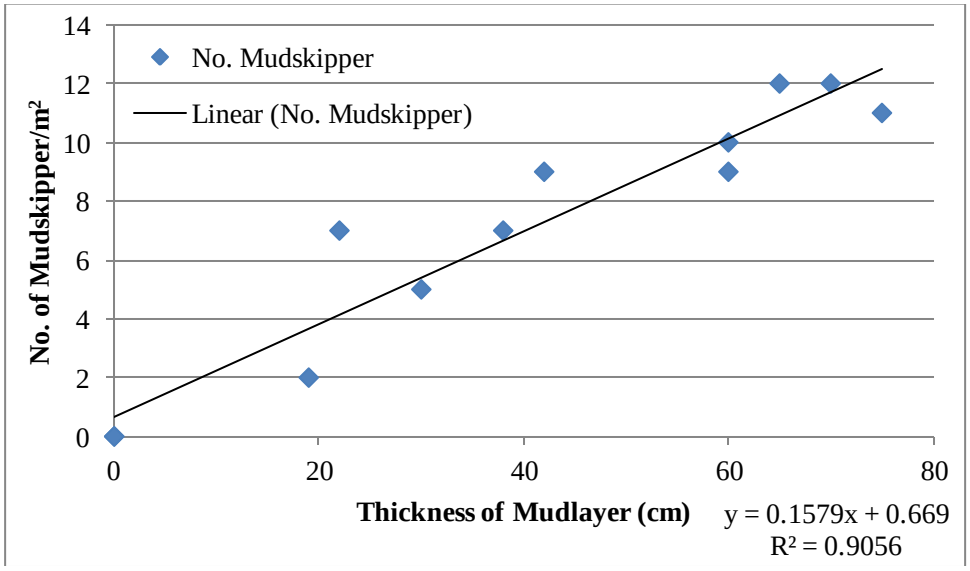

Figure 4: Relation between Mudskippers and Mud Layer Thickness

Sediment plays an important role in the selection of area where the mudskipper forms a burrow (Ravi, 2005, 2011). This may be one of the major reasons that where the percentage of clay was low, the mud was somewhat hard and where the percentage of clay is high where the mud was somewhat soft. It may be helpful to mudskipper to burrowing activity. We can also say that the soft mud more occupied by *S. histophorus* and hard mud occupied by *B. dussumeiri*.

The mudskippers population varied from place to place depending upon the environmental parameters. The parameters such as DO, pH, clay and soil moisture found to have significant relationship with the mudskipper distribution (Mahadevan and Ravi, 2015).

Study shows that Mudskipper fevers the somewhat alkaline condition (Figure 5). The temperature and salinity has adverse effect on mudskipper as it increases the density of mudskipper is decreases (Figure 6 & 7) respectively.

The distribution and abundance of mudskippers in coastal waters could consider as the direct indicator of intertidal health. Mudskippers are on the verge of dilapidated trend and threatened to a combination of

anthropogenic and natural calamities such as tsunami. Rema Devi (1992) listed *B. dussumeiri* in endangered mudskippers of India along with few others, based on pollution status and habitat loss.

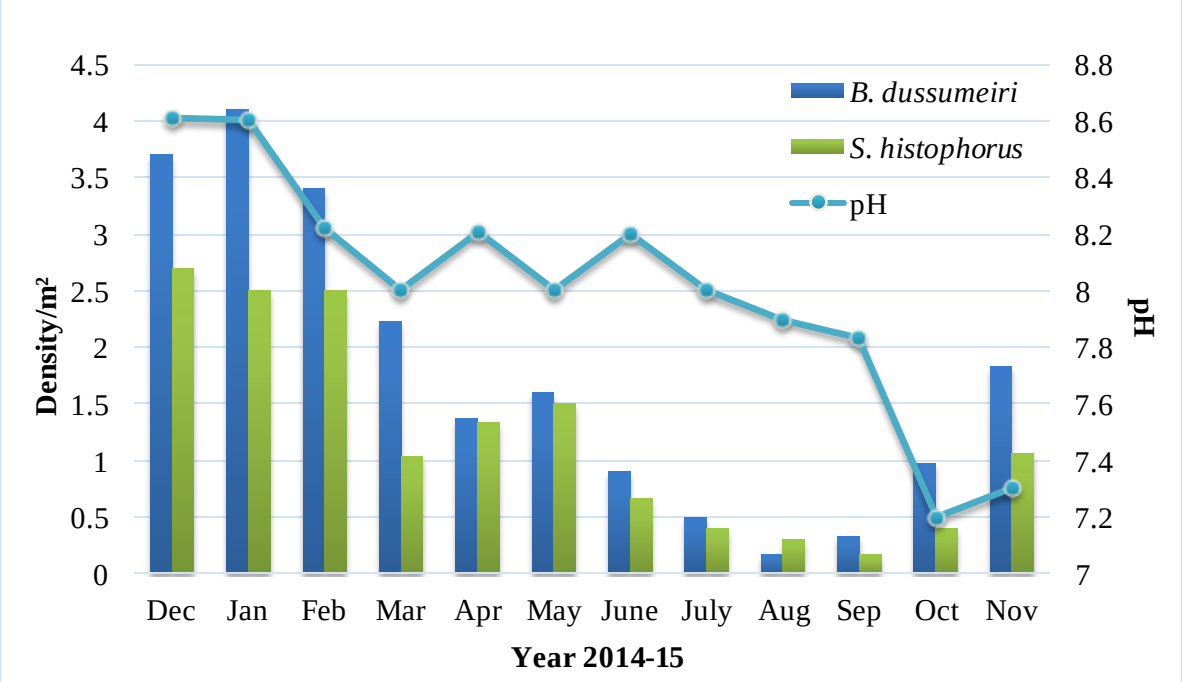

Figure 5: Relation between Mudskipper Density and pH

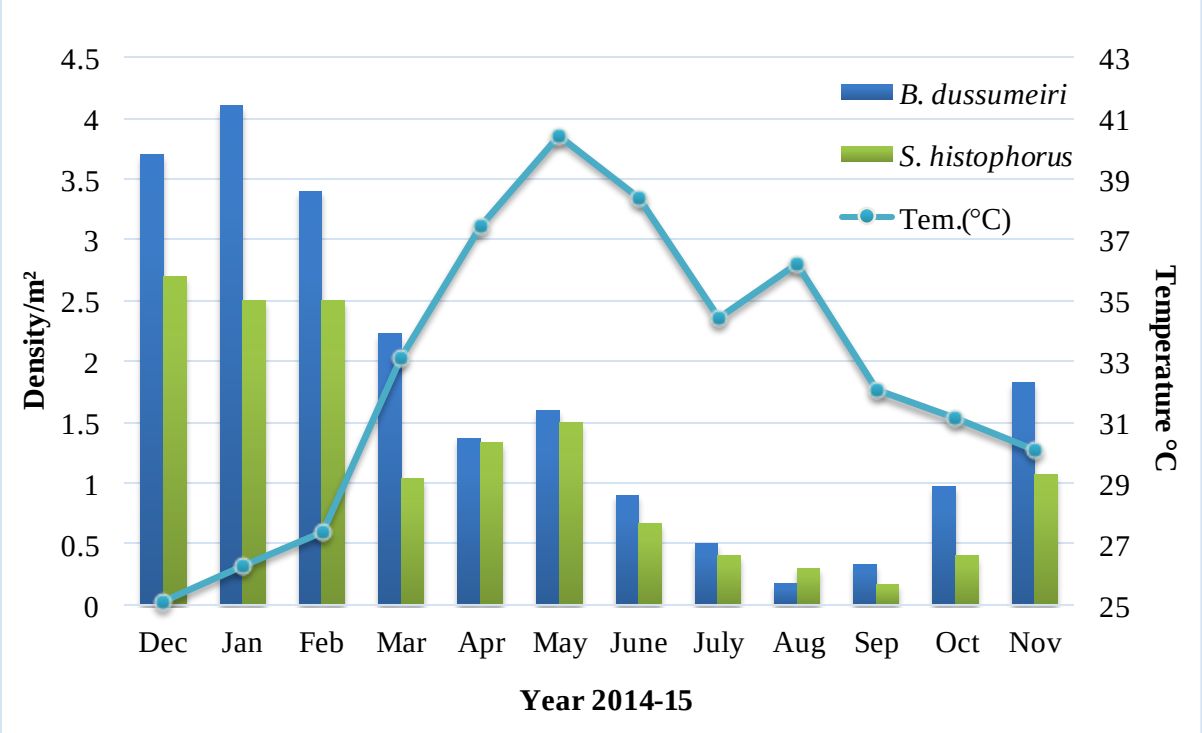

Figure 6: Relation between Mudskippers Density and Temperature

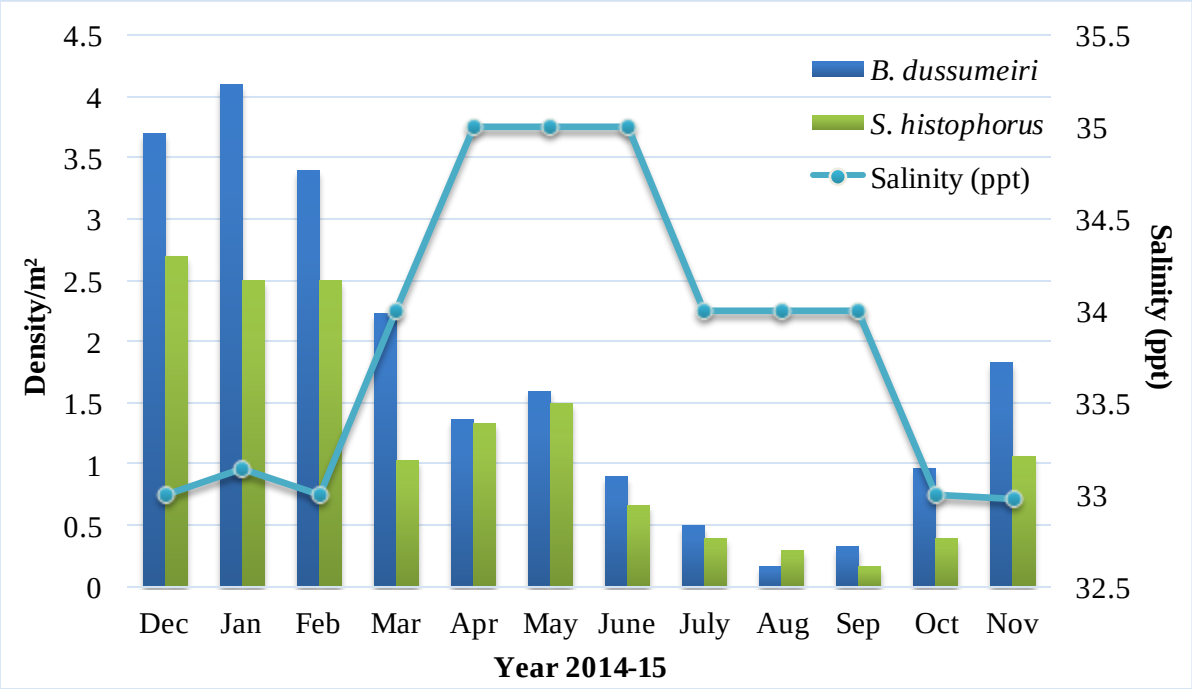

Figure 7: Relation between Mudskipper Density and Salinity (ppt)

Conclusion

The Hathab is one of the finest habitats for the Mudskipper where highly muddy as well as sandy intertidal zone found. This provides expellant site for burrowing activity to the Mudskipper. The thickness of mud layer has great correlation with the density of mudskipper. In addition, the composition of sediment plays an important role in habitat preference to the mudskipper. On the distribution of Mudskipper, The environmental factors like pH, Temperature and salinity found to have significant relationship. The hard mud (less amount of clay) preferred by *B. dussumeiri* and soft mud (higher amount of clay) preferred by *S. histophorus*.

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