Importance of Mud Crab in Saline Water Ecosystems

Subjects: Marine & Freshwater Biology
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Mud crabs genus *Scylla* (*S. serrata*, *S. tranquebarica*, *S. olivacea*, and *S. paramamosain*) is an important member of mangrove/estuarine saline water ecosystems than other crustaceans due to its major activities (biological burrowing and bioturbation creation) in protecting and spreading mangrove forests. Mud crabs are generally found in estuaries, especially in mangrove forests of India, Taiwan, Japan, China, South Africa, Indonesia, and the Philippines of Indo-Pacific places. Similarly, Malaysia, Singapore, Western Samoa, Salmon Island, Fiji, and New Caledonia are big mud crabs habitats.

Keywords: mud crabs ; habitats ; saline water ; mangrove

1. Direct Contribution of Mud Crabs into Habitat

With the above economic values, mud crabs also contribute to the mangrove or estuarine water management indirectly. They form a bioturbation structure in sediment soil that helps in trapping the seeds of mangrove plants. It increases the chance of a mangrove forest area, and this has a positive impact on the management of water quality in the area as it leads to a green ecosystem in the area. Mud crabs play a significant role in changing nutrients, increasing mineralization, the oxygen-carrying capacity of the soil, and providing support for other aquatic organisms [1]. Extended fishing and dependency on natural sites gradually damage the number of crabs and natural habitats for other organisms. The purposive sampling method is generally used to analyze abundance, the frequency distribution of carapace, and the growth parameter of crabs by using FISAT 111 and Bengen statistics. Additionally, the carapace takes 4 and 6 months to mature in males and females, respectively [2]. Thus, extended fishing of mud crabs on a commercial basis should be avoided in their natural habitat. The exact role in protecting the mangrove ecosystem is quite interesting.

Mud crab plays a key role in balancing ecosystems by using their biological burrowing activity on the soil, making soil porous, laid to aeration, and nutrient flow in soil. They make burrows where the water level is below 100 cm, and the percentage of burrows increases by more than 40% with a lack of shade [3]. In the natural habitat, the porous soil makes mangrove forest conservation as the soil holds the seeds of the plant (bioturbation), which greatly impacts forest making and coastline protection [4]. Another dimension of facilitating aquatic life by mud crab is that they produce a large number of pelagic larvae that provides a great source of food for planktophagus aquatic organisms. Thus, from the above data and observation, it has been clear that mud crab plays a vital role in the food web by directly controlling the complex mangrove ecosystems.

The mangrove mud crabs that contribute to world fisheries are under-threat in many places due to varied water physicochemical factors, overfishing, pathogens, heavy metals, and chemical toxicants in water. Along with environmental factors, such as temperature and salinity, the effects of xenobiotics, heavy metals, and other toxicants must be checked in their habitat water and soil for their better growth, production, and reproduction [5]. Their omnivorous food habits have been experimentally proved, so the larval and adult care of these species under a suitable environment is suggested for their health management. Different behaviors of mud crabs, such as migration, reproduction, and breeding, are exclusively hormonally and environmentally regulated as a function of age [5]. Finally, mud crabs and their bio-waste are also used for various purposes, such as environmental monitoring, analyzing toxic loads, and in clinical and pharmaceutical sciences, indicating their demands. Therefore, the ecological interaction of these species during their life stages is environmentally important [5].

2. Role of Habitat Water on Ecology and Life Cycle of Mud Crabs

The lifecycle of mud crabs such as *S. serrata* comprises three primary stages: the dispersing larvae phase, the benthic juvenile stage, and the adult stage. In order to mature into adults, mud crabs generally migrate from the seawater to estuaries during their benthic juvenile stage [6]. Usually, in these stages, they inhabit a muddy mangrove forest with changing temperatures and salinities [7][8]. *S. serrata* in Okinawa inhabits marshy mangroves, and in Taiwan and the Philippines, it prefers sandy, muddy bottoms of seaward water [9]. According to some studies, they prefer varied habitats at various stages of their life cycle, from larvae to adults. Its larvae prefer stenohaline water and structurally complex habitats, which contain both refuge and food, but the seagrass habitat is preferred by crablets of *S. serrata* [7]. Extensive studies in this field proved that water physicochemical factors play a huge role in maintaining the variation among these habitats (**Table 1**).

Specifically, in India, it is noticed that mud crabs inhabit a variable benthic coastal region of different estuaries with fluctuating several abiotic and biological factors in the water of coastal sites. They can sustain in a varied range of soil sedimental and physio-chemical water parameters, such as pH, organic carbon, turbidity, temperature, and salinity affecting their growth and survivability (**Table 1**). *Scylla* sp. can thrive well in water temperatures ranging from 18–31 °C, 1–33 ppt of salinity range, alkalinity range from 70 to 119 mg L^{-1}, and the dissolved oxygen concentration in water fluctuating between 4–10 mg L^{-1} [10]. Tidal heights ranging from 8.60 to 72.52 cm are optimum for crab survivability and growth. Additionally, organic matter content in water between 1.91% to 3.25% and a slightly basic pH with an average pH of 7.04 is optimum for *Scylla* sp. [11]. Food availability also plays a major role in their survivability in varied environmental factors and habitats depending on their life cycle.

Table 1. Effect of pH, temperature, and salinity on the physiology of mud crabs.

Water Physicochemical Factors	Location	Ranges	Duration (days)	Effects on Crab	Reference
pH	Coimbatore, Tamil Nadu, India	8.2	60 days	Normal growth, feed intake, and survival rate	[12]
		7.8			
		7.6			
		7.2		Decrease in growth rate, survival rate, and feed intake	
		7.0			
	Chantaburi, Thailand			Hemolymph osmolality (%)	[13]
		4–6	10 days	11% decrease	
		6–12	10 days	15% increase	
Temperature	Terengganu, Malaysia			Growth rate (%)	[14]
		24 °C	45 days	7.28 ± 1.31	
		28 °C	45 days	9.69 ± 0.75	
		32 °C	45 days	7.83 ± 0.56	
		27–30 °C	45 days	9.48 ± 1.02	
	Northern Territory of Australia	20 °C/20 ppt	1 day	7.75 ± 1.28	[15]
		25 °C/20 ppt	1 day	12.68 ± 0.77	
		30 °C/20 ppt	1 day	15.98 ± 0.36	
		35 °C/20 ppt	1 day	12.59 ± 0.60	
Salinity	Queensland, Australia			Hemolymph osmolality (mOsm kg^{-1})	[16]
		4 ppt	NA	415 ± 12 (hyperregulated)	
		12 ppt		312 ± 8 (hyperregulated)	
		20 ppt		194 ± 15 (hyperregulated)	
		28 ppt		122 ± 12 (hyperregulated)	
	Iilan, Taiwan	14 ppt	1 day	772.38 (stabilized)	[17]
		24 ppt	3 days	803.50 (stabilized)	
		34 ppt	0 day	1034.50 (stabilized)	
		44 ppt	1 day	1274 (stabilized)	
	Queensland, Australia	30 ppt	4 days	968.73 ± 8.85 (stabilized)	[18]
	Odisha, India			Mitochondrial respiration rate complex I and II (nmol)	[19]
		10 ppt	21 days	4.42 ± 0.88 and 6.41 ± 1.69	
		17 ppt	21 day	1.69 ± 0.41 and 4.04 ± 0.58	
		35 ppt	21 day	2.19 ± 0.55 and 4.42 ± 0.88	

Note(s): Mud crabs need 27–30 °C temperature and salinity of 34 ppt for better growth and acclimatization. In addition, the optimum pH of water is 7.8–8.2 for normal growth and other physiological activities of mud crabs, as concluded from different local studies.

3. Predatory Contribution to Food Chain under Varied Water Habitats

The gut analysis and presence of material remnants like 51% mollusks, 10% crustaceans, 22% fishes, and 4% plant products in adult mud crabs suggest that the crabs are predatory in nature [20][21]. The feeding pattern varies with each larval stage of mud crabs, but they prefer rotifers and *Artemia nauplii* (decapsulated cysts) as their food due to their non-motile nature [22]. Nutrients rich in essential fatty acids are beneficial for the growth and survivability of larval stages of crabs [23]. *Scylla* species tend to feed at night, making it difficult to spot during the day [21][24]. Reports on the dietary preferences of mud crabs indicate that it has both an animal and plant-feeding nature. However, seasonal and environmental changes in water quality have a major impact on the way the mud crab feeds and interact with other organisms and the ecosystem in which it lives [7].

4. Behavioural Contribution to Ecosystem

The nocturnal feeding habit of mud crabs' juveniles and their burrowing behavior helps them to escape from predators in deep water as well as marshy areas. Generally, hiding behavior is noticed in mud crabs' juveniles (e.g., they are found under the leaf and aquatic plants in order to avoid direct sunlight). Habitats of most aquatic animals are simple and have little interference with others, but in the case of mud crabs, *S. serrata* habitat is quite complex in structure [25] as mud crabs are not static to a particular zone, so they can change their habitat according to their favorable condition by covering a long distance of 219 m to 910 m in water per night. Male shows great care towards female mud crab protection during molting and shell casting in the mating season. Molting and food scarcity induce autobalism and cannibalism nature in *S. serrata.* Besides this behavior, mud crab shows abnormal development and physiology under varied environmental conditions.

5. Contribution as Biomarkers and Bio-Indicators

Biomarkers are essential to assess the health status of an aquatic animal with respect to varied water environmental conditions and for their monitoring. Polychlorinated biphenyls (PCB) and poly-halogenated compounds (PHC) are particles that gradually increase in water bodies and are consequently consumed by aquatic organisms like mud crabs. Enzymatic and non-enzymatic antioxidant assays in *S. serrata* show a considerable downregulation of the defense genes in summer with respect to the winter season when the PCB and PHC are at their peak concentration in water [26]. Additionally, ulcerative skin disease and parasitism epidemics in *S. serrata* were reported to coincide temporally and spatially with changes in water quality [27]. Another biomarker on mud crab was reported by Van Oosterom et al. (2010) [28], and it is an enzyme called Glutathione-S-transferase (GST) that can be used to study pollution impact assessment in saline water bodies.

Mud crab larvae are proposed to be used as an effective bioindicator for measuring the effects of sewage loads in saline water because they show a slower rate of larval development from stage I to stage II larval forms under pollution loads in habitat water. Secondary treated sewage has a significant role in toxicity in the zoea larva development of mud crabs, and it was observed when the progress of larval stages from stages I to II was examined [26]. Under a condition of constant photoperiod (12 hL/12 hD), a salinity of 35 ppt, and a temperature of 30 ± 2 °C, the growth of larval stages is found to be high when the habitat has sewage loads. Based on the aforementioned data, it is evident that mud crabs have a high potential to serve as bioindicator species. However, an extensive study of environmental factors and pollutants is essential to evaluate their impact on crab physiology.

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