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Man-made activities affecting the breeding ground of horseshoe crab, *Tachypleus gigas* (Müller, 1795) along Balasore coast: Call for immediate conservation

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ABSTRACT

Four species of horseshoe crabs exist today. All the four species of horseshoe crabs are classified as either near threatened or data deficient. Out of the four, two species are distributed along the northeast coast of India. Spawning activity has been adversely affected by the degradation and destruction of spawning beaches. The study was carried out from February 2015 to June 2017 to identify the most influential factors that worked against the nesting sites of *Tachepleus gigas* in two estuaries namely Khandia (Site-1) and Balaramgadi (Site-2). The nesting activity of *T. gigas* was found only during full moon periods and took place mostly at Site-1. The present study also confirmed that Khandia was a potential breeding ground for *T. gigas* where its male and female brooders were found throughout the investigation during 2015-16, but due to over human activities their population declined drastically during 2017. Balaramgadi estuary was earlier reported to be a national breeding ground for the *T. gigas*. Due to the rapid development along the coast and extensive fishing activities, the natural sandy beach and estuary environment of Balaramgadi has been destroyed. These changes drastically affect the breeding habit of *T. gigas*. It is a matter of concern and perhaps that day is not far away when we will not be able to encounter *T. gigas* breeding pairs at Khandia estuary.

Key words: Balaramgadi estuary, Khandia estuary, horseshoe crabs, *Tachepleus gigas*

INTRODUCTION

Oceans and ocean floors form an extensive and complex bio-geosphere system, contain a treasure trove of resources, both living and nonliving , benefitting mankind greatly. They contain a stunning range of marine resources yet to be fully explored and understood. In the ocean, about 26 phyla of marine organisms are found, while arthropods contribute four-fifths of all marine animal species with over 35,000 varieties. Surprisingly, quite a few numbers of marine organisms, suspected to be extinct, still burgeon as living animals (Chatterji, 1994). Horseshoe crabs are more closely related to arachnids (includes spiders and scorpions) than to crustaceans (includes true crabs, lobsters, and shrimp). It is one of the oldest marine living fossils, whose origin can be dated back to 445 million years ago before dinosaurs existed and they are often called 'living fossils'. Hence, it carries significant evolutionarily importance. Despite inhabiting the

planet for so long, horseshoe crab body forms have changed very little over all of those years. They are now represented by four extant species. *Limulus polyphemus* (Linnaeus, 1758) is native to the eastern shoreline of North America, from Southern Maine to the Yucatan Peninsula, with Delaware Bay as the centre of the population. The other three species, *Carcinoscorpius rotundicauda* (Latreille, 1802), *Tachypleus tridentatus* (Leach, 1819) and *T. gigas* (Müller, 1785) are found along coastlines of Asia. *T. gigas* and *C. rotundicauda* are distributed in the Indo-Pacific region from the Bay of Bengal to Indonesia, whereas *T. tridentatus* is recorded from the coast of the Philippines, Malaysia to the south western seas of Japan (Sekiguchi, 1988; Chatterji and Pati, 2014). Among the four species of horseshoe crabs that exist today, the Asian horseshoe crab *T. tridentatus* and the coastal horseshoe crab *T. gigas* live in sandy to muddy habitats (Chatterji and Abidi, 1993; Shin et al., 2009; Pati et al., 2015) while the mangrove horseshoe crab *C. rotundicauda* inhabits muddy areas, commonly in brackish waters (Chatterji and Abidi, 1993). In India, some *T. gigas* co-exist with *C. rotundicauda* (Chatterji, 1999; Mishra, 2009a). Horseshoe crab ((IUCN, 2017)) is grouped into three genera in two families in the Super family Limulacea (Sekiguchi and Shuster, 2009): Phylum: Arthropoda, Class: Merostomata, Order: Xiphosura, Family Limulidae: *Limulus polyphemus* (Linnaeus); Family Tachypleinae: *T. tridentatus* (Leach, 1819), *T. gigas* (Muller, 1785) and *C. rotundicauda* (Latreille, 1802). The ir population is decreasing over the years due to anthropogenic disturbances (e.g. over exploitation, release of untreated sewage, factory effluent, etc.), (Chatterji and Shaharom, 2009; Shin et al., 2009; Hu et al., 2010; Cartwright-Taylor et al., 2011) more than the natural causes (beach erosion). Among others, the physicochemical changes in the coastal environment such as beach morphology (erosion/ accretion), sediment texture and water chemistry are severely affecting the horseshoe crab populations and thereby a shift or permanent loss of its spawning grounds (Jackson et al., 2007; Hadnan et al., 2010; Hu et al., 2010). Though two Asian horseshoe crabs are present in the Indian waters for ages, they have gained considerable scientific attention only recently owing to their endangered status and a nationwide priority for its conservation. Most of the research has done on Indian horseshoe crab about its biomedical importance and application, feeding behavior, migration pattern and laboratory rearing (Parab and Chatterji, 2003; Ghaskadbi et al., 2008; Mishra, 2009b; Alam et al., 2015a,b; Biswal et al., 2016), but the study of the breeding ground and its condition is infrequent.

MATERIALS AND METHODS

Study area

Balasore district is located in the northeast of the state of Odisha and lies between 21° 3' to 21° 59' north latitude and 86° 20' to 87° 29' east longitude. The average altitude of the district is 19.08 m and has a total area of 3634 km^2. The coastal belt is about 81 km wide and shaped like a strip (Fig. 1). In this region, sand dunes are noticed along the coast with some ridges. This region is mostly flooded with brackish water of estuarine rivers which is unsuitable for cultivation any kind of marine livestock. Two important rivers namely Budhabalanga and Subarnarekha and many sub rivers pass through this district from west to east direction before surging into the Bay of Bengal and making the estuary a fertile and suitable for

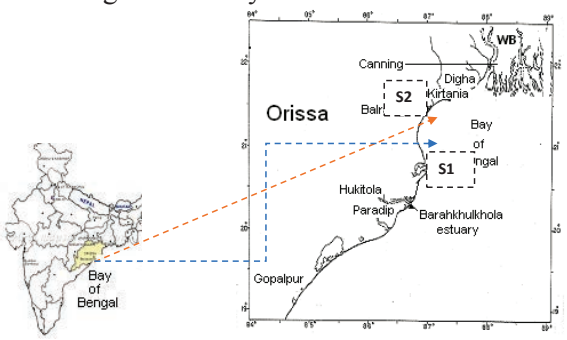


Fig. 1. Map showing study areas

this horseshoe crab breeding. Out of them Khandia estuary, Site 1 (Fig. 2b), Balaramgadi estuary, Site 2 (Fig. 2a), was selected for the survey under Balasore coast of Bay of Bengal (Fig. 1). Khandia estuary is located at 21°24'35.97"N and 86°58'43.02"E in coast of Balasore district near the mouth of Khandia river and surrounding areas. It is about 12 km away from Chandipur. Balaramgadi sea beach is located at 21°28'10.06"N and 87°3'37.00" E in

Fig. 2. Map showing two study sites. S1-Khandia estuary. S2-Balaramgadi estuary

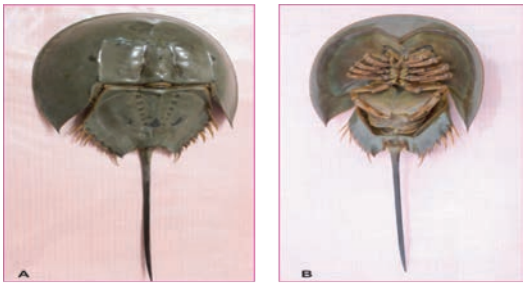
Balasore district near the mouth of Balaramgadi Estuary River and surrounding areas. It is about 6 km away from Chandipur. As such these two estuary areas was identified for regular collection of the data.Dead carapace of both specimens of *T. gigas* at two sites (Odisha) were collected to know the rate of mortality and availability of horseshoe crabs to gauze the density.

Data collection

At each sample site, the number of nests i.e., horseshoe crab imprints that contained eggs, were identified by gently removing the sediment (using plastic hand shovel). From each nest, the available egg clutches were collected into a 2 mm sieve (using hand) and cleaned with the sea water to separate them as well as remove debris/sediment particles attached. Once the total eggs were counted, they were placed back into the same pit and covered by the sand. The number of male/female brooders were obtained through counting them by sight and/or catching them with hand (after seeing at the air bubbles they released to the surface water).

Factor assessment and trade assessment

The survey over illegal trading was carried from January to June, 2016. These two sites and nearby areas were identified and surveyed. The primary objective of the survey was to quantify and document the protected horseshoe crabs on sale in the marine curio trade. The required information was collected. Efforts were made to convince the respondent that the interviewers were neither tourists nor working for the government. This strategy was adopted so as to minimize the interference with other people, which could distract the vendor during our interview.



A- Dorsal View **B**-Ventral view

Fig. 3. *T. gigas*

Fig. 4. Mating in *T.Gigas* lying eggs on breeding ground

Fig. 5. Dead Horseshoe crab lying in the sea shore because of

RESULTS AND DISCUSSION

Nesting activity of *Tachypleus gigas*

Field observation unveiled the intensive fishery activities along the sampling locations

besides increased industrial activities and human settlements. Extensive surveys were undertaken three times every month along the above two sites to assess the population density of the horseshoe crab. It was observed that due to increase in human activities on the spawning beaches, the population of the horseshoe crab had affected significantly. However, Khandia area was found to be least affected where normal occurrence of the horseshoe crabs observed during 2015 (Fig. 2, 4). The nesting activity of *T. gigas* was found mostly during full moon periods and took place mostly at Site-1 (Fig. 2). In addition, the egg yield was higher during the first year of investigation (2015), whereas it was decreased significantly in 2016 and completely absent in 2017 (Fig. 8). In relation to the changes in nesting places, *T. gigas* preferred Site-1. Overall, there was a considerable decrease in the number of brooders as well as the nests because of the loss of breeding ground (Table 1). The day is not far off when breeding pairs will be completely missed from the picture in Khandia (Fig. 10).

Table 1: Biological observations from the nesting (1-2) sites along Balasore coast

	2015												2016												2017					
	Jan		Mar		May		July		Sept		Nov		Jan		Mar		May		July		Sept		Nov		Jan		Mar		May	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
No. of nests	20	2	23	3	16	1	9	-	3	-	6	-	18	2	20	3	12	-	7	-	1	-	4	1	7	1	2	-	-	1
No. of clutches	35	3	40	4	25	-	12	-	5	-	9	-	27	1	31	4	20	-	9	-	-	-	5	-	9	1	-	-	-	-
No. of eggs	2300	300	3000	525	1820	200	1100	-	600	-	1230	-	2435	420	3000	680	1670		1350		220		900	207	1669	160	430			180
No. of male *T. gigas*	30	8	20	-	28	-	9	-	4	-	6	1	26	1	20	2	8	-	11	2	7	-	4	-	3		1	-	-	1
No. of female *T. gigas*	33	8	20	-	30	-	7	-	3		6	1	29	2	18	2	7	-	10	2	9	-	4	-	3		1	-	-	1
Total no. of crab	63	16	40		58		16		7		12	2	55	3	38	4	15		21	4	16		8		6		1			1

'-' indicates no sample available; S1 stand for site-1, S2 stands for site 2

From trade assessment surveys, it was clear that horseshoe crabs in India were not subjected to commercial exploitation for biomedical, fertilizer, and bait purposes. The real threats were from the human population, which played important role in the coastal ecology. In addition, natural calamities such as super cyclones and tsunamis cause serious damage by shifting the sands from the beaches (Chatterji and Shaharom, 2009). But some communities use its dead shells as traditional medicine to heal the wound (Fig. 6c). The survey team encountered that domestic pig feed seriously hampered the breeding pattern of horseshoe crabs (Fig. 6e) which corroborates with the study undertaken by Pati and Dash (2016).

In recent years, there have been considerable human intervention in the form of aquaculture (including sport fishing, fish landings) and leisure boating activities at Balasore coast (Fig. 5). In addition, the sand mining and the jetty construction

Fig. 6. Factors influencing population of horseshoe crabs, a-Captured in constructed jetty stone constructed near breeding shore, b- Standing nets and fishing activities along the intertidal zone resulting in the mortality of horse shoe crab, c- Dead carapace/ molted carapace of horseshoe crabs boiled with mustard oil and used for treating rheumatic pain in India and they also crushed those and used them as fertilizers in their fields, d- Wild dog captures horseshoe crabs, e- Pigs feeding on the ventral side of horseshoe crabs, f- Crows feeding on horseshoe crabs near estuary

in the vicinity (Fig. 6b) created inevitable changes to the local environment.

Habitat requirements for the spawning activity of the horseshoe crab species are almost same, except for *C. rotundicauda* that breeds in muddy areas (Anderson and Shuster, 2003; Lee and Morton, 2005; Seino, 2009). The female crabs of *T. gigas, T. tridentatus and L. polyphemus* spawn along the intertidal beaches of the estuarine coasts, where the eggs will be fertilized by an attached male and/ or satellite male(s) (Ehlinger and Tankersley, 2003). In the east coast Balasore, Odisha only two beaches namely, Khandia and Balaramgadi are well-known for the occurrence of *T. gigas*. This study confirmed Khandia to be a potential breeding ground for *T. gigas,* where it's male and female brooders were found throughout the investigation. The sandy areas in-between upper and mid tidal zones are providing a suitable environment for spawning, nurture and development of the horseshoe crab eggs as also observed by the other researchers (John et al., 2012; Shin et al., 2014).

Most brooders were either satellite males or solitary female than to the amplexus. The overexploitation of these crabs (especially females) for fish meal and edible purposes locally were the main reasons for their limited counts in the present study. Similar (over) utilization patterns

Fig. 7. a - Study station Balaramgadi (site-2), b - Study station Khandia (site-1), c and d - Dead carapace / molted carapace of Horseshoe crabs (*T. gigas* and *C. rotundicauda*), e- Constructed jetty at breeding ground, f-fishing boat at breeding ground. g- Horseshoe crab in study station Khandia

have also been reported from the other countries like Thailand, Hong Kong, America, etc. (Ferrari and Targett, 2003; Jackson et al., 2007; Ngy et al., 2007; Basudev et al., 2013). On the other hand, the satellite males (older) were less healthy than the attached ones (young) and engage themselves only in sperm competition. Therefore, the dropdown in the number of brooders as well as the frequent spotting of satellite males/solitary females leads to scientific concerns related to ageing population of HSC in the area, other than overexploitation, momentary loss or unsuitable environmental conditions. Since the disturbances at Balasore coast owing to human activities, especially, sand mining and jetty construction were practically witnessed, the spawning activity of *T. gigas* can be inferred to be dependent on the natural seawater and that the spawning gets affected due to intrusion/disturbance of the natural setting of the estuary/sea coast.

CONSERVATION STRATEGIES

Human threats adversely affect the survival of horseshoe crabs by affecting spawning grounds and their activities, for example, beach development and shoreline modifications prevent them from reaching the nesting sites (Chatterji et al., 1996). The dead horseshoe crabs are found in the sea shore indicating the degradation and destruction of breeding beaches by excess of human activities (Fig. 6a-f) and other factors such as trolling activity by fishing community, natural calamities etc. have been posing a serious threat (Mishra, 2009a). Not much is known about the predation of Indian horseshoe crabs in the natural ecosystem except that predation of *T. gigas* by crows (Fig. 6f) and domestic pig (Fig. 6e) and dogs (Fig. 6 d), observed in India (Debnath and Choudhury, 1988; Pati and Dash, 2016). Natural factors such as predation, beach stranding and diseases cause deaths in adults coming to the shore for spawning (Behera et al., 2015). Horseshoe crabs were harvested to be used as fertilizer and to feed the livestock (Shuster et al., 2004). The risk of declining in the horseshoe crab population depends on several biological and environmental factors which affect the natural harvesting of horseshoe crab eggs because some bait

Fig. 10. Year wise (2015-2017) conditions of horseshoe crab breeding ground (S1-Khandia estuary)

harvesters prefer females those are carrying eggs. Beach erosion, tsunami, natural calamities etc. also lead to the destruction of nesting ground and change in the salinity and temperature (Chatterji et al., 2009). Now-a-days, the significance and usefulness of horseshoe crabs are coming to prominence because of the biomedical usage. In United States, traders collect horseshoe crabs to obtain their blood for pharmaceutical importance (Novitsky, 2015). Since females release pheromones, they are further used in the bait industries to catch conch and eel (Smith et al., 2009).

The loss of habitat leads to the loss of biodiversity. In the case of Asian horseshoe crabs, their decreased populations have already been reported from various countries including India. Local authorities should think as a 'protected area'. Sign boards indicating and highlighting the 'horseshoe crab region' as 'fishing prohibited', 'protected area' etc. which would create better awareness among the local people. These measures can help not only to retain the glory of this place as one of the very few breeding grounds for *T. gigas* in Odisha, especially Balasore coast, but also receive a nationwide priority for its conservation and management.

RECOMMENDATIONS

- Measurements on water current/sediment transport (at river mouth and inside estuary) to study the nesting, density and breeding biology.
- Enact a no-harvest regulation on adult female *T. gigas.*
- To consider Khandia estuary as a 'Marine Protected Area'.
- Increase awareness and education of local people on horseshoe crab's significance and conservation, along with possible health risks if they were consumed.
- Continued monitoring on the arrival of spawning of *T. gigas* at Khandia estuary as well as other places along the Balasore coast.
- Marking, tagging or microchipping for experiments to find revisits of the horseshoe crabs.
- Establishment of an '*Horseshoe Crab Estuary and Research Centre*' for population restoration.

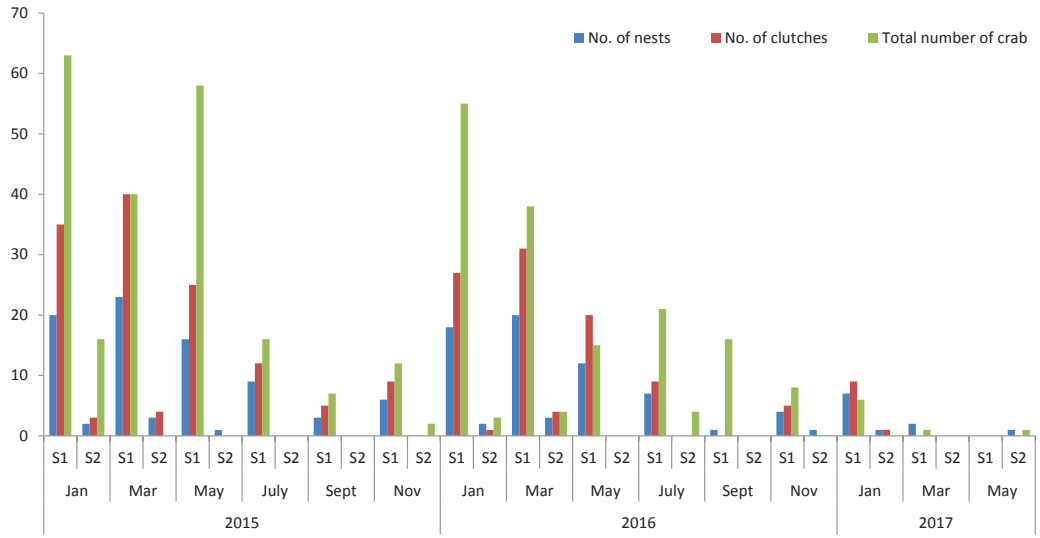


Fig. 8. Biological observations from the nesting (1-2) sites along Balasore coast

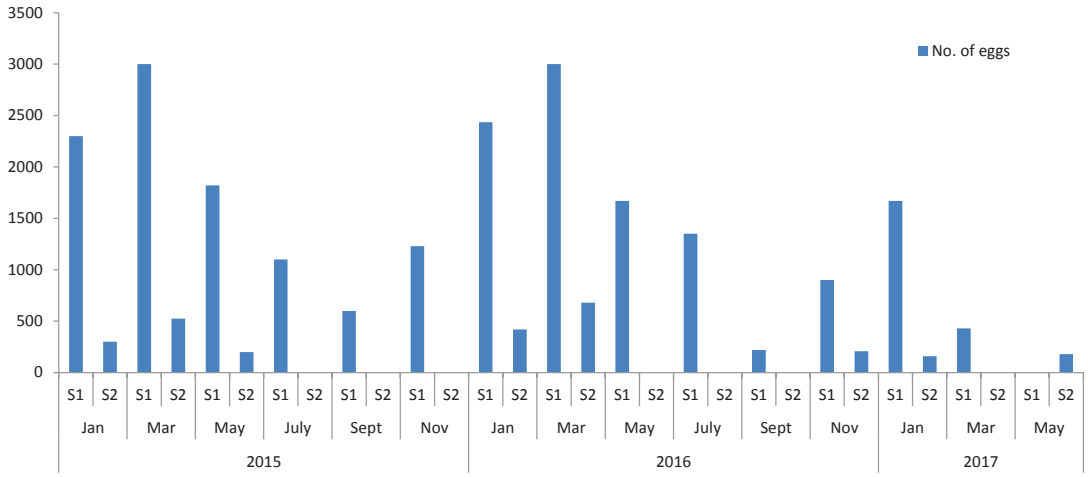


Fig. 9. Biological observations from the nesting (1-2) sites along Balasore Coast

CONCLUSION

Though much of the horseshoe crab literatures are available in India, the present study is claimed to be the only investigation with wide array of the environmental observations. The normal nesting behavior of *T. gigas* was also influenced by the seasonal water currents and fine sediment transportation. However, to facilitate a better understanding on their nesting behaviour, further measurements on water current/sediment transport (at river mouth and/or estuary) are essential. As is evident from the present status of breeding beaches at Balarmgadi, it is a matter of great concern that the day is not far off when we will not be able to encounter breeding pairs in Khandia coast. Hence, more efforts should be given to create public awareness, educate fisher folks and provide alternative sites for boat building and repairing. Enforcement of laws should also be stringent to protect these precious species from the brink of extinction.

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