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Horseshoe crab: A biogem of the estuarine ecosystem

Abstract

Conservation of horseshoe crab is currently done by several ecological and biotechnological approaches. The species is considered a multiple-use resource, as it plays an important role as bait in a commercial fishery, as a source of an important biomedical product, as an important food source for multiple species of migratory shorebirds, as well as in several other minor, but important, uses. Concern has arisen that horseshoe crabs may be declining in number. In this report we have discussed the general biology, ecology, and population status of the horseshoe crab species inhabiting the shore of Chandipur (Orissa). We have also discussed the role played by the species in the commercial fishery, in the biomedical industry, as well as for the shorebirds. An account of the strategy of horseshoe crab conservation is also included in context to establishment of fish landing station at Chandipur (Orissa).

Volume 1 Issue 2 - 2017

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Received: May 25, 2017 | **Published:** June 13, 2017

Introduction

Horseshoe crabs, the closest living relatives of the trilobites,[1] have persisted for more than 200 million years.[2] Unmistakable fossil forms of horseshoe crabs have been found as far back as 500 million years ago, in the latter half of the Paleozoic era.[3] Four species of horseshoe crabs are present today in the planet Earth restricted in some belts (Table 1).

Table 1 Geographical distribution of horseshoe crabs

Species	Distribution
Limulus polyphemus	Atlantic coast of North America from Maine to Yucatan [Shuster, 1957]
Tachypleus tridentatus	Northern shores of Japan up to South Vietnam and along the Western islands of the Philippines [Pocock, 1902]
Tachypleus gigas	Source of Bay of Bengal, particularly along the coast of Orissa (India) to Indo-China, North Vietnam, Borneo and Celebes
Carcinoscorpius rotundicauda	North eastern sector of the Bay of Bengal particularly along the coast of West Bengal (Sundarban mangrove ecosystem) to the Southern coast of Philippines

Table 2 Systematic position

Phylum	Arthropoda
Sub-phylum	Cheliceratata
Class	Merostomata
Order	Xiphosurida
Species	a) *Limulus polyphemus* b) *Tachypleus tridentatus* c) *Tachypleus gigas* d) *Carcinoscorpius rotundicauda*

The need for the species by pharmaceutical industries for endotoxin detection has put the species under stress. We detail the controversy surrounding the horseshoe crab by describing the various user groups and their stakes in this issue. These include the migratory shorebirds that rely on the eggs of horseshoe crabs for food, the biomedical companies that extract blood from horseshoe crabs to produce a widely used test for the presence of endotoxins, and the commercial fishery that harvests horseshoe crabs for use as bait. In addition the species often get entangled in the fishing net, dragged to the shore (preferably on the supra littoral zone) resulting the death of the animal.

Economic stakes include the effects of eco-tourism associated with bird watching enthusiasts, the increasing worldwide demand for horseshoe crab blood for endotoxin testing, as well as the increasing demand for horseshoe crabs as bait in commercial fisheries. As the demand for horseshoe crabs increases, so does the need for alternatives to horseshoe crabs. These issues include whether migratory shorebirds could utilize alternate food sources, whether the biomedical product could be produced synthetically, as well as whether decreased numbers or other sources of bait could be used to attract eel and conch. The management of horseshoe crabs had historically, been minimal to nonexistent, as they had been considered a "trash-fish", not worthy of limited management resources. For years, they had been ground up and used as fertilizer. Consequently, time series population data are absent due to the lack of reporting regulations and harvest restrictions associated with the fishery. With concerns of diminishing populations coupled with a trend of expanded use, increased management attention has become a necessity. We discuss the management and conservation of horseshoe crabs by restoring the habitat of the species and creating a favourable niche for their survival, growth, and breeding.

General biology, ecology, and life history of the horseshoe crab

An overall understanding of *L. polyphemus* as well as the three other extant species of horseshoe crabs (*Tachypleus tridentatus, T. gigas*, and Carcinoscorpius rotundicauda) is important to discerning the natural history of merostome fauna and even the trilobites, as the horseshoe crabs are the sole aquatic survivors from these time periods and can provide a plethora of information not available from the fossil record.[4] The horseshoe crab is more closely allied to the ancient sea scorpion and to modern scorpions and spiders than it is to true crabs, but it was originally mistakenly identified as a crustacean

by Europeans.[5] Other common names used in the past include the "horsefoot crab", "horsefeet", "swordtail crab", and "pan crab",[5] as well as erroneously as "king crab." (Paralithodes camtschatica is the true king crab.[5] The external morphology of the horseshoe crab is shown in (Figure 1).

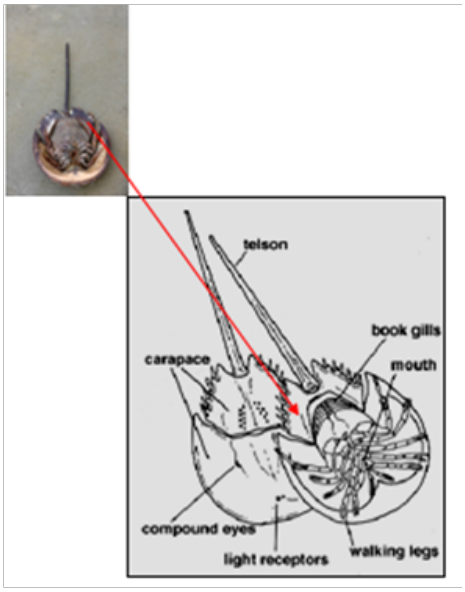

Figure 1 Morphology of horseshoe crab.

General biology

Horseshoe crab, a Chelicerate arthropode belonging to the Class Merostomata, is an amazing animal of marine and estuarine ecosystems, which has not exhibited any significant phenotypic change even over a period of 350 million years. This shows the tremendous adaptive elasticity of this creature to cope up with wide range of environmental conditions that have deviated and fluctuated to a great degree during the long evolutionary period of time.

Horseshoe crabs are considered both ecological and behavioral generalists, tolerant of a broad range of conditions, and capable of reacting to their environment in many ways. However, it has been suggested that characteristics, including behaviour, of any one population are not identical to those of another.[6] There is evidence of genetic variability,[5] including evidence of gene flow,[6] as well as morphological variation in both size and shape.[7] Horseshoe crabs appear to exhibit marked population subdivision even over a relatively small geographic range.[8] Horseshoe crabs are fairly long-lived, and some may reach a maximum age of 20 years.[5] It is difficult to determine adult age directly, so it is approximated using indirect methods. This is generally accomplished through tagging, by aging any epibionts (symbiotic organisms) present on the shell,[9] or by examining the type and site of carapace wear and the size and kind of epibionts. Three categories are commonly used to describe the ages of adult horseshoe crabs. These categories include:

i. Young Adults: Carapace is lustrous with few, if any, scratches or epibionts. Virgin males can be identified by the atrophied nonmoveable chela, which break off after first mating. Virgin females can be identified by a pristine shell with no mating scars.

ii. Middle-aged Adults: Lustrous sheen of carapace is being eroded away, as a black layer of shell becomes exposed. Both genders exhibit increasingly extensive scratches on their carapace. Female horseshoe crabs have large black areas on the middle and posterior portions of their abdomens that are mating scars resulting from abrasion during mating. "Pressure spots" are evident where the claspers of the male attach to the trailing edges of the female's abdomen during spawning. Epibionts are usually present on the carapace.

iii. Old-aged Adults: Carapace tends to be almost completely blackened, and in the case of extreme erosion the black layer is also worn away, exposing a brownish-colored layer that is often tinged with green. The shell of the horseshoe crab is thin and can be easily depressed. Epibionts are almost always present and may have reached large sizes.

Diet of horseshoe crabs

An adult horseshoe crab diet consists of several species of bivalve molluscs (including razor clam (Ensis spp.), macoma clam (Macoma spp.), surf clam (Spisula solidissima), blue mussel (Mytilus edulis), wedge clam (Tellina spp.), fragile razor clam (Siliqua costata), soft-shelled clam (Mya arenaria)), and worms (polychaete Nereis spp. and nemertean Cerebratulus spp.).[1,10,11] Botton[10] also found vascular plant material in nearly 90% of horseshoe crabs sampled. To eat, L. polyphemus digs after its food, grasping its prey with pincer-tipped legs.[1] The food is then crushed between the legs and pushed forward into the mouth.[1] A more detailed description of feeding can be found in other sources.[4] Horseshoe crabs depend on benthic organisms for their nutrition. Gut-contents have been analysed from 5 crabs of each species and the major food items included bivalves, gastropods, polychaetes, a few crustaceans (mainly amphipods), a few insect larvae (tabanids) etc.; some plant matter and foraminiferan shells were also identified.

Ecology of horseshoe crabs

The horseshoe crab is a hardy animal and can thrive well in estuarine dilution or saturation of sea-water by maintaining osmotic steady state.[12] Detailed investigation made on L. polyphemus reveals that the species is tolerant to a wide range of environmental extremes, including hypoxia, salinity ranging from full sea water down to 5% sea water (whose salinity is about 1.7ppt) and temperature ranging from below 0C to over 40C .The mudflats and sandy shore of northeast coast of India are the visiting ground of the living fossils. Preliminary investigations along the coast of Orissa and West Bengal revealed that Carcinoscorpius rotundicauda occurs on the muddy beaches of the estuarine Sundarbans delta (Figure 2) and Tachypleus gigas prefers soft sandy beaches.

Figure 2 Carcinoscorpius rotundicauda inhabiting muddy substratum.

These two species are observed during their respective breeding seasons only, which begin for both species in late February or early

March and ends in late June, although T. gigas can still be found in August in some localities.[13]

In the mangrove-based mudflats and sandy beaches, the horseshoe crabs arrive in pairs during the breeding season. A large sized female usually carries the smaller male on her back, the latter remaining attached to the females's opisthosoma (abdomen) with his modified clasper legs. Periodically they cover the same ground, seeking a suitable place for the female to lay her eggs. The female digs a burrow and lays her eggs in a cluster, while the male sheds sperm on them.

Study done on the population distribution of the two species of horseshoe crabs (Chatterjee and Abidi, 1993) reveals the preference of Tachypleus gigas for sandy substratum, while Carcinoscorpius rotundicauda has affinity for muddy substratum, where there is dominancy of silt and clay. Accordingly the population of T. gigas is maximum in sandy coast of Orissa (particularly Chandipur). According to Chaudhuri and Choudhury[13] the population size of T. gigas at Chandipur was estimated at approximately 8000–9000 in and around full moon tides during March 1985. The rate of capture was higher at night than in the day. The recovery rate at Chandipur was 11.41 percent for males and 10.93 percent for females. The ratio of males to females was found to be 6.89:1 at Digha (in West Bengal) and 1.04:1 at Chandipur. The high ratio of males to females at Digha seems to be due to high predatory pressure on the gravid females by crows (Corvus sp.).

A study conducted by the team members of Techno India University in the sandy beaches of Chandipur during April, 2015 documented a population density of 0.8/m^2 for Carcinoscorpius rotundicauda, while for Tachypleus gigas, the value was 1.8/m^2. The team members also carried out a comprehensive research on the diet spectrum of both the species for their long term conservation in the system. Gut-contents analysis of 5 crabs of each species revealed the presence of food items like bivalves, gastropods, polychaetes, a few crustaceans (mainly amphipods), a few insect larvae (tabanids) etc.; some plant matter and foraminiferan shells were also identified. Horseshoe crabs face dangers from a variety of predators throughout their lifecycle. These include molluscs, crustaceans, fish, sharks, eels, shore birds, sea turtles, and, maybe most importantly, man.

Life history

Male horseshoe crabs usually outnumber female horseshoe crabs on spawning beaches,[14] creating male-biased sex ratios and male-male competition for mates.[15] Males use their modified, claw-like pedipalps to grasp onto females' terminal spines[16] as they head from the water to the spawning beaches[5] (Figure 3). In addition, unattached males also come onto shore looking to find mates.[16] Sometimes, a single female may have numerous satellite males trailing behind her within her spawning group.[17,18] Satellite males show nonrandom distributions around the females, as unattached males appear to be preferentially attracted to some females over others.[19] Several studies have investigated the male horseshoe crabs' use of vision when finding mates.[20,21]

Hassler et al.[22] demonstrated that male horseshoe crabs use both chemical and visual cues when locating mates. Each adult female horseshoe crab may produce at least 88,000 mature eggs, although this number is highly variable.[1] Females dig an excavation below their body and deposit their eggs in clumps within the intertidal zone at depths ranging from 5 to 30cm.[23,15] Each clump contains approximately 3650 eggs, on average, which are fertilized when waves wash spermatozoa released by males into the area of the eggs.[1] It has been suggested that adult horseshoe crabs can spawn multiple times each season.[14] Weather can negatively affect spawning activity by disrupting spawning sites, driving animals off the beach, diminishing the number of pairs able to spawn, or by preventing the animals from coming to the beach at all.[1] One study reported that the numbers of spawners in the Cape May, New Jersey, area vary, and that when the numbers are low in that area they are conversely numerous on the Delaware shores .Another negative impact on spawning occurs as some of the eggs on the sandy shore and in shallow waters are eaten by shorebirds, shrimp, and a number of species of small fish.[1]

Figure 3 Mating pairs of horseshoe crabs.

After the eggs incubate for 2 to 4weeks, larvae begin to emerge[24,25] although some larvae may not hatch until the following spring, spending their winter buried under the sand.[18] Larvae enter the water as they are freed from their clusters by a combination of churning wave action and from their own digging and burying.[5] After hatching, the horseshoe crabs' lives consist mainly of foraging for food and growing.[5] As the horseshoe crabs grow, they gradually move several kilometers from their natal beaches into deeper waters, where they will begin their spawning migration once they reach adulthood.[5] Horseshoe crabs molt numerous times as they grow from their larval stage, shedding their exoskeleton at least 16 or 17 times before reaching sexual maturity. The molting process occurs during the warm-water months, and becomes more difficult and time consuming at each growth stage.[5] Horseshoe crabs require 9 to 10years to reach sexual maturity,[26] and at this time, apparently cease to molt and grow.[1]

Conservation of horseshoe crabs

From the commercial point of view, the horseshoe crabs can be incorporated in the list of "marine gems" due to their unique biomedical properties. All the horseshoe crab species exhibit high sensitivity to bacterial endotoxin. The cell lysates obtained from the blue blood of these species are widely used for estimating the contamination of bacterial endotoxin. The reagents manufactured from the cell lysates (namely CAL, TAL and LAL) are extremely sensitive and are used for the rapid and accurate assay of gram-negative bacteria even if they are present in a very minute quantity. This unique property of horseshoe crab's blood has pushed the species within the greed of several pharmaceutical companies.

The horseshoe crabs are regular visitors in the northeast coast of India particularly during the premonsoon season (March to June) when the aquatic salinity reaches its peak. During this period, they are found in mating pairs in the mangrove creeks and mudflats. However, with the vague belief of the ability of this crustacean to cure arthritis, they are often killed by boiling and the extract is sold in the district markets for curing arthritis. This activity has severely reduced the population of this valuable species. In addition

several coastal activities like unplanned tourism, establishment of industrial units, ports, harbours, industries and shrimp farms often pose a negative impact on their survival by way of destructing their habitats. It is high time to conserve this living fossil of the planet with an effective management action plan. Increased awareness has now initiated the species to move on a path from being ignored to being scientifically managed. Reaching the endpoint is dependent on two things: sufficient time to collect informative data and planned scientific management to preserve their habitat. Everyone involved must realize that there is no quick fix to the horseshoe crab issue. As with any fishery, effective management of the horseshoe crab will require proper habitat restoration and conservation.

Creation of proper habitat (with mangrove flora and fauna) is an effective approach to conserve the species. Care should be taken to monitor the movement of fishing vessels and trawlers so that their habitat is not disturbed. Awareness should be generated amongst the fisherman community and local inhabitants regarding the ecological and biomedical values of horseshoe crabs, so that the entangled species is quickly released in their habitat. Along with this strong restriction should be imposed during their breeding season (preferably May/June) to avoid bottom trawling, which may otherwise disturb the mating pairs. Although a holistic approach is needed to conserve the species in and around the fish landing units at Chandipur, but the method requires several steps as stated below:

i. The fisherman and the fishing community should be made aware through group discussion and audio-visual programme the importance of horseshoe crabs.

ii. A 100mX100m swampy ground with true mangrove vegetation and associate species (preferably Porterasia coarctata, Suaeda sp., etc.) would be developed for releasing the rescued species (that are often entangled in the nets of the fisherman). This swampy ground should be connected to a creek that would meet the river mouth (Figure 4). This would help the matured horseshoe crab to return their natural habitat.

Figure 4 A natural habitat of horseshoe crab connected with the river mouth through creek.

iii. The swampy ground should be monitored for the preferred diet of horseshoe crab like gastropods, bivalves, small crabs etc. Proper care should be taken to monitor the ambient media that may get contaminated with oil grease and heavy metals originating from the antifouling paints.

iv. Band should be imposed on bottom trawling in and around the landing station in the months of early April to June (premonsoon) when the horseshoe crabs migrate in the inshore regions in mating pairs.

v. The present act of Govt. of India states the complete banning of fishing season from 16th April to 31st May. This time period is not in accordance with the breeding time of the horseshoe crab species as mating pairs are seen during early premonsoon (March) when the salinity of the ambient water starts rising. Expansion of the ban period is therefore a necessity to conserve the horseshoe crab species.

Acknowledgements

None.

Conflict of interest

The author declares no conflict of interest.

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