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The Olive Ridley sea turtle (*Lepidochelys olivacea*) in Orissa: An urgent call for an intensive and integrated conservation programme

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The Olive Ridley sea turtle, which nests along the east coast of India, is highly endangered today. This sea turtle is especially known for its mass nesting or arribada when several thousand turtles migrate to the breeding ground to mate and nest simultaneously. The rookery at Gahirmatha in Orissa is the largest in the world with annual nesting of hundred to five hundred thousand turtles, but there has been no mass nesting at this site for the past two years. Over the past five years, sea turtles have suffered mass mortality along the Orissa coast due to death by drowning as incidental catch in trawl-fishing nets. The first step in conserving this species would be the enforcement of the existing ban on near-shore mechanized fishing. The use of turtle excluder devices should be made mandatory for all trawlers operating in offshore coastal waters. Close monitoring and protection of the three major rookeries would curb predation of hatchlings, and the introduction of controlled lighting in these areas would greatly reduce hatchling mortality. Since the major cause of mortality of adult turtles is due to modern fishing practices which have also endangered traditional coastal lifestyles in addition to the turtles, a solution lies in encouraging the return of artisanal fishing to the Orissa coast.

THERE are several species of endangered animals in India today, some of which are in danger of extinction in the very near future. The Olive Ridley sea turtle is one of the high profile species which has received substantial media coverage and scientific attention in recent years. The question remains as to whether these conservation efforts have had any effect at all and if not, where have they failed. Does the sea turtle conservation issue present the same conservation dilemma in a different context (read habitat) or are there issues here that are fundamentally different from other conservation programmes such as say, the tiger and the elephant. We believe that in some ways the case of the Olive Ridley is truly different because they are 'innocent bystanders' in that their major cause of mortality is not directed at them in any way. Further, the conservation solution is also unique in that it combines the interest of the local traditional lifestyles and the interest of the animal, which is not the case in the conservation of many large mammals, at least as projected by conservationists.

Five species of sea turtles – the Olive Ridley (*Lepidochelys olivacea*), Hawksbill (*Eretmochelys imbricata*), Green (*Chelonia mydas*), Loggerhead (*Caretta*

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caretta) and Leatherback (*Dermochelys coriacea*) – occur in Indian coastal waters. Barring the loggerhead, all the species are known to nest in India. While all four species nest in the Andaman and Nicobar Islands, the Olive Ridley is most numerous on the mainland coasts of India. Although the Olive Ridley nests in low densities along the entire east coast, the most important nesting beaches lie in Orissa, where the mass nesting occurs. The Olive Ridley sea turtle is well known for its annual mass nesting or *arribada*, when several thousand turtles migrate to the breeding ground to mate and nest simultaneously. The 480 km Orissa coast harbours three such mass nesting beaches. These are the Gahirmatha rookery near the mouth of rivers Brahmini and Baitarani along the northern Orissa coast, the rookery near the mouth of river Devi, located 100 km south of Gahirmatha and the Rushikulya rookery, located 320 km south of Gahirmatha near the mouth of river Rushikulya along the southern Orissa coast. A significant proportion of world's Olive Ridley population that migrate every winter to the Indian coastal waters nest at these three rookeries.

Sea turtles, in general, nest at night. During the breeding season, males and females migrate from their feeding ground to the breeding ground, which may be thousands of kilometres apart. Mating occurs in the offshore waters of the breeding ground, and the females then come ashore to nest, usually several times during a season. They crawl ashore above the high water mark and dig a flask-shaped nest about 1.5 to 2 feet deep and lay 100–150 eggs in each clutch. Hatchlings emerge *en masse* about 50 days later and locate the sea by a light cue, the water providing a brighter horizon. Hatchlings then lead a pelagic lifestyle, drifting along various currents as planktonic feeders until they finally reach their feeding ground a few years later[1]. When they mature (which could range from 30 to 50 years), they are believed to return to the same breeding grounds to nest. Approximately one in a thousand hatchlings are believed to survive to maturity. The sex of the hatchlings is determined by incubation temperature[2] and this could have implications for their conservation[3]. Olive Ridleys are the smallest of the sea turtles measuring about 70 cm in length and weighing about 50 kg. They nest between December and April along the coast of India. Though the origin of the turtles that nest on Indian beaches is unknown, Olive Ridleys are in general known to be pelagic and to feed in the open ocean[4]. (For a more detailed description of the natural history, see refs 5, 6.)

Status of the Olive Ridley during the last decade

The Gahirmatha beach was the first of Orissa's nesting beaches to be made known to the scientific community in the mid 1970s by the FAO/UNDP crocodile project[7]. Substantial nesting has been recorded at this site with over 100,000 turtles in most years and over 600,000 turtles in peak years[8]. Due to a cyclonic storm and beach erosion, the Gahirmatha beach was considerably reduced in size when a 3 km long spit broke away from the mainland in 1989, reducing the 10 km nesting beach to a 3 km island. Since 1997, this 3 km long island has further been fragmented into two parts and has been greatly reduced in length, width and height. It is a matter of considerable concern that there has been no mass nesting at Gahirmatha since 1997.

The rookery near the mouth of river Devi was discovered in 1981 (ref. 9) and was then completely forgotten by the scientific and conservation community. Since then much of the nesting area at this rookery has been altered by Casuarina plantations and the nesting population has shown a considerable reduction in number[10]. The rookery near the mouth of river Rushikulya was discovered in March 1994 (refs 10, 11). Since 1994, Olive Ridleys are nesting *en masse* at this rookery with considerable fluctuations in the number of nesting females from 60,000 in 1995 to 8,000 in 1998.

All the five species of sea turtles occurring in India are legally protected, being included in Schedule I of Indian Wildlife Protection Act (1972) as well as in Appendix I of Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) which prohibits trade in turtle products by signatory countries. The mass nesting beach at Gahirmatha is a part of the Bhitarkanika Wildlife Sanctuary. The coastal waters off Gahirmatha coast have been declared a marine sanctuary in 1997. The coastal waters off Devi and Rushikulya rookery have been declared as a no-fishing zone during the sea turtle breeding season.

Death by drowning

Despite the legal protection given to the sea turtles, the sea turtle population migrating to the coastal waters off Orissa has been declining in recent years. The death of several thousand adult breeding individuals in Orissa each year has become a major concern of the national and international community. Apart from this large scale mortality, the sea turtles which spend almost six months in the coastal waters off Orissa face a multitude of problems which need to be addressed immediately.

The biggest cause of mortality is the incidental capture of adult turtles in trawl-fishing nets. Turtles are trapped in large trawl-fishing nets from which they are unable to escape. Since the nets are usually operated by mechanized boats for several hours at a stretch before being hauled in, the turtles are unable to breathe and drown in the nets. Uncontrolled mechanized fishing in areas of high sea turtle concentration has resulted in heavy mortality of adult sea turtles during the last dec-

ade. Dash and Kar report[8] the stranding of 4,682 adult Olive Ridleys at Gahirmatha rookery between September 1978 and May 1985. In 1993, during a six month survey of sea turtle nesting beaches in Orissa by the Wildlife Institute of India (WII), 5,400 carcasses of Olive Ridleys were found washed ashore along the 480 km Orissa coast[10,12]. Since then, more than 30,000 dead adult Olive Ridleys have been documented in Orissa. Mortality due to illegal near shore trawling and gill netting has been increasing each year and reached a record high of 14,000 turtles in 1998. These 14,000 turtles were counted only on a stretch of 282 km of the 480 km Orissa coast. Hence, the actual number of dead turtles washed ashore the entire Orissa coast could have been much higher (Figure 1).

A second major cause of disturbance is artificial illumination along the coastline. Developmental activities such as the establishment of missile test range and construction of a major port near Gahirmatha and mushrooming growth of aquaculture farms and chemical industries near Rushikulya rookery have resulted in increased illumination near the nesting beaches. Sea turtles which nest at night, get disoriented by artificial lights and are known to avoid brightly illuminated beaches. Further, sea turtle hatchlings emerging from the nests at night are strongly oriented towards the source of illumination and stray away from the nesting beach. As a result, they remain stranded on the land during the day and are either predated by avian predators like crows, kites and sea gulls or are desiccated, resulting in very heavy hatchling mortality.

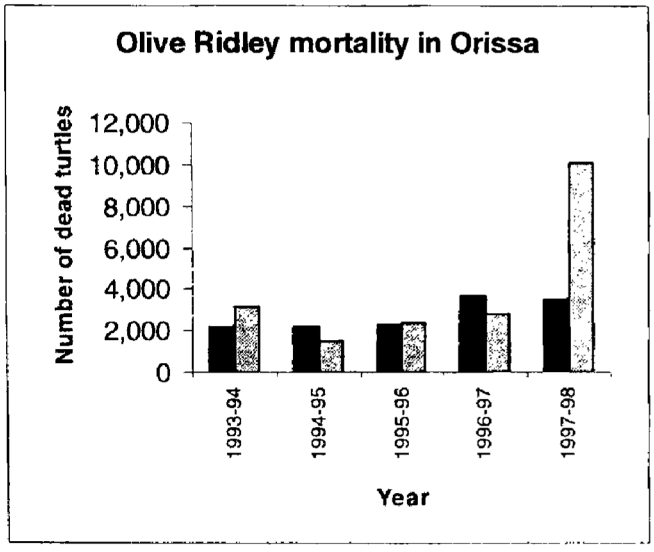

Figure 1. The mortality of Olive Ridley turtles in Gahirmatha (black), which is merely 35 km of coastline and along the rest of the Orissa coast (grey). The total coastline surveyed included 282 km of southern Orissa coast, while another 200 km of the coastline was not surveyed. Therefore, one can expect actual mortalities of Olive Ridleys to be much higher than quoted here. It must also be noted that the number of dead turtles on the Orissa coast over the past three years (33,617) far exceeds the number of turtles nesting at Rushikulya and Devi River mouth (10–15,000). There has been no mass nesting at Gahirmatha since 1995–96.

Human consumption of sea turtle eggs or meat is minimal in Orissa. However, heavy predation on sea turtle nests by feral dogs and jackals takes place at Rushikulya rookery after the mass nesting. Estimates show that almost 25–30% of the eggs laid during the *arribada* get predated by non-human predators at Rushikulya. Casuarina has been extensively planted along the Orissa coast after 1970 mainly to act as a barrier to cyclonic storm. However, sea turtles prefer to nest in open sandy beaches devoid of vegetation. The planting of Casuarina in some of the prime nesting grounds of sea turtles restricts the space available for them to nest. Besides this, Casuarina with its superficial root growth and thick litter fall, renders the beach unsuitable for the turtles to nest.

Conservation measures

The first step is a strict enforcement of the ban on nearshore mechanized fishing and in areas of high sea turtle concentration. The Government of Orissa has declared the coastal waters off Gahirmatha a marine sanctuary and the coastal waters off Devi river mouth a no-fishing zone. Besides this, the Orissa Marine Fishing Regulation Act, 1983 prevents any kind of mechanized fishing within 5 km of the shore line. However the enforcing agencies, the State Forest Department, the State Fisheries Department and the Coast Guard, lack the infrastructural facilities to enforce the ban on fishing in these areas. Therefore the concerned agencies should be provided with adequate sea going vessels and personnel for strict enforcement of these bans.

The use of Turtle Excluder Devices (TED) in trawl nets should be made mandatory for trawlers operating in the coastal waters beyond 5 km of the shore line. TEDs are essentially trapdoors which can be attached to trawl nets that allow large animals like sea turtles to escape from the net without significant loss of fish catch. However, use of TED alone will not bring down the turtle mortality because turtles are also caught and killed in gill nets and TEDs cannot be used in gill nets. Therefore strict enforcement of the existing law on no fishing zones, along with TED in other fishing zones, seems to be the best answer to bring down turtle mortality.

With a sharp decline in the number of nesting females and a steep rise in the number of dead turtles in past two years, the loss of 25–30% of the total eggs laid at Rushikulya becomes more serious. The area may need to be fenced and properly guarded to minimize non-human predation.

A major step towards saving this population would be giving protected area status to the sea turtle nesting beaches as well as the coastal waters having high sea

turtle concentration. Of the three mass nesting beaches in Orissa, only Gahirmatha and its coastal waters are legally protected. The nesting beaches at Devi mouth and Rushikulya lack any kind of legal protection status thus making them vulnerable to anthropogenic disturbances. It is necessary to protect these areas (by declaring them as sanctuaries) so that the state Forest Department has jurisdiction over these nesting beaches and can provide protection for adults and hatchlings. On the other hand, it would be a mistake to completely exclude local people from the protection initiatives.

The tagging studies at the Wildlife Institute of India (Pandav and Choudhury, unpublished data) have revealed the movement of turtles between these three rookeries and have demonstrated that turtles use more than one rookery for nesting during a season. This implies that the turtles nesting off the coast of Orissa may be part of a single population, meaning that turtles at all three rookeries are equally important. Further, if the nesting beach at Gahirmatha continues to decline due to geographical factors, these turtles may nest at the other rookeries and it is important that these alternate nesting beaches are 'turtle friendly'. Thus, the protection of all these three rookeries is extremely crucial for the survival of turtles in Orissa.

These steps would drastically reduce mortality of turtles on the coast in the immediate future. However, the key to long-term conservation of the Olive Ridley on the Orissa coast lies in mobilizing the local community to participate in the programme. This would involve creating awareness among the local communities for sea turtle conservation. A community participation approach, where the local communities benefit vocationally and economically, would be expected to yield better results than a completely protectionist approach.

Research in support of conservation

Research programmes on sea turtles in India (and to a large extent worldwide) have been focussed on conservation. In Orissa, the tagging of nesting females indicates that there is inter-rookery nesting, while the tagging of mating pairs has provided information on the reproductive biology of the species (Pandav and Choudhury, unpublished data). While the Wildlife Institute of India has been carrying out tagging and monitoring programmes over the past few years, more work can be done on the east coast of India that would go a long way towards aiding conservation efforts. Some suggestions include:

Continuous monitoring of sea turtle nesting beaches and tagging of nesting females

The three sea turtle rookeries as well as the sporadic nesting beaches in Orissa need constant monitoring during the breeding season to determine the intensity of sea turtle nesting based on which detailed management programmes can be laid out. Regular surveys of the coast during the breeding season will also provide crucial information on sea turtle mortality. Tagging of sea turtles at the nesting beaches in Orissa will help in estimating the size of nesting populations and mortality rates due to incidental catch. Tagging also facilitates studies of internesting biology and long distance tag returns may provide clues about the origin of the turtles.

Figure 2. A dead Olive Ridley sea turtle.

Quantification of incidental capture of sea turtles in fishing nets and fisheries-related mortality in Orissa

No quantitative information is available on the capture rates of sea turtles in shrimp trawls or in gill netting and on their mortality rate due to such incidental capture. In order to prevent this large-scale incidental capture, it is essential for the managers to know when and where turtle captures occur, which species are impacted, at what depths the majority of captures occur and how many turtles are killed. Therefore, it is necessary to do a quantitative study of incidental capture-related mortality of sea turtles in fishing nets.

Conservation genetics study of Olive Ridley on the east coast of India

Many questions have been raised regarding the origin and population structure of the Olive Ridley population migrating to the Indian coast. Clarifying these questions would lead to a better understanding of these turtles. Molecular genetics provides tools with which many questions regarding the biology and conservation of an animal can be addressed with great economy and precision[13]. A molecular genetic analysis of mitochondrial and nuclear DNA of the Olive Ridleys on the east coast

of India would provide insights into the population genetic structure of the turtles at the three rookeries and elsewhere along the coast. One may also be able to trace the origins of these turtles by comparing these turtle samples with those from other parts of the Indian Ocean.

Monitoring the route followed by the turtles through satellite telemetry

Though Olive Ridleys spend almost six months in a year in the coastal waters off Orissa, it is not known where they spend the remaining six months. The arrival of males and females in the breeding grounds in Orissa and their departure from these areas has so far been little understood. Satellite telemetry study will provide crucial information on these aspects of sea turtle migration biology.

Other studies that would be integral to sea turtle conservation would include:

- Study of changes in coastal geomorphology using satellite imagery.
- Bio-economic analysis of existing and proposed fisheries management strategies.
- Monitoring of traffic and trade of turtles and turtle products.

Discussion

While Olive Ridley adults were once sold *en masse* in the markets of Calcutta, the trade in adult meat has reduced greatly in the last decade. We reiterate that the present danger to them is mortality as *incidental catch*. They are trapped in trawl nets, drown and are then discarded to be washed ashore by the thousands. While it is apparent that the first step that needs to be taken is strict action against nearshore fishing by mechanized trawlers, a long(er)-term solution may lie in mobilizing the local fishing community. Mechanized trawling has not only endangered turtles, but also the lifestyles of the local artisanal fishing community. Mechanized fishing has also been responsible for overfishing and may have severely depleted fish stocks in the region. Further, it would appear that most of the trawlers are owned by economically forward communities in inland Orissa and neighbouring states and even as far away as Delhi, and local fishermen are only used as labourers. The resources and people are clearly being exploited by a community with more power, both economic and political. It makes economic and social sense to return the control of resources in coastal Orissa to the local community. It is a matter of some debate whether artisanal fishing will persist in the coastal community. However, as long as it does persist, it will pose far less a threat to turtles, and therefore should be promoted.

Solutions are also available to many other problems of Olive Ridleys on the Orissa coast. TEDs are available for use on trawlers. While foreign TEDs may be expensive, they can be indigenously designed; Project Swarajya in Orissa is attempting to do this, but the bigger problem would lie in getting the trawlers to use them. Intensive research has been done on artificial illumination and many kinds of turtle friendly lights are available[14]. Again, the difficulty lies in getting people to use the technology. For example, the Defence Research and Development Organization (DRDO) has a missile testing range on the island adjacent to the nesting beach in Gahirmatha. In the past few years, the bright lights from the DRDO island have been extremely hazardous to turtles. Recently however (since 1996), the DRDO has made a commitment to turtle conservation and has been switching off some lights during the turtle season, though this may not be adequate. Work has already been done on the effects of lighting on turtles, especially hatchlings, and alternate varieties of lamps, screens and filters are now available such that turtles are not affected and there is ample illumination[14].

In the case of other highly endangered species, conservationists have advocated a highly protectionist approach, arguing that, though substantial damage may have been caused by industrial and urban development, the few remaining habitats cannot even tolerate minimal disturbances by local traditional people. However, we argue here that the best solution for the Olive Ridleys along the coast of Orissa (and perhaps elsewhere along the coast) would be to encourage artisanal fishing and to return the coastal waters to the local traditional fisherfolk.

In 1998, the Wildlife Protection Society of India has launched a conservation effort, Operation Kachhappa, with the cooperation of local conservation groups and the Orissa Forest Department. This initiative hopes to implement management practices by strictly enforcing the ban on nearshore mechanized trawling by providing the necessary support to the Forest Department and seeking the cooperation of the Coast Guard. The Wildlife Society of Orissa and other local NGOs are seeking to expand the education and awareness programme initiated by the Wildlife Institute of India in coastal Orissa, involving and mobilizing the local people, especially the fishing communities. One hopes that these efforts will turn the tide for Olive Ridleys in Indian coastal waters.

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REVIEW ARTICLES

Non-equilibrium atomic dynamics in solids

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Atoms, molecules, electrons and impurities in solids are subjected to short-lived large energy fluctuations (SLEFs) arising from the background phonon-sea due to anharmonic interactions. These SLEFs arise from the 10–100 atoms situated within a few nanometer size volume surrounding the affected entity and have lifetimes of the order of a few pico-seconds. The resulting dynamics is not in equilibrium with the remaining system over these space and time intervals; it results in unusual and fast atomic/cluster displacements and electronic transitions. The study of this 'fluctuations dynamics' has led to understanding 'abnormal' diffusion, desorption, chemical kinetics, ionic conductivity, etc. in solids especially in situations when the associated Arrhenius parameters are beyond the realm of conventional rate theory. This article reviews (a) advances made by the SLEF theory with a few examples drawn from literature and (b) results from computer experiments that reveal the microscopic nature of the fluctuations.

CONVENTIONALLY, the subject of 'lattice dynamics' deals with atomic and molecular vibrations in solids within the confines of harmonic approximation[1,2]. Phonon spectra derived from theories of lattice dynamics and measured by experimental techniques of inelastic scattering of neutrons have played an important role in understanding the nature of various macroscopic thermodynamical properties of solids like specific heat, velocity of sound, thermal expansion, elastic moduli, temperature dependence of elasticity and thermal conductivity, etc. Equation of state of metals and alloys are fairly predictable. In order to understand the temperature dependence of some of these properties one invokes 'quasi-harmonic approximation'. Phase diagrams of various systems are foreseen based on evaluation of the total energy of the systems as functions of temperature and pressure. However, many phenomena like evaporation, diffusion, viscosity or plastic deformation at high temperature, etc. cannot be understood within the scope of conventional lattice dynamics.

Frenkel studied this aspect of the subject by considering what is referred to as 'energy fluctuation dynamics'[3], wherein the atoms and molecules in a solid possessing energy at least an order of magnitude greater than the average energy, as given by conventional dynamical approaches, were contemplated upon. His work has later on led to information concerning the nature of energy fluctuation of atoms in detail in terms of their temporal evolution, spatial localization and statistics. Another area that is influenced considerably is the study of heterophase fluctuations related to phase transitions[3,4].

In recent times Khait[5] has provided a nanoscopic stochastic dynamic many-body theory of energy accumulation by an atom in any solid as a result of a directional flow of energy flux from the immediate causal nanometer environment of the atom during a time of the order of pico-seconds through correlated motion of the fluctuating atom and its surroundings consisting of a few tens or hundreds of atoms and electrons. (The dynamical treatment is in terms of interrelated statistical distribution functions governed by coupled integro-differential kinetic equations derived from the Lioville equation;