Sea Snakes of the Gulf of Mannar Marine National Park. The Species and their Conservation

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Cover photographs

Front cover: The Wart snake *Acrochordus granulatus* is a non-venonomous marine snak that inhabits shallow seas of the Gulf of Mannar.

Back cover: The author handling a large Yellow sea snake (*Hydrophis spiralis*). This species is the longest recorded sea snake in the world.

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The Species and their Conservation

A Report

Submitted to

The Rufford Small Grants Foundation, UK

By

Aaron Savio Lobo

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Chapter 1

The Gulf of Mannar: A Marine Biodiversity hotspot

The Gulf of Mannar is located along the south-eastern coast of India. It is represented by the portion of the Indian Ocean along the southern coast of India which is partially enclosed to the north and west by the Indian state of Tamil Nadu. It has a 365 km long coastline extending from Rameswaram in the north to Kanyakumari in the south, which constitutes a part of four districts: Ramanathapuram, Tuticorin, Tirunelveli and Kanyakumari of Tamil Nadu. The Gulf of Mannar covers a total area of 10,500 sq. km in the Indian Ocean stretching across towards Sri Lanka.

The Gulf of Mannar Marine Biosphere Reserve (GOMBR) was set up on the 18th of February, 1989 as part of UNESCO's Man and Biosphere Reserve Programme (MAB), jointly by the Government of India and the state of Tamil Nadu. It is the first biosphere reserve as well as the first marine protected area in South and Southeast Asia (See Box-1). Given the richness of its biological wealth and its threatened status the area was chosen among six others for inclusion in an action program to secure India's protected areas for future generations.

Box. 1 Man and Biosphere Reserve Programme
(Source: http://www.unesco.org/mab/mabProg.shtml)

Man and Biosphere Reserve Programme (MAB) was launched in 1970 and initiated work in 14 Project areas covering different ecosystem types. The MAB governing body consists of 34 Member States elected by UNESCO's biennial General Conference.

The biosphere reserve concept was initially developed in 1974 and was substantially revised in 1995 with the adoption by the UNESCO General Conference of the Statutory Framework and the Seville Strategy for Biosphere Reserves. Today, there are 480 sites in over 100 countries. The World Network of Biosphere Reserves provides context-specific opportunities to combine scientific knowledge and governance modalities to:

- ☐ Reduce biodiversity loss
- ☐ Improve livelihoods
- ☐ Enhance social, economic and cultural conditions for environmental sustainability
- ☐ Contribute to the pursuit of the Millennium Development Goals, in particular those pertaining to environmental sustainability

The regions unique location in the sub-tropical region and the fact that it lies in a sheltered zone has allowed it to harbour several, different micro ecosystems. These include coral reefs, rocks, sea weeds, sea grasses, each with its own characteristic community structure and zonations. This is one of the few regions on the Indian mainland where crucial ecosystems - coral reefs, mangroves and sea-grasses occur in close association with each other. As a result of these unique features, the area supports a diverse spectrum of flora and fauna resources, of

taxonomic and economic importance. These include 128 species of corals, 641 species of crustaceans, 731 species of molluscs, 441 finfish, five species of sea turtles and several species of Cetaceans (Whales and Dolphins). The Gulf of Mannar, because of the good sea grass patches it supports is also one of the last remaining habitats for the highly elusive and endangered sea cow (*Dugong dugon*). Mortality due to incidental capture in fishing nets and killing for its meat has resulted in this species becoming extremely rare in the region.

In terms of its biodiversity the Gulf of Mannar is probably the richest marine protected area on the mainland Indian coastline

Study Area: The Gulf of Mannar Marine National Park

The study was conducted in trawlers that operated in the region of the Gulf of Mannar Marine National Park (GOMNP). The GOMNP forms the core area of the GOMBR and is located between latitude 08°47' to 09°15'N and longitude 78°12' to 79°14'E, i.e. the area from Rameswaram to Tuticorin and covers a total area of 560 sq. km. It received its national park status in 1986. The coastal plain of the GOMNP has been broadly categorized into four geomorphic units: marine, fluvio–marine, Aeolian and biogenic land forms, each of which are further classified into several sub-categories.

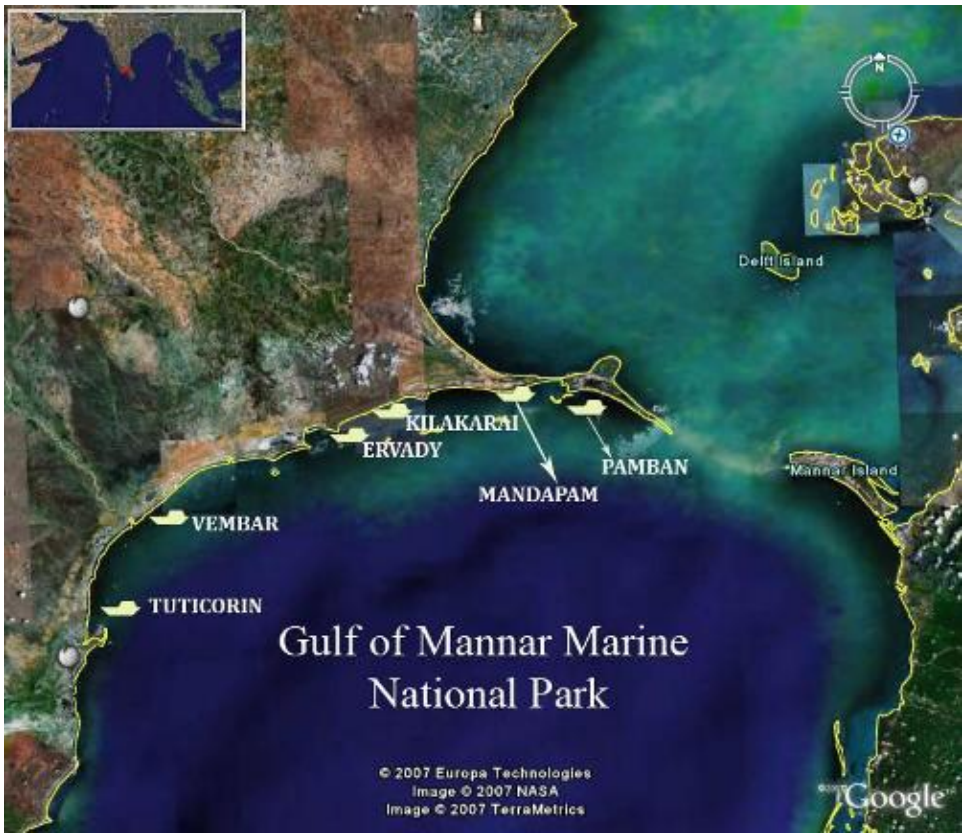
Constituting part of the GOMNP are a chain of 21 islands which form part of the Mannar Barrier Reef, which is 140 km long and 25 km wide between Pamban and Tuticorin. The depth beyond the chain of islands ranges from 3.5 to 15 m.

Trawl fishing operations in the Gulf of Mannar (Jayasankar et al. April 2000) The trawling grounds in the Gulf of Mannar lie between 79o and 79o25’ E Long and 8o46’ and 9o10’N Lat, about 2 – 26 km from the

coast. The sea bottom is largely muddy or sandy, though some areas have coral structures. Depth of operation ranges from 20 to 42 m.

Trawl fishing takes place round the year in the Gulf of Mannar. During June – September when the sea is rough due to the South west monsoons, trawlers operate during the day. During October to April about half the trawler units engage in night fishing, while the other half go for two nights and one day fishing. A fishing ban is enforced, through the entire state of Tamil Nadu, from 15th April to 1st June every year.

Map of the Gulf of Mannar Marine National Park depicting locations of the trawler bases along the coast.



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Outline of this report

The main body of this report is constituted in 4 chapters, viz. chapters 2, 3, and 5.

Chapter 2 provides a pioneer account to the sea snakes of the Gulf of Mannar Marine National Park. It provides a detailed description to

each of these species. A key has been provided to aid researchers and park managers for the easy identification of these species.

Chapter 3 is an account of the dietary specialization of the sea snakes found in this region. Several previously unrecorded prey families and species were documented during this study. The chapter also discusses the links between the foraging ecology and the vulnerability of sea snakes to shrimp trawling

Chapter 4 includes results of a survey for amphibious marine snakes (subfamilies: Homalopsinae and Laticaudinae) conducted on the islands of the Gulf of Mannar Marine National Park. Since the dog-faced water snake (*Cerberus rynchops*) was the only species encountered on some of the islands of the National Park, this chapter provides details of the status, ecology and threats faced by the species on the islands of the Marine National Park.

Chapter 5 is based on interviews and provides an insight of how fishermen handle and deal with venomous species such as sea snakes that are encountered on trawls. Most importantly this chapter underlines how fishermen view marine resources and the role of local knowledge in the management of these ecosystems.

Besides the 4 Chapters which constitute the main body of the report, I have also included 4 appendices which include additional crucial information and outcomes of this project.

Appendix 1 is a table that outlines important scale counts, which are among the most crucial taxonomic characteristics used in snake identification. This table also provides variations (if any) from the original descriptions.
Appendix 2 is a description of *Hydrophis caerulescens,* which constitutes the first record of this species in the Palk Bay and a geographical range extension of this species in general. Appendix 3 discusses the significant variation in colour between *Cerberus rynchops* found on the islands of the Gulf of Mannar and those encountered on the mainland. Finally Appendix 4 outlines the outreach in terms of public education that was carried out as part of this project.

Chapter 2

The Sea snakes of the Gulf of Mannar

Abstract

A survey for sea snakes encountered as trawler bycatch, in the Gulf of Mannar yielded nine species. Two additional species *Cerberus rynchops* and *Pelamis platurus* were also recorded; the former while surveying the islands of the marine national park and the latter beached ashore. Thus a total of 11 sea snakes were encountered, which represents nearly half (44%) the sea snake fauna documented in the waters of the Indian sub-continent. All these are first records of the sea snakes in the area. Here I present a key using morphological and scale counts and characteristics to aid in the field identification of these species.

Introduction

25 species of marine snakes belonging to three families and five sub-families have been documented from Indian waters (Das 2003). Of these, 20 are represented in the family Elapidae, of which 18 belong to sub-family Hydrophiinae (True sea snakes) and two belong to sub-family Laticaudinae (sea kraits); four species belong to the sub-family Homalopsinae under family Colubridae, and a single species *Acrochordus granulatus* is represented in the family Acrochordidae.

Sea snakes are common in coastal waters of India and are often encountered as bycatch in a number of fishing operations. However, most research on sea snakes in India was conducted in the colonial period (pre-1947) and primarily dealt with the taxonomy of this group (Smith 1926). Ironically, this still remains the most comprehensive piece of work on this group so far produced. Post colonial information available in India is based on opportunistic collections made from a few scattered localities along the coast (Ahmed 1975; Murthy 1977; Murthy and Rama Rao 1988; Kalaiarasan and Kanakasabai 1994; Venkateswarlu, Pattanayak et al. 1995).

The paucity of data has led to only 14 of the 25 species being assessed according to IUCN criteria (Molur, Nameer et al. 1998). Nine of these are placed in the Data Deficient Category, three in the Low Risk Category, one (*Fordonia leucobalia*) in the Vulnerable Category and one (*Homalopsis buccata*) in the Critically Endangered Category. However, considering that no systematic research was conducted on any of these species, even placement into these categories cannot be totally justified. It is thus clear that research on sea snakes is still in its preliminary phases. The need of the hour would be to get a clear idea of the distribution of the various species along the Indian coastline, before we can take up specific studies or blindly assign a conservation status to the species.

The Management plan of the Gulf of Mannar Marine National Park is an important document, which maintains details of species and habitats and lays out priorities for their conservation. However lack of research or even a basic survey on sea snakes has resulted in them not being included in the species lists of this document. Thus, though sea snakes are among apex predators in a marine ecosystem they lack the legal protection status they deserve.

The Gulf of Mannar is located along the Southeast coast of the country. The region, by virtue of its location and being in a sheltered zone harbours at least three important marine ecosystem types viz. coral reefs, mangroves and sea grasses and is known to support a high diversity of marine life, which probably ranks it among the most productive and bio diverse regions along the mainland coast of India. As a result of its unique biological heritage there has been a large body of marine biological research that has been conducted on several taxa in this area (Nammalwar and Joseph 2002).

The tropical waters of the Gulf of Mannar are located well within the distributional range of sea snakes (Voris 1977). However for various probable reasons viz. no commercial value, their venomous nature, difficulties in sampling have led to these creatures being under represented in the research conducted in this area. Thus, except for a few anecdotal notes e.g. see. (Mahadevan and Nagappan Nayar 1965) there exist no records or information on the sea snake fauna of this region. Here I provide the first taxonomic list along with detailed descriptions of the species that occur in the region of the Gulf of Mannar Marine National Park, which can also serve as an identification guide for park managers and researchers in this area.

Methods

Sea snakes were collected from shrimp trawlers that fish in the Gulf of Mannar and land their catches on the bases (Pamban, Mandapam, Ervady, Vembar) along the Gulf of Mannar Marine National Park from Dec 2004 – July 2005. Voucher specimens were deposited in the museum collections of the Bombay Natural History Society (BNHS).

In addition to collections made from trawlers, a systematic survey were carried out across 20 islands in the Gulf of Mannar Marine National Park for the amphibious species such as the Homalopsines and Laticaudines. Besides this, opportunistic collections were also made for specimens that were found cast ashore.

Results

Sampling from trawlers, island surveys and casual beach walks yielded a total of 11 species belonging to three families. All these represent new/first records of the sea snakes in this area. Sampling

from trawlers resulted in a total of 106 individuals which constituted 9 species belonging to two families Elapidae (sub-family-Hydrophiinae) and Acrochordidae. These were *Hydrophis cyanocinctus*, *Hydrophis* (*Microcephalophis*) *gracilis*, *Hydrophis fasciatus fasciatus*, *Hydrophis lapemoides*, *Hydrophis ornatus ornatus*, *Hydrophis spiralis*, *Lapemis curtus*, *Thallasophina viperina* belonging to the former and *Acrochordus granulatus* belonging to the latter. In addition, the Dog-faced water snake (*Cerberus rynchops*), belonging to family Colubridae (Sub-family: Homalopsinae) was encountered on at least seven islands of the Gulf of Mannar Marine National Park. Two live individuals of *Pelamis platurus* (Elapidae, subfamily: Hydrophiinae) were collected opportunistically that were washed ashore; one on the beach behind the Central Marine Fisheries Research Institute, Mandapam Camp and the other at Ervady.

Here I present a key for the field identification of the marine snakes that occur in the Gulf of Mannar Marine National Park, followed by a description of each of these. During this study, I have also observed that some of these sea snake species were encountered as trawler bycatch in the Palk Bay viz. *Acrochordus granulatus*, *Hydrophis cyanocinctus*, *Hydrophis* (*Microcephalophis*) *gracilis*, *Hydrophis spiralis*, *Thallasophina viperina*. In addition to these another species *Hydrophis caerulescens caerulescens* was encountered from the Palk Bay off Rameswaram. This species has also been included in the key in the likelihood of it occurring in the Gulf of Mannar. A description of this species has been included in Appendix 2. *Cerberus rynchops* has not been included in this key as this species was only encountered in shallow areas of islands and was not encountered as trawl bycatch.

A key to the identification of the marine snake species caught in shrimp trawlers in the Gulf of Mannar and Palk Bay

1. Tail laterally flattened into a paddle shaped structure. Body laterally compressed_____Hydrophiinae (True sea snakes)

2. Body is of thick girth and cylindrical with a tapering tail_____Go to 3

3. Scales on the head and body are granular. White rings encircle the body, which are broad on the ventral surface usually tapering dorsally. Ventrals, poorly developed_____ *Acrochordus granulatus*

4. Body generally stout and robustly built in proportion to it's length_____Go to 7

5. Body slender anteriorly, head is small to tiny and not distinct from the neck

_____Go to 8

6. Body elongated and of an almost uniform girth throughout. Head is medium to large and distinct from the neck_____Go to 9

7a. Presence of dark grey dorsal bars with narrow creamish white interspaces of fixed width and almost equidistant from each other. Body scales overlap_____*Hydrophis ornatus ornatus*

7b. Parietal scales are usually fragmented. Ventrals are difficult to Discern_____*Lapemis curtus*

8a. Head small and elongated, with a long rostral scale projecting over the lower jaw_____*Hydrophis* (*Microcephalophis*) *gracilis*

8b. Head is small and shiny black, body slender anteriorly, more than 410 ventrals_____*Hydrophis fasciatus fasciatus*

8c. Head small with a blunt, squarish snout_____*Hydrophis caerulescens*

9a. Interspaces between annuli/bands 2-4 times broader than bands. This character is more pronounced towards the posterior portion of the body_____*Hydrophis spiralis*

9b. Interspaces between annuli/bands are narrower than or about the same width as the bands_____*Hydrophis cyanocinctus*

9c. Body with blackish grey bands strongly dilated dorsally; tail with 3 to 5 bands and with a black tip. A prominent yellow horseshoe mark is present on the dorsal surface of the head_____*Hydrophis lapemoides*

10. Head elongated, unlike any other sea snake. Body usually black/ dark. On the dorsal portion and yellow on the ventral portion _____*Pelamis platurus*

11. Head triangular in shape and distinct from the neck. Ventrals are broad anteriorly and narrow posteriorly_____*Thalassophina viperina*

Description of the sea snakes species of the Gulf of Mannar

Family Elapidae

Sub-family: Hydrophiinae

Hydrophis cyanocinctus (Daudin, 1803) - **Annulated sea snake**

Voucher specimen numbers - (BNHS 3365,3366,3369)

Morphological characteristics: Head is moderate, body is elongate and not slender anteriorly with a gradual increase in girth posteriorly.

Colour in life: Body is olive/yellow with black annuli. Each annulus is usually broad dorsally, tapers slightly towards the flanks and again broadens ventrally. The black annuli are broader or as broad as the interspaces between them. The dorsal surface of the head in juveniles usually has a yellow horseshoe mark. Juveniles and younger individuals often have a black ventral stripe that runs through the entire length, which usually fades with age. The horseshoe mark on the head may or may not persist and is usually lost with age, the head attaining a uniform olivaceous or yellowish colour

Scale counts/characteristics: 27 to 35 scale rows on the neck, 37 to 4 scale rows around the thickest part of the body. 290 – 390 ventrals, are distinct throughout.

Maxillary teeth behind poison fangs: 5 or 6

Hydrophis spiralis (Shaw, 1802) - **Yellow sea snake**

Voucher specimen numbers - (BNHS 3363, 3367, 3368)

Morphological characteristics: Very similar to *Hydrophis cyanocinctus* in form

Colour in life: Head dorsum is usually a golden yellow, occasionally with sporadic faded black speckling. Body is yellow with 41 to 46 narrow black annuli encircling the entire body. There are wide yellow interspaces between the annuli. This character is more pronounced towards the posterior portion of the body. This can be used as one of the key characters to separate this species from *H. cyanocinctus*. Similar to *H. cyanocinctus*, the annuli broaden dorsally and again ventrally and are narrow in the flank region.

Scale counts/ characteristics: 25 to 31 scale rows on the neck, 33 to 3 scale rows around the thickest part of the body. 295 – 362 ventrals, are distinct throughout.

Maxillary teeth behind poison fangs – 6 to 7.

Hydrophis ornatus ornatus (Gray, 1842) - **Ornate sea snake**

Voucher specimen number - (BNHS 3359)

Morphological characteristics: Head is large. Body is robust and not markedly elongate

Colour in life: Head dorsum is olive green to grey. Body pale brown/ olivaceous on the dorsum with dark broad brown dorsal bands. A key character of this species are the narrow creamish-white interspaces between the dorsal bands which are usually of a fixed width, and are almost equidistant from each other. The dark dorsum extends halfway down the flanks where it meets a creamish white venter at a clear line of demarcation.

Scale counts/characteristics: Sexual dimorphism exists in scale counts with females having consistently higher counts than males. The differences are indicated in the table below.

	Neck	**Mid-body**	**Ventrals**
Male	28-37	33-45	209-260
Female	31-45	39-55	236-312

Maxillary teeth behind poison fangs – 10 to 13

Hydrophis gracilis (Shaw, 1802) - **Common small-headed sea snake**

Voucher specimen number - (BNHS 3364)

Description: Small elongated head, followed by a narrow neck about the same diameter as the head anteriorly. The body gradually thickens, the posterior region being three to four times thicker than the neck anteriorly. The snout projects well above the lower jaw and has an elongated rostral scale.

Colour in life: In juveniles up to ¼ th of the anterior portion of the body (head, neck and considerable portion after that) is a shiny black. Colour fades with age, the black transforming to a bluish grey. Adults possess 40 – 60 bluish grey/black annuli, with white interspaces between them

Scale counts/ characteristics: 17 to 21 scale rows around the neck; 30 to 36 scale rows around the body; 220 to 287 ventrals. Ventrals are entire on the slender portion of the body and completely divided in the posterior region by a median longitudinal fissure, the two halves being opposed to each other or alternating. In large individuals belly scales have backwardly directed spine like scutes.

Maxillary teeth behind poison fangs – 5 or 6

Hydrophis lapemoides (Gray, 1849) - **Persian Gulf sea snake**

Voucher specimen numbers - (BNHS 3357, 3358)

Description: Head is of moderate size. The body is of an almost uniform girth throughout and is slightly robust. The flat tail appears to have a significantly greater height than the posterior portion of the body and has rounded edges.

Colour in life: The dorsal surface of the head has a dark triangle mark with rounded edges that occupies most of the head. This leads to the formation of a cream-yellow horse shoe shaped marked, the close end of the horseshoe being directed towards the snout region. In old individuals this mark may be faded and at times totally absent. Body is usually cream in colour and in some cases is yellowish–orange on the dorsal surface, with black annuli. These annuli are strongly dilated on the dorsal surface and appear as rhomboidal spots when observed from above. The annuli sometimes fade with age in the flank region and are retained only as rhomboidal spots on the dorsal surface. The tail has faded black bands which may disappear with age and the tip is black.

Scale counts/characteristics: 28 to 35 scale rows around the neck; 40 to 57 scale rows around the body is; 288 to 395 ventrals. The posterior rows of scales round the body are hexagonal/quadrilateral in shape. Sexual dimorphism in scalation exists, with adult females possessing scales with a feeble tubercle or short central keel; while adult males possess a strong spinose tubercle. This gives males an extremely rough texture.

Maxillary teeth behind poison fangs – Eight to 13

Hydrophis fasciatus fasciatus (Schneider, 1799) - **Banded sea snake**

Voucher specimen number - (BNHS 3360)

Description: Head is very small (as in *Hydrophis gracilis*), however it's snout is blunt. Neck is narrow, about the same diameter as the head and greatly elongated. The girth of the body increases greatly towards the posterior end and could be as much as three times that of the neck.

Colour in life: Head is of a shiny black colour. Black annuli occur only in the neck region (i.e. they encircle the body in this region). When viewed from above the annuli appear as black rhomboidal spots. In large individuals, these black annuli are not continuous on the flank and the ventral region and remained restricted as black rhomboidal spots on the dorsal surface. The interspaces are orangish-yellow in colour on the dorsal surface and cream on the flank region.

Scale counts/ characteristics: 28 to 33 scale rows around the neck; 47 to 58 scale rows around the body; 414 to 514 ventrals, which are distinct throughout.

Maxillary teeth behind the poison fangs – Five or Six

Thalassophina viperina (Schmidt, 1852) - **Viperine sea snake**

Voucher specimen number – (BNHS 3362)

Description: Head is triangular in shape and distinct from the neck. Body is compressed laterally. In large individuals there is the presence of a distinct vertebral ridge.

Colour in life: Two of the three forms mentioned in Smith 1943 were found in the Gulf of Mannar.
Type I – Dark green above, white below, the two colours meeting on the flank in a fairly clear line of demarcation.
Type II – Dorsum with grey rhomboidal spots connecting from end to end and running through the entire length of the body.

Scale counts/ characteristics: 27 to 34 scale rows around the neck; 37 to 50 scale rows around the body; 226 to 274 ventrals. Another key character are the ventrals, which are broad anteriorly and narrow posteriorly.

Maxillary teeth behind the poison fangs - 5

Lapemis curtus (Shaw, 1802) – **Short/ Shaw's sea snake**

Voucher specimen number – BNHS 3356

Description: Head is large, body short and robustly built in comparison to most other sea snake species.

Colour in life: Individuals are yellow to olive green in colour with black dorsal bands, tapering towards the flanks and in some cases encircling as annuli and confluent along the vertebral line. The yellow is pronounced in young individuals and usually changes to olive green with age.

Scale counts/ characteristics: 23 to 35 scale rows around the neck; 25 to 43 scale rows around the body; 114 to 230 ventrals, which are not distinct throughout. Large individuals have spiny scutes on their ventral scales belly scales

Maxillary teeth behind the poison fangs – 3 to 6

Pelamis platurus (Linnaeus, 1766) – **Yellow belly sea snake**

Description: A distinct species that is difficult to mistake with any other. This species has an elongated narrow, and a slightly dorso-ventrally compressed head that is unlike that of any other sea snake.

Colour in life: This snake is black or dark brown above and bright yellow below.

Scale counts/ characteristics: 49 to 67 scale rows around the body; 264 to 406 ventrals are broken up or identical to the adjacent scales.

Maxillary teeth behind the poison fangs – 7 to 11.

Family: Acrochordidae

Acrochordus granulatus (Schneider, 1799) - **Western wart snake**

Voucher specimen number – (BNHS 3371)

Morphological characteristics: The head is moderate in size with a roughly squarish snout and indistinct from the neck. The eyes are small with a vertical elliptical pupil. The snake has round nostrils which are situated close together and are directed upwards. Females of the same snout–vent length have larger heads than males.

The body is stout, cylindrical in shape and with loose skin and covered by many granular scales. Back scales are about twice the size of those on the flanks. There exists a fold of skin that runs on the ventral side along the entire length of the body that enables the snake to swim efficiently. Unlike true sea snakes the tail of this species tapers towards the tip and is slightly compressed.

Colour in life: Head is black/ dark grey, with/without sporadic white speckling. The body consists of alternating white and black or dark-brown bands, which are broader on the back, narrower towards the sides and may extend across the belly.

Differences between *Acrochordus granulatus* and the True se snakes.
The body in case of the true sea snakes are usually covered by smooth scales, however in *A. granulatus* the scales are granular, giving it a rough/ file like texture. True sea snake have flattened, oar shaped tails. In *A. granulatus* the tail tapers and is only slightly compressed.

Discussion

From the Indian context it is evident that the Gulf of Mannar supports a high diversity of sea snakes, representing 44% of the marine snake fauna and 50% of the Hydrophiine (true sea snake fauna) in India. This area for its size is thus rich in terms of its sea snake fauna which is unlike any other parts of the country from where sea snakes have been recorded. The high diversity of sea snakes in this area could be possibly attributed to the complexity of habitats this area supports viz. coral reefs, seagrass beds and mangroves, each of these with their own characteristic microenvironment and species assemblages. Moreover, the fact that this area is Marine Protected Area and that as per legislation anthropogenic activities are controlled and commercial fishing operations such as shrimp trawling are prohibited furthers its importance as an important custodian for the sea snakes of the region.

The absence of *Enhydrina schistosa* in this region was quite surprising, considering this species among the most common along the Indian coastline and often encountered in fishing operations (Daniel 2002) and is often among the dominant species in most of its distributional range. This species is however known to inhabit near shore areas in close proximity with rivers and estuaries (Voris, Voris et al. 1978). The absence of any major estuaries flowing into the Gulf of Mannar Marine National Park could possibly explain its absence. The likely occurrence of *Hydrophis biturberculatus* from this region is plausible, considering the type locality of this species is Colombo, Western Srilanka. However, since the collection of the holotype in 1870, no more specimens of this species have been collected from this region and was only much later rediscovered from Phuket in Thailand (Rasmussen 1992). It is likely that further intensive surveys in the regions Gulf of Mannar, Palk Bay and possibly in the seas surrounding Sri Lanka might lead to the rediscovery of this species in the area.

The sea snake community in the Gulf of Mannar is a diverse one, even in terms of the kinds of niches they occupy. Sea snakes are among predators and play a key trophic role in near-shore marine ecosystems (Voris 1972). Most species that occur in this area, specialize on particular fish families or on species with a particular body shape. Some, especially those specializing on burrowing eels may be among the only predators specializing on these groups (see Chapter 3). Many of the eels (morays and congers) themselves are predators and in turn help keep check on several fish species they prey upon. Incidental capture and consequential removal of predators such as sea snakes by commercial fishing operations, could have far reaching consequences on the functioning of marine ecosystems. These effects have clearly been documented in other parts of the world, with other species of apex predators such as sharks, where their removal has been known to affect the health of the ecosystem, and cause cascading effects down

the food marine food chain (Agardy 2000). The inclusion of sea snakes in important documents such as the management plan of the GOMNP could be the first step to conserving these species. In addition, using certain large species such as *Hydrophis spiralis* as 'Flagship species' could further their cause for conservation, besides aiding the protection of other species in the area. Protecting important habitats such as coral reefs, sea grass beds and soft bottom environments for e.g. by enforcing no fishing zones can greatly help the conservation of sea snakes and several other species that are highly dependent on these areas.

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Photographic guide to the Sea snake species of the Gulf of Mannar

Hydrophis cyanocinctus

Hydrophis spiralis

A. **B.**

A comparison of head scalation in two morphologically similar species A. *H. cyanocinctus* and B. *H. Spiralis*

Hydrophis ornatus

Hydrophis lapemoides

Hydrophis gracilis

Hydrophis fasciatus

A. **B.**

A comparison of the head shape of two microcephalophic species of sea snakes A. *H. gracilis* and B. *H. Fasciatus*

Thallasophina viperina

Lapemis curtus

Acrochordus granulatus

Pelamis platurus

A.

B.

Distinctive Heads: Square snout, small granular head scales in A. *Acrochordus granulatus*, elongated head in B. *Pelamis platurus*

Chapter 3

Trophic ecology of sea snakes in the Gulf of Mannar Marine National Park.

Abstract

Diet data is presented for seven species of sea snakes that were incidentally caught in shrimp trawlers in the Gulf of Mannar Marine National Park. Data from this study reveals that all of them fed on benthic fish families, with as many as five of them solely specializing on them. Past research reveals that the remaining species viz. *Lapemis curtus* and *Hydrophis ornatus* (occasionally) and *Pelamis platurus* (predominantly) fed on pelagic fish families. Eels constituted the diet of at least three species (*Hydrophis spiralis*, *Hydrophis cyanocinctus* and *Hydrophis gracilis*) and the sole prey items of *Hydrophis gracilis*. The remaining two species *Acrochordus granulates* and *Thallasophina viperina* were found to specialize on goby like fish, with *T. Viperina* solely feeding on species belonging to the family Platycephalidae. The sea snake assemblage, except for *P. platurus* in this region predominantly fed on benthic fish families and thus classified as benthic foragers. There is thus a high likelihood that the habitats these species forage in frequently overlap with trawl fishing grounds, making them particularly vulnerable to these fishing operations.

Introduction

It has been well documented that sea snakes are primarily piscivorous. Several studies have documented the specific fish taxa eaten by marine snakes (Voris 1972, McCosker 1975, Voris et al. 1978, Glodek and Voris 1982, Lobo et al. 2005). Most species have been found to specialize on particular fish families or prey with unique morphological characteristics to suit their dietary requirements (McCosker 1975, Glodek and Voris 1982). Some examples of dietary specialists include *Laticauda colubrina* and *Hydrophis gracilis* preying exclusively on eels, *Enhydrina schistosa* on catfish, *Aipysurus eydouxi*, *Emydocephalus annulatus* and *Emydocephalus ijimae* exclusively on fish eggs (Heatwole 1999). There are however some species eg. *Lapemis curtus* which are generalists and feed on a large number of fish families and occasionally also on marine organisms, such as cephalopods (Glodek and Voris 1982, Lobo et al. 2005).

Studies on the diet of sea snakes occurring in the Indian waters are restricted to a few anecdotal records for eg see (Wall 1918) and make no attempt to discuss their foraging ecology or the role they fulfil in the marine food chain. A single detailed study on the food habits of sea snakes was conducted along the small coastal state of Goa but remained restricted to the diet of a single generalist species (Lobo 2005).

Information on food habits should be considered vital as it can give us important insights into the foraging ecology of the species and will also greatly facilitate in understanding the trophic role of these predators in near shore tropical marine ecosystems. Since sea snakes largely inhabit areas they forage in (Heatwole 1999) their food habits would also give us insights into the habitats they would occupy thereby giving us a better understanding of their specific ecological niche in marine ecosystems for eg. see (Voris et al. 1978, Shetty and Shine 2002). Taking into account various facets of species ecology is vital in the development of an effective strategy for their conservation.

The Gulf of Mannar hosts an assemblage of at least 11 species, (9 belonging to the family Hydrophiinae (True sea snakes), one belonging to the family Acrochordidae and one to the family Colubridae). However, only the species that were encountered as trawler bycatch (9 Hydrophiines and 1 Acrochordid) were used in this analysis.

Methods

The sea snakes obtained from trawlers operating from designated fishing sites (see map, Chapter 1) were dissected and their gut contents examined. The following data was recorded for every snake dissected; (I) presence or absence of food in the crop. (II) Prey condition was ranked as 1, 2 and 3, to estimate feeding time in the snakes. A rank of 1 if the prey is intact, 2 if partially digested and 3 if the prey was in the form of an unidentifiable mass of tissue. If prey was intact or partially digested it was preserved in 10% formalin for its identification (III) Since sea snakes primarily feed on fish, prey identification was carried out up to family level and wherever possible up to species level using published keys (Fischer and Bianchi 1984). This was further confirmed by comparing these prey specimens with museum specimens (CMFRI museum, Mandapam Camp). (IV) Measurements of the intact prey items (total length, greatest width (girth) and height) were taken using a Vernier caliper (Mitutoyo TM). In case of partially digested prey, prey length was estimated by comparing with intact specimens collected from trawls as well and preserved museum specimens (V) Feeding direction, the position of prey within the crop was recorded to know whether the fish was ingested head first or tail first. (V) Every diet item was categorized either into commercial or non commercially important species.

Results

A total of 87 sea snakes, which included seven species were dissected to examine their gut contents. Food was present 38 times (46%) and was absent in the remaining 49 (56%) of the time. Table 1 indicates the frequency of food present/ absent in the different species.

Table 1 – Frequency of the presence/absence of food in the sea snakes dissected

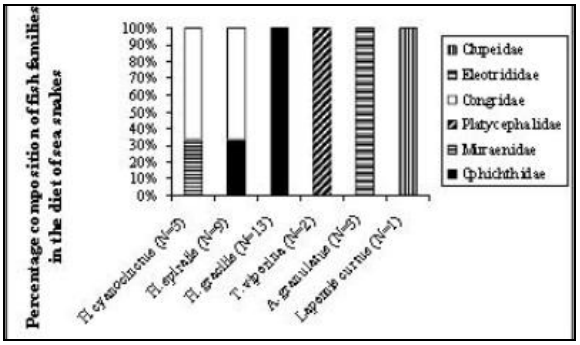
Species	Food absent	Food present	No. dissected
Hydrophis cyanocinctus	12	4	16
Hydrophis spiralis	12	10	22
Hydrophis gracilis	13	14	27
Hydrophis ornatus	5	2	7
Thallasophina viperina	1	2	3
Acrochordus granulatus	4	5	9
Lapemis curtus	2	1	3
Total	49	38	87

Sea snakes Diet

In 79% (30) of the snakes that the food was present, the prey could be identified up to family level. In the remaining cases, it was in the form of a digested mass and thus unidentifiable.

Eels constituted the sole prey items of at least three sea snake species (viz. *H. cyanocinctus*, *H. spiralis* and *H. gracilis*). Of the three prey items that were identified from *Hydrophis cyanocinctus,* two belonged to family Congridae (Conger eels) and one to Muraenidae (Moray eels), which was identified as *Gymnothorax ruepelliae* (Ruppell's moray eel). In *Hydrophis spiralis*, prey could be identified to family level on nine occasions, six of which belonged to family Congridae and three to family Ophichthidae. One of the eels belonging to family Congridae was identified as *Uroconger lepturus*. In *Thallasophina viperina* both the prey identified belonged to family Platcephalidae and in both the species was *Rogadius pristiger*. All three prey items obtained from *Acrochordus granulatus* belonged to the family Eleotrididae. The single dissected individual of *Lapemis curtus* contained a single prey item belonging to the family Clupeidae. In *H. gracilis*, all 13 identifiable prey belonged to the family Ophichthidae Ophichthidae. Fig. 1 indicates the prey composition of the sea snake species that occur in the Gulf of Mannar.

Fig. 1 - Percentage composition of fish families in the diet of sea snakes.



A larger sample of prey items in *H. gracilis* permitted a more detailed analysis of its eel prey. The SVL of the snakes dissected varied from 676 in the smallest snake to 869mm in the largest snake. They were thus all classified as adults (following Heatwole 1999). Moreover *H. gracilis* was the only species in the assemblage of sea snakes found in the region that fed on multiple prey items. Multiple prey items were obtained from four individuals (three prey items were present in one individual and two in three individuals). However, the presence of more than one prey was not influenced by the size of the snake. This species fed on eels of an average length of 263.34 and average girth of 4.67. There however, did not appear to be any relationship between snake SVL and GW with eel length (PL) and width (PW) respectively (Fig 2 & 3). Even though data suggests a weak relationship between snake (*H. gracilis*) length and prey length, it is difficult to draw any conclusions owing to the fact that no diet data is available for juveniles.

Fig. 2 - Relationship between SVL in *Hydrophis gracilis* with eel length

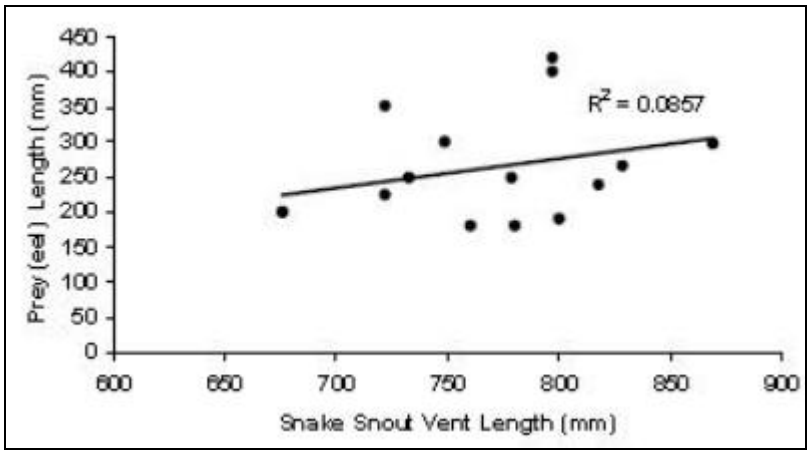
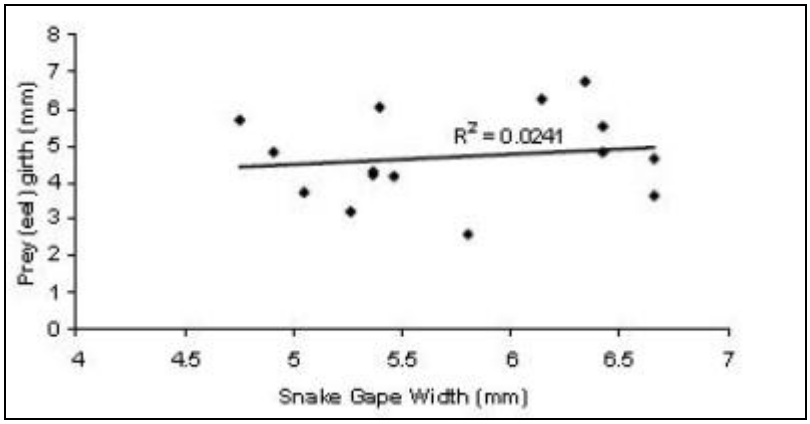


Fig. 3 – Relationship between Gape width in *Hydrophis gracilis* with eel Girth



Discussion

Diet data of sea snake species occurring in the Gulf of Mannar demonstrates that the majority (9) of these species are benthic foragers. This conclusion has been based on the results obtained during this study, however include the remaining two species viz. *H. fasciatus fasciatus* and *H. lapemoides,* which were encountered in the Gulf of Mannar, but for which dietary analysis wasn't possible due to the lack of sample (Klawe 1964, Glodek and Voris 1982, Rasmussen 1993)). Past and present data demonstrate that the remaining two species *L. curtus* and *H. ornatus ornatus* were generalists in their diet and though they fed on a large number of pelagic fish families also included several benthic species in their diet (Glodek and Voris 1982, Lobo et al. 2005).
P. platurus was the only species that occurred in this region that exclusively fed on pelagic fish (Klawe 1964). The dietary preference of benthic fish families in the majority of the sea snake species in this area would imply that they spend a considerable time foraging on the sea benthos. These peculiar life history characteristics and habitat preferences would make them particularly vulnerable to fishing operations such as shrimp trawling. This has been demonstrated in Australia where sea snake catches were several times higher in shrimp trawlers, where the nets were towed along the sea floor (Ward 1996) as compared to fish trawlers where the nets were towed mid-water (Ward 1996). This is also a probable explanation as to why the pelagic species, *P. platurus* was excluded from trawl catches in the Gulf of Mannar.

The finding that *H. cyanocinctus* and *H. spiralis* are predominantly eel eaters largely conforms with previous findings (Voris 1972, Voris et al. 1978). The fish family Gobiidae that was a previously documented diet item from *H. cyanocinctus* was not encountered during this study. However the Banded moray eel *Gymnothorax ruepelliae* (Muraenidae) and the slender conger eel *Uroconger lepturus* (Congridae) constitute the first record of these eel families and species in the diet of *H. cyanocinctus* and *H. spiralis* respectively. The absence of Gobiidae in their diet could possibly be attributed to small number of snake samples that were dissected.

The findings largely conform with previous findings and that *H. Gracilis* exclusively fed on Anguilliform eels belonging to the family Ophichthidae. Eels (Snake and worm eels) belonging to the family Ophicthidae are usually long and of a narrow girth. These eels spend most of their time in deep burrows on the sea floor and usually remain partially exposed i.e. with their head sticking out (Nelson 1994). Field observations made on *H. Gracilis* demonstrated that this species actively forage on the sea bottom by probing burrows with its narrow head and its long and narrow neck in search of their eel prey (MacLeish 1972, Heatwole 1975). This type of foraging also known as

crevice foraging, is probably the most common foraging method (Heatwole 1999), and has been documented in file snakes (Voris and Glodek 1980), sea kraits and several other species of Hydrophiines.

Even though prey sample sizes were low for *A. granulatus* and *T. viperina*, the present study reinforces the fact that both these species specialize on gobylike benthic fish prey and belong to the broad category of crevice foragers.

Findings of this as well as past studies have revealed that *T. viperina* largely fed on fish species belonging to the family Platycephalidae. Members of this fish family are benthic forms and often conceal themselves by burying just below the bottom substrate (Nelson 1994). This could possibly suggest *T. viperina* uses olfactory and tactile stimuli to locate its concealed prey. This also conforms to the fact that odour plays an important role in the location and identification of prey (Heatwole 1999).

Though diet data for *L. curtus* during this study was only restricted to a single individual, past research on this species from several parts of the world has documented it to be a generalist in its food habits (Glodek and Voris 1982, Lobo et al. 2005) This could also explain the reason for its wide spread distribution, and it's presence as a dominant species in several areas where other specialist Hydrophiine species may be absent (Gritis and Voris 1990).

None of the fish/eel prey of the sea snakes in the Gulf of Mannar were commercially exploited. Families Muraenidae (morays), Congridae (congers) and Eleotridae (gudgeons) though occasionally caught by shrimp trawlers are of no commercial importance though they are often represented in the bycatch of this fishery. The family Ophichthidae is rarely caught in trawl operations and is also of no commercial value. Only large individuals of Platycephalidae (Spiny flatheads) are occasionally consumed though of little commercial value.

It can be concluded that the sea snake assemblage that occurred in this area primarily preyed on species which were predominantly sedentary, benthic, burrowing or crevice/ dwelling and based on their foraging strategy, these species have been classified as crevice foragers (Heatwole 1999). This also happens to be the broad category to which majority of the sea snake species belong. Besides crevice foraging, there are other foraging strategies employed by sea snakes. These include "Cruising near bottom" seen in sea snakes such as *Enhydrina schistosa* (Voris et al. 1978)and some of species such as *Emydocephalus annulatus* that prey on fish eggs (Voris 1966).

This study besides giving us an important insight into the trophic ecology of sea snakes in marine ecosystems has important conservation implications. Considering that majority of the species found in this region are benthic foragers, the areas they forage are also likely to be areas heavily fished by trawlers. This coupled with other possible threats faced by these species such as pollution and an array of life history characteristics (Heatwole 1999) make species such as these particularly vulnerable to overexploitation.

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Chapter 4

The Dog-faced water snake (*Cerberus rynchops*) of the islands of the Gulf of Mannar Marine National Park

Abstract

A survey was conducted for amphibious marine snakes (belonging to sub-families Laticaudinae and Homalopsinae) on 20 islands of the Gulf of Mannar Marine National Park. *Cerberus rynchops* was the only species encountered on at least seven of these islands. The occurrence of this species was strongly influenced by the presence of good mangrove habitats. Especially high numbers were encountered on the northern sides of the Manoli and Hare islands. Highest snake abundances were encountered along the shorelines, shallow bays or narrow water channels. Tides seemed to have an influence on the activity, with higher abundances being encountered at low tide. Threats to this species in this area appears to be the illegal gill net fishing that takes place in the areas surrounding the islands and the loss of mangrove habitat and the colonization by an invasive weed *Prosopis juliflora*.

Introduction

There are four separate lineages of snakes that have evolved independently to live in a marine ecosystem (Heatwole 1999). Representatives of two of these (Hydrophiinae and Acrochordidae) are exclusively marine and never come onto land (Heatwole 1999). However the remaining two viz. Laticaudine sea snakes (sea kraits) and the Homalopsine colubrid snakes, represent an intermediate/ amphibious state, and are able to come onto land for various purposes.

Sea kraits unlike other marine snakes retain their oviparous mode of reproduction and come ashore to lay their eggs, besides performing several other life's activities (mating, moulting and digestion of prey) on land (Greer 1997). Marine homalopsines generally occur in shallow areas of estuaries and near shore ecosystems, though unlike sea kraits, homalopsines are ovoviviparous and give birth to live young. They often venture onto land to forage for their occasional terrestrial prey which may include species such as crustaceans, frogs and mud skippers (Voris and Murphy 2002).

Two species of sea kraits (*Laticauda colubrina* and *Laticauda laticaudata*) have been recorded from the Andaman and Nicobar islands and few near shore islands off the Indian mainland (Smith 1943, Bhaskar 1996). There are four species of marine homalopsines that occur in brackish and marine ecosystems in the country viz. *Cerberus rynchops*, *Gerarda prevostiana*, *Cantoria violacea*, *Fordonia leucobalia* and *Homalopsis buccata* (Das 2003).

The Gulf of Mannar Marine National Park includes a chain of 20 islands with area varying from 0.95 to 130 ha along the 140km stretch between Tuticorin and Rameswaram (Lat 8o55′ – 9o15′N and Long 78o0′ – 79o16′ E).

The GOMNP is regarded among the most significant marine biodiverse regions in India; as a result of which the region has attracted a large quantum of research on various aspects of the marine biodiversity. This is especially true with respect to the islands of the National Park which for various reasons such as their accessibility have led to surveys and research being conducted on various floral and faunal taxa. However marine snakes even though a relatively conspicuous group, fail to find a mention in the literature or the species checklists for these islands. The islands of the national park were thus surveyed for these two main groups of snakes.

Methods

Each of the islands was surveyed twice for snakes between April to June 2005. These months coincided with the closed fishing season, where no trawl fishing took place and thereby collection of sea snake bycatch from trawlers was not possible. All islands are considerably small and thus each survey was conducted on foot along the periphery of the entire island using two additional assistants. Small water channels from the sea inwards, were also scanned for snakes. Location, habitat at which snakes were encountered was recorded.

Two islands Manoli and Hare were found to support the highest abundances of the Dog-faced water snake *Cerberus rynchops.* These were returned to at a later stage where intensive sampling was carried

out to document the habitat preference and other ecological aspects of the species on these islands.

Initially sampling the shoreline was conducted at all tidal stages and at three times of the day – sunrise, noon and at night. Individuals of *C. rynchops* were found to be most active immediately after sunset to about two hours after that. Thus sampling was restricted from 1900 – 2300. Whenever a Dog-faced watersnake was encountered, the following data was recorded: time of capture, habitat, tidal stage, water depth and distance to water (if on land) in cms. The specific activity, the snake was engaged in at the time of capture was also recorded. After recording the necessary data, the snake was captured and placed in a bag with a labelled tag. Snakes found in pairs were placed together in a single bag.

All snakes encountered in the study area were hand caught and marked by the sub-caudal scale clipping technique (following Blanchard and Finster, 1933) and released after the necessary data was collected. Voucher specimens of this species encountered were preserved using standard protocol (Simmons, 1987). The following morphometric data was recorded for every snake collected: Snout Vent Length (SVL) and TL (Tail length) to nearest 0.1 cm with a steel Freeman tape, Head width (HW) and Head Length (HL) to the nearest 0.01 cm with a vernier calliper (Mitutoyo TM), Mass (Wt) to the nearest gm using a PesolaTM scale. Sex was determined by the presence/absence of hemipenis, wherein snakes were gently pressed posterior to the cloaca in order to evert the hemipenis in males.

Various threats faced by the islands in general and to the dog-faced water snake (*Cerberus rynchops*) in particular were recorded during this study.

Results

The only species encountered on some of the islands of the GOMNP was the Dog-faced water snake (*Cerberus rynchops*). This species was recorded on seven of the 20 islands surveyed. Table. 1 summarizes the presence/absence of this species on the different islands. A single dead specimen of the Wart snake *Acrochordus granulatus* was recorded on the northern beach of Hare island. However the species was never encountered in subsequent surveys. It is likely that this individual was caught as bycatch in some fishing operation and drifted ashore.

Table. 1. Presence/Absence status of the Dog-faced water snake (*Cerberus rynchops*) on the various islands of the Gulf of Mannar Marine National Park.

Island group	Island name	Circumference (km)	Area (Ha)	Presence(+)/ Absence(-) status
Mandapam	**Shingle**	1.736	12.69	-
	Krusadai	5.193	65.80	+
	Pullivasal	5.520	29.95	+
	Poomarichan	2.5	16.58	+
	Manoli putti	0.94	2.34	+
	Manoli	2.958	25.9	+
	Hare	11.52	129.04	+
Keelakarai	**Mulli**	1.712	10.2	-
	Valai	1.889	10.15	-
	Talairi	8.338	75.15	-
	Poovarasanpatti	0.161	0.25	-
	Appa	4.84	28.63	-
	Valimunai	1.17	6.72	-
	Anaipar	1.6	11	-
Vembar	**Nallathanni**	4.7	110	+
	Pulvinichanni	1.37	6.12	-
	Upputhanni	2.292	29.94	-
Tuticorin	**Villanguchalli**	0.614	0.95	-
	Karaichalli	1.610	16.46	-
	Kasuwar	2.16	19.5	-
	Van Tivu	2.05	16	-

Description of Cerberus rynchops found on the islands of the GOMNP

Voucher specimen deposition # BNHS 3370

External morphology: Snout is elongate and rounded at the tip; it broadens gradually to the base of the head. Nostril is connected by a suture to the first labial. Snakes reach a moderate length with females growing larger and heavier than the males. In this region the average SVL and Mass were 623.16mm and 237gms in females (N=12) and 568mm and 152gm in males (N= 14).

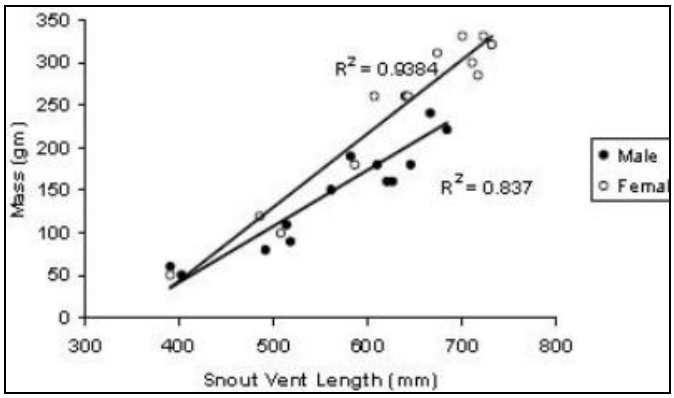
Neonate snakes up to a SVL of 400mm were of similar weight. Sexing based on external morphological characteristics is usually possible for individuals with a SVL of 400mm or longer. There is an allometric increase of mass with SVL. However beyond 400mm, there develops a divergence in the weight between sexes, and females begin outweighing males of the same SVL (Fig. 1a). Females were ultimately found to grow longer and heavier than males.
However males had longer tails in proportion to their body length than females (Fig. 1b). Another interesting and sexually dimorphic morphometric trait is the Gape Width. The average Gape width in females is larger than in males and this is true even for males and females with a similar SVL (Fig. 1c).

Scalation: Scales are imbricate, strongly keeled and vary from 23-25 rows around the body. Internasal scale is divided by a longitudinal suture. The frontal scale is broken into small scales, the anterior half usually being distinct. Loreal large, higher than long extending well onto the upper surface of the snout, in contact with, or just separated from, the internasal; 1 pre, 1 post and 2 suboculars. Temporals scales are small. There is the presence of 9 -10 supralabials, 5th and 6th below the eye, the last 2 or 3 horizontally divided; 3 pairs of genials, anterior largest in contact with 4 infralabials; the remaining pairs separated by small scales.

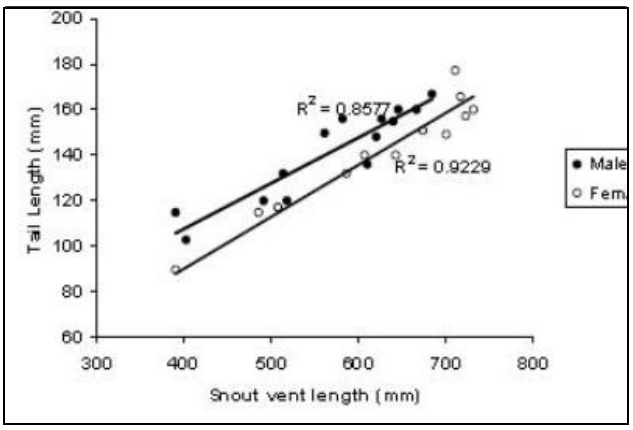
Coloration: In coloration, individuals found on these islands differed markedly from their mainland conspecifics in several ways (Appendix 3).

Figure. 1 – Allometric relationship between SVL and a) Mass, b)TL and c) GW

a



b



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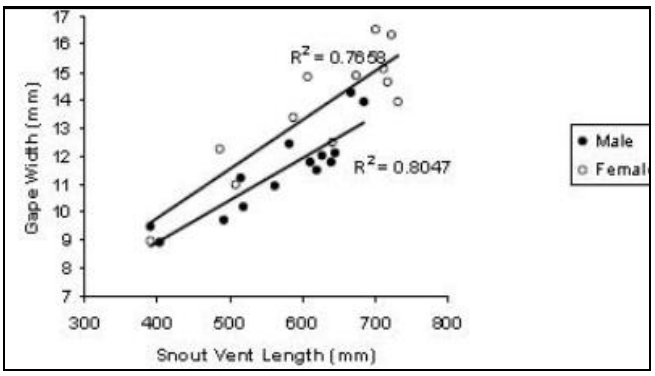


Habitat Preference of C. rynchops

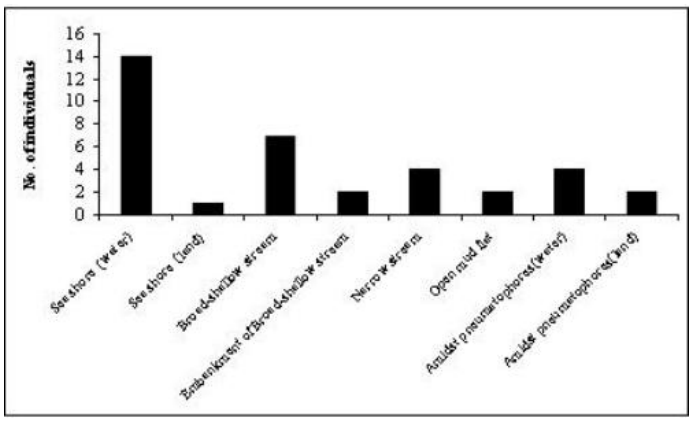
The majority, 29 snakes (80.56%) were encountered in water, while the remaining 7 snakes (19.44%) were encountered on land. Of the snakes encountered in water, 24 snakes (83%) were encountered in water of depth of half a foot or less, while the remaining six were encountered in waters of one foot or less.

Of the seven snakes that were encountered on land all except one were found at a distance of one foot or less from the water's edge. The habitat where the highest number of snakes, 14 (39%) were encountered was along the shoreline in the shallow water, this was followed by 7 snakes (19%) that were encountered in broad shallow streams. Six individuals were encountered on embankments that were in close vicinity of mangroves and amidst pneumatophores and four in a narrow stream adjoining these mangrove areas. Fig. 2. depicts the number of snakes that were encountered in different habitats.

Influence of the tide on the activity of C. rynchops

Even though sampling was conducted across all (high, intermediate and low) tidal stages, 64% of the snakes were encountered at a low tide and the remaining 36% were encountered at an intermediate tide.

Fig. 2. Relative number of individuals encountered in different habitats



Threats faced by the Dog-faced water snake

Illegal fishing - The only direct threat faced by the dog-faced water snake in the region is the illegal fishing using gill nets that happens in the region surrounding the islands. The snakes when trapped in these nets entangle themselves and drown. During this survey, we encountered six individuals found in a gill net confisticated by the forest department on one of their island patrolling sessions. All of them were dead, and these also included three gravid females.

Feral dogs and cats - The artisanal fishermen fishing in areas around the island usually travel in small family groups often bringing along women and children to assist in the fishing operation. During these surveys we often found some of these fishermen illegally setting camp on these islands. Some often brought along their pet dogs and cats. On some of these islands these animals have probably managed to establish feral populations. The islands where dogs were encountered during this study were Krusadai, Poomarichan, Pullivasal, Manoli and Hare. A single feral cat was spotted on Pullivasal. Feral animals, especially cats have been well known to decimate native species of mammals, birds and reptiles. It is very likely that these introduced predators could prey on species such as the dog-faced water snakes that are relatively easy to access in very shallow shore areas or on mudflats. Besides this, many of these islands support a high diversity of birds, many of which are ground nesting, or roost and nest on the shrubs and the short trees on these islands. The continued persistence of feral predators on these islands is likely to have profound impacts on the native fauna if timely action is not taken to eradicate them.

Illegal fishing using gill nets off the islands of the GOMNP is among the worst threats to species such as the Dog-faced water snake.

Weed (*Prosopis juliflora*) invasion

An invasive weed *Prosopis juliflora* has started colonizing some of the islands. This weed has become a major problem in several parts of India including the mainland coast of the Gulf of Mannar as it out competes with native vegetation, sometimes totally colonizing areas, besides greatly reducing the carrying capacity of these areas (Sharma and Dakshini 1996). *Prosopis* thrives in saline and semi-arid environments, conditions which are prevalent on these islands. This species has colonized some of the islands to such an extent that it represents the dominant vegetation on many of them The exact time and mode of it of its invasion is unknown. *Prosopis* could possibly out compete and colonize areas thereby preventing the colonization of native beach vegetation and mangroves in the area. This will in turn severely affect species that are highly dependent on these mangrove habitats. These include the dogfaced watersnake, several species of birds, fish and diversity of other marine and estuarine species that use these mangrove habitats for shelters or nurseries. It terms of dog-faced water snake abundances, islands of the Mandapam group eg. Manoli, Hare, Pullivasal and Poomarichan which had the highest cover of mangroves also supported the highest abundances of dog-faced watersnakes. However the remaining islands of the Kilakarai, Vembar and Tuticorin group were largely colonized by *Prosopis julliflora*, had low mangrove cover. All, except one of these islands was completely devoid of dog-faced watersnakes and generally appeared depauperate of other fauna in comparison to the Mandapam group.

Discussion

Cerberus rynchops is a widely distributed species ranging from India across South East Asia to New Guinea, with India representing the western limit of its distribution (Alfaro et al. 2004). Throughout its range, this species appears to be well represented in a variety of coastal habitats (Smith, 1943; Gyi, 1970; Tweedie, 1983). In India, it is probably the most common marine homalopsine and has been recorded from estuarine areas from all the coastal states of the country including the Andaman and Nicobar islands. This is however the first record of *C. rynchops* from the islands of the Gulf of Mannar Marine National Park and probably the first in an exclusively marine system, which receives no freshwater influx from the islands.

There appears to be strong preference of *C. rynchops* for mangrove habitats and they are not generally seen in areas that do not support mangroves. This finding conforms with previous studies eg. See (Karns et al. 2002), that *C. rynchops* shows a strong affinity to mangroves in close affinity to water bodies. This also possibly explains its occurrence and relatively higher abundances on islands that support a good mangrove habitat for eg. Manoli, Hare as compared to

islands that are mangrove free or have relatively sparse growth eg. Shingle and Appa islands.

Research conducted on *C. rynchops* in other parts of the world indicate that this species is predominantly a piscivore (Jayne et al. 1987, Voris and Murphy 2002), and this could be the probable reason that most of its active time was spent in water. The only part of its terrestrial existence is probably spent in the shelter of its crab holes or on rare occasions, foraging for terrestrial prey.

Its fish eating habits could also be a reason as to why this species encountered in higher numbers at low tide or occupying shallow areas in the region of these islands. The possible explanation to this could be that some of the islands of the Gulf of Mannar Marine National Park for eg. Manoli group have broad shorelines extending seawards or wide shallow bays (as seen in the Manoli island). These bays are filled with water of an average depth of a foot. However at intermediate - low tide the water level drops to an average depth of half a foot. This low water level on these wide shore flats tend to harbour a large number of stranded fish which seems to facilitate the snakes on their hunts. In Malaysia reveals this species is known to forage in waters as deep as 1.3m by swimming on the riverbed (Jayne et al. 1987). This is contrary to my observations. However, the former observations were mainly restricted to the Muar river and estuary which most probably had a weaker water currents as compared to the waters surrounding the islands of the Gulf of Mannar, where amphibious species such as this could run the risk of getting displaced and predation.

Proper management of these islands by the forest department through prevention of illegal fishing/ camps, active eradication of weeds (*Prosopis juliflora*), coupled with mangrove plantation can ensure the persistence of this species on these islands.

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Chapter 5

Fisher Perception towards sea snakes in the Gulf of Mannar Marine National Park

Abstract

We interviewed 164 fishermen who worked on trawlers that fished in the Gulf of Mannar to elicit their attitudes and knowledge primarily concerning sea snakes besides other species that were incidentally caught in trawling operations. While a majority of them believed that sea snakes were dangerous, most of them (85%) were not sure if the bites were fatal or even if any treatment was available. Despite this, 92% admitted to releasing the live caught sea snakes. Most interviewees believed that sea snakes were far more abundant in the past and that there were observable declines in catches of sea snakes, certain large fish species and many other marine species, with nearly 76% admitting that the decline was noted from 1995 onwards. Through this fisher-perceptual study it appears that although sea snakes are neither commercially exploited nor killed by fishermen, trawling seems to have had a negative impact on their populations. The study stresses on the importance of local knowledge, especially in the case of rare or sometimes extinct species or in cases where data collection is particularly difficult. This method also gives us a useful insight into the popular local misconceptions associated with local systems and the crucial need for education in these cases.

Introduction

It is widely accepted that conservation projects are most effective if the views and needs of the local people are taken into consideration (Sutherland 2000). It has been clearly demonstrated that local knowledge is a useful tool and has often proved crucial to compliment the scientific methodology used in developing effective conservation programmes (Johannes 1989, Abele 1997, Berkes et al. 2000). Local knowledge/perceptions become especially vital in cases where little/no past data exists, or in cases where field sampling is difficult e.g. see. (Huntington and The communities of Buckland 1999), or where the species in question is rare e.g. (Mallory et al. 2003).

In India, most research on marine species has so far primarily focused on commercially exploited forms. However, it is now clearly known that fishing operations such as shrimp trawling, apart from their target catch, also capture several non-target species (bycatch), with bycatch to catch ratios as high as 20:1 in the tropics (Alverson et al. 1994). However since the advent of mechanization (eg. Trawl fishing, purse seining, etc.) in India which took place in the late 1950's most fisheries data remains largely restricted to commercially exploited species. The little information that has been collected on bycatch is largely in the

form of grey literature such as unpublished reports and that too remains scattered to a few parts of the Indian coastline and has not been collected at a regular scale (Biju Kumar and Deepthi 2006). This is especially the case in large and often occasional to rarely represented bycatch, which for certain reasons such as: low commercial value (eg. Moray eels), venomous nature (eg. sea snakes) or because of their legal protection status (eg. Cetaceans, sea turtles and certain species of elasmobranchs) are rarely landed with the other commercial catch to the fish landing sites, where most fisheries statistics data is collected. Moreover in situ studies on these species, their catch and mortality rates are very few and scattered and this is mainly because such studies would require onboard observers on fishing vessels which can be extremely expensive and logistically cumbersome. In such cases, obtaining fisher perceptions is of crucial importance and sometimes the only possible method by which data on these often overexploited and thereby depleted bycatch species can be collected (Saenz- Arroyo et al. 2005).

In several countries in Southeast Asia and Australia's Northern prawn fishery sea snakes caught as bycatch are commercially exploited for their skins, food and medicine (Heatwole 1999). Moreover, in many parts of their range they are simply killed because they are venomous (Milton 2001a). In areas such as these, it would be expected that all live caught sea snakes would be killed see (Han et al. 1991, Wong 2006) for related information. There is however no documented evidence of the commercial exploitation of marine snakes in India, though several statistics are available for terrestrial snake species which are killed in large numbers for their skins (Hawkins 1986). Therefore the case of sea snake population declines due to targeted harvesting of the species in India does not arise.

Sea snakes captured in a trawl operation are prevented from surfacing to breathe. This coupled with several other factors in the trawling operation result in their mortality. Some of these include, the time it enters the net in the tow, duration of the trawl, weight of the catch, treatment it receives aboard the trawler and its morphology (Heatwole 1975, Wassenberg et al. 2001). However, a significant proportion of the captured sea snakes often manage to survive a trawling operation, with the survival rate as high as 70% of the total caught sea snakes (Wassenberg et al. 2001). In India there is little information on the attitudes, knowledge and behaviour of fishing communities towards most species of marine fauna. How fishermen deal with venomous marine species aboard a trawler has never been documented. Such information however would be of key significance while designing a conservation strategy for sea snakes. Consider for example if we learnt that fishermen killed the proportion of sea snakes brought aboard alive this could add a new dimension to the trawling problem which is

already known to have a devastating impact on sea snake populations (Ward 1996a, b, 2000, Milton 2001a, Wassenberg et al. 2001, Lobo et al. 2005).

Nine sea snake species were encountered as rare bycatch in shrimp trawlers during one part of this study, eight of which are highly venomous (See Chapter 2). Sea snake antivenin is not manufactured in India, thereby making most bites potentially lethal. In a job that entails occasional encounters with these venomous creatures, one could expect fishers to kill all the sea snakes they encounter.

This is the first study on the sea snakes of this region, therefore data on past abundances and distribution is not available. Moreover, personal observations made by accompanying trawlers and discussions with known people in the fishing community, made it clear that sea snakes were rarely encountered as trawler bycatch. So besides obtaining information on how trawler fishermen deal with live sea snakes and other venomous creatures encountered in the catch, this study through the perceptions of fishermen also provides crucial insights about past abundances and spatio-temporal changes in the abundances of sea snakes and other bycatch species. Many of these species are rare and obtaining data on their catches/abundances is difficult and most often totally absent.

Interviewing fishermen at a fish landing site

Methods

We interviewed 164 fishermen from the designated fish landing sites (see map, Chapter 1), located in the Gulf of Mannar Marine National Park during the period from December 2004 to July 2005, who worked on trawlers that fished in the region. Interviews were conducted

during the morning when the trawlers returned from their fishing voyages[1]. A questionnaire containing a mix of closed and open-ended questions was applied at random to fishermen we met at the fish landing sites. All interviews were conducted in private to minimize peer influences on the respondents. We interviewed one fisherman per vessel. Our questionnaire was answered by fishers working on 5 and 25 percent of the trawlers in the area. The total number of trawlers that operated from the bases in the Gulf of Mannar Marine National Park was obtained from the annual fisheries statistics report published by the fisheries department (Fisheries 2004). This was further verified with the trawler association office at each of the individual fishing bases. The total number of trawlers ultimately arrived at was 872. To avoid results being influenced by bio-geographic differences in species composition and abundance, we conducted interviews exclusively in the region of the Gulf of Mannar Marine National Park.

Of the 164 fishermen who were interviewed 72% were Christians, 25% were Hindu's and 5% were Muslim. Most trawler fishermen in the region of the Gulf of Mannar Marine National Park belong to the Paravar caste, which is a fishing caste (Bavinck 2001). Most of them, especially the older generation started off working on *vallams* (the smaller artisanal canoe/crafts) and thus have rarely engaged in any other profession.

To elicit fisher perceptions on whether trawl fishing has brought about changes in sea snake numbers and in the general abundance of the target catch of shrimp and fish, we questioned fishers on the catch rates of target and non-target species and specifically on the catch rates of sea snakes (present and past). Trawlers were introduced in the Gulf of Mannar in the 1970s. If they observed a change in the catch rates of sea snakes in trawlers, we questioned them on the year since when they began observing a decline.

To understand how fishermen handle/treat live caught sea snakes we questioned them about their perceptions of sea snakes in general and what was done to the live sea snakes that were encountered.

Morphological similarities, often lead laymen to mistake eels for snakes. However fishermen clearly know the differences between sea snakes, morays and conger eels which are known by different local (Tamil) names. Of these, the conger eels are clearly known to be harmless and usually constitute the bycatch that is sold to the poultry industry or in case of the larger conger eels, their swim bladders are surgically removed to be sold for the manufacture of bio-sutures (pers.

[1] Information on trawling grounds has been mentioned in Chapter 1

obs). Therefore besides sea snakes we also questioned fishermen on their perceptions towards and interactions with moray eels.
The interviews were restricted to the trawler fishermen, because of the fact that sea snakes are only very rarely captured by the other artisanal fishing methods in the region. The most prominent of these artisanal fisheries are the '*Vallams*'. These are small traditional crafts that mainly fish using gill nets in shallow areas and primarily catch pelagic fish.

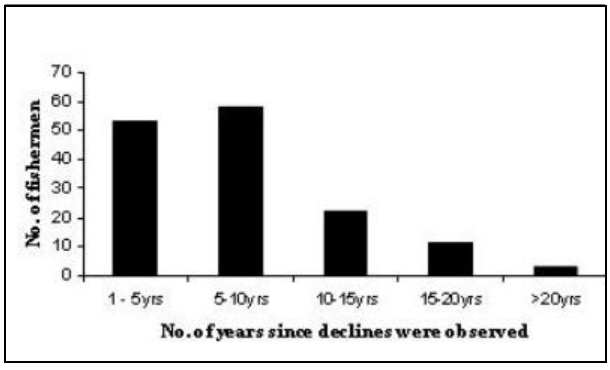
Results

Perception of temporal variation in abundances

147 (90%) of the 164 interviewed fishermen believed that the catches of sea snakes having declined from various points in time in the past since trawlers were introduced. The following No.(%) of fishermen, 53 (36%), 58 (40%), 22 (15%), 11(7%) and 3 (2%) believed that perceivable declines in sea snake catches began around 5 yrs ago (2000 - 2005), 5-10 yrs ago (1995 - 2000), 10-15 yrs ago (1990 -1995), 15-20 yrs ago (1990 – 1985) and less than 20 years ago (< 1985) respectively (Fig. 1). Thus, 76% of the interviewed fishermen believed that declines in sea snake catches started and persisted since 1995. The remaining majority (22 %) believed that the declines began from 1985. Besides sea snakes, fishermen also attributed the above periods to observable declines in certain large fish species, of which special mention was made to elasmobranchs, and groupers.

The majority 147 (90%) of the fishermen also reported to declines in the target catch (shrimp). However they believed that though declines were apparent over a period, very steep declines in catches began around 2-5 years making it very difficult for the fishermen to even break even and actually making trawling nonprofitable.

Fig. 1. Fisher perception regarding declines in sea snake capture rates in shrimp trawlers.

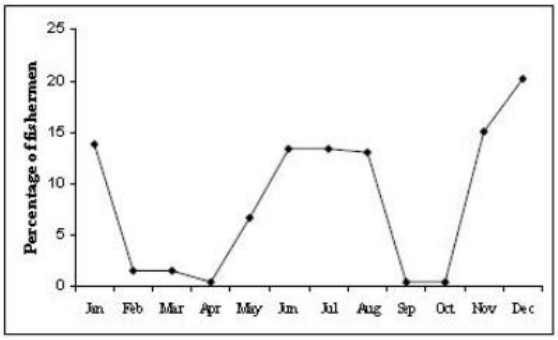


Perception of Seasonality in sea snake abundances

While 72 (44%) of the fishermen believed that there is no seasonal variation in the catches of sea snakes on trawlers and that they are generally rare throughout the year, the remaining 92 (56%) of the

fishermen interviewed however believed that the sea snake catch rates on trawlers vary during the year. Those who believed that the catch rates of sea snakes varied also believed that there are two periods in the year when sea snakes are commonly caught; one from November to January and the other from June to August (Fig. 2).

Fig. 2. Fisher perception regarding seasonal capture rates of sea snakes by shrimp trawlers in the Gulf of Mannar

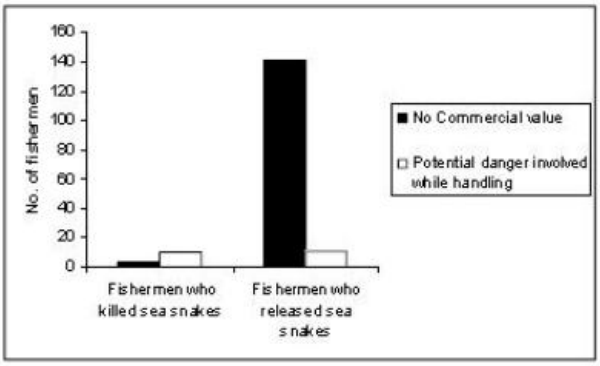


Sea snakes' fate – at the mercy of the fisherman

Only a minority of the interviewed fishermen 13 (8%) admitted to killing sea snakes that were caught alive in trawling operations. However, the remaining majority 151 (92%) admitted to releasing them, which was done either by tossing them overboard by holding them by the tail or with the help of a shovel, also used to discard other forms of bycatch.

Of the 13 fishermen who admitted to killing sea snakes 10 did so because they feared sea snakes because they were venomous, while the other 3 did so simply because sea snakes had no commercial value. Of the fishermen who released the live caught sea snakes, only 11 (7%) did so because they feared sea snakes as being potentially dangerous, while the majority 141 (93%) did so because sea snakes had no commercial value (Fig. 3).

Fig.3. Interactions of fishermen towards live caught sea snakes



When asked if there was a treatment for sea snake bites, 135 (85 %) fishermen were not sure, 20 (12%) said that bites could be treated by being administered with an injection available at a public hospital, though none of them knew what its constituents were and only 5 (3%) strongly believed that there was no treatment and that all bites could potentially result in the death of the person.

All fishermen held the general belief that moray eels were aggressive and a majority 127 (77%) even believed that they were also venomous. Moray eels were thus often killed when encountered in the trawl catches.

Discussion

111 (76%) of the fishermen believed that there has been a dramatic decline in sea snake catches and the same were of the opinion that these declines began around 1995. Trawlers were introduced in the Gulf of Mannar around 25 years before the perceived decline (~1970). All these fishermen also believed that these declines were not just observed for sea snakes but were apparent for several other large fish species which included shark, rays, sawfish and groupers. These species once commonly represented trawl bycatch, but are now rarely seen.

Some fishermen believed that certain species such as Manta Ray (*Manta sp*) and Sawfish (*Pristis sp*) that were once caught in this region are now extinct. During my entire study I never saw any of the latter two mentioned species in the catch landings or while aboard fishing vessels. However, evidence of the past presence of species such as sawfish (*Pristis sp.*) in this region was seen as trophies (saw like bill approximately 1 meter in length) in the homes of two affluent families in Mandapam (northern coast of the Gulf of Mannar).

These finding seems to corroborate with the larger global pattern, where in large marine species, high in the trophic food chain are the first ones to disappear in areas subjected to sustained fishing pressure followed by lower trophic groups (Pauly et al. 1998, Myers and Worm 2003). Sea snakes fall in this category of species, in that they are long-lived, grow slowly, are late to mature sexually and have low rates of natural mortality (Lemen and Voris 1981, Heatwole 1999). Such species are highly vulnerable to overexploitation due to trawl fishing and may not be able to survive increased commercial fishing activities (Milton 2001a). The life history strategies of species such as sea snakes (also referred to K selected species) contrasts sharply with shrimp. Shrimp are J selected species i.e they are short lived, early to mature sexually, have a high fecundity and have high rates of natural mortality. Thus, this may allow such fisheries to persist for a long period before collapsing. This is also a plausible explanation as to why shrimp

catches took a much longer period to decline as compared to the other larger incidentally caught species. The pattern of this differential catch decline also makes it evident that sustained trawling in this region was responsible for this phenomenon.

Trawl fishing in the Gulf of Mannar was introduced in the 1970's and because of the efficiency in this fishing technique, among other factors, there has been a rapid increase in the number of trawlers. Research on trawling impacts conducted in the Gulf of Mannar documented large scale impacts on various aspects of the marine biota (Jayasankar et al. April 2000).

The fishermen's explanation to releasing live sea snakes was to reduce the risk of being bitten and to prevent further distractions while sorting the catch. This they did right when the catch was landed and was usually carried out for all species that they deemed dangerous. Similar handling behaviour was documented in another coastal state (Goa) which had an ethnically different fishing community (personal observation). We can thus broadly conclude that the main cause for sea snake mortality can be attributed to the trawl fishing process itself, with an insignificant number of sea snakes being killed by the fishermen itself. Moray eels on the other hand were regarded as dangerous and in most cases venomous. This could probably be attributed to the aggressive nature of these species, which often led them to being killed.

The fact that the majority of the fishermen knew that sea snakes were venomous but were oblivious to the fact that their bites were fatal could imply that the fishermen themselves are rarely bitten, thus also making subsequent mortalities due to their bites extremely rare. However, this also reveals their lack of awareness regarding the potential danger of sea snake bites. However their knowledge of other venomous creatures that were occasionally encountered in trawling operations (eg. stingrays, scorpionfish, conesnails, eel catfish etc) appeared to be reasonably good and these creatures were usually handled with great caution and often employing certain techniques for e.g. species such as lionfish and scorpion fish (order Scorpaeniformes), eel catfish (*Plotosus sp*) are scooped overboard employing a wooden board that's used for sorting catch. In species such as sting rays the stinging spine or sometimes the entire tail is chopped of before being introduced to the fish holds. This study thus further reinforces the argument on the importance of local knowledge as a crucial alternative in cases where scientific data is difficult to collect. This study also stresses the need for the development of a well-designed education campaign to educate fishermen on the potential dangers of sea snakes and the setting up of proper treatment facilities in the event of casualties which at present has not been given it's due attention.

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Appendix 1

A comparison of scale counts of sea snakes collected from the Gulf of Mannar with those recorded by Malcom Smith(1926)

		Scale Counts					
		Neck		Mid-body		Ventrals	
		GoM	Smith (1926)	GoM	Smith (1926)	GoM	Smith (1926)
Species	**N**						
H. cyanocinctus	17	28-32 (Avg-30)	27-35	35-43 (Avg-39)	37-47	290-348 (Avg-320)	290-390
H. spiralis	25	25-32 (Avg-28)	25-31	31-37 (Avg-34)	33-38	299-362* (Avg-325)	295-362
H. gracilis	27	17-20 (Avg-19)	17-21	31-37 (Avg-33)	30-36	204-273 (Avg-237)	220-287
H. ornatus	9	35-38 (Avg-36)	28-45	41-46 (Avg-43)	33-55	230-276 (Avg-252)	209-312
P. viperina	4	29-32 (Avg-30)	27-34	39-46 (Avg-42)	37-40	230-266 (Avg-255)	226-274
H. fasciatus	2	29,31	28-33	51,54	47-58	493,496	414-514
H. lapemoides	3	28-32 (Avg-30)	29-35	41-47 (Avg-44)	43-51	285-330 (Avg-313)	314-372
L. curtus	3	28-32 (Avg-30)	28-35	31-36 (Avg-34)	33-43	150-160 (Avg-155)	154-194

Two species *Acrochordus granulatus* and *Pelamis platurus* have not been added to this table. This is because their scalation and other morphological characteristics closely conformed with those of Smith. Moreover they have very distinct morphological characteristics, which make it unlikely to mistake these for any other species. * In one individual the No. of ventrals was 375. The remaining counts followed Smith (1926).

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Appendix 2

First record of the Many-toothed sea snake (*Hydrophis caerulescens*) in the Palk Bay.

A sea snake was landed at the Rameswaram fish landing site along with other bycatch on 22nd Feb '2005. The snake was identified as *Hydrophis caerulescens* (Smith 1943) and was deposited as a voucher specimen to the collections of Bombay Natural History Society (Voucher # BNHS 3361).

The individual was a female and the following were its various morphometric measurements: Snout Vent Length - 703mm, Tail Length - 66mm, Head width - 7.91mm, Head length - 12.05mm, Mass - 120g. The Scale counts for the individual were as follows. Scales around the neck: 39, midbody: 49 and number of ventrals: 293. Moreover the individual had 44 bluish-black bands around the body.

This species is represented by two sub-species which are *Hydrophis caerulescens caeruescens*, whose distributional range comprises the seas of India, coastal areas of Ceylon and Burma and the Straits of Malacca. The other sub species is *H. caerulescens hybridus* whose distributional range comprises the Gulfs of Thailand and Tonkin, the Yellow sea, coastal areas of Java and Kalimantan and the Gulf of Carpentaria (Kharin 2004).

In India, this species has been recorded along the western coast in the seas north of the Malabar coast, between Karwar to Mumbai. It has

also been recorded in the Indian ocean, and the Bay of Bengal, from Chennai to the mouth of the Ganges (Smith 1943). This thus represents the first record of this species from the Palk Bay. Because of its occurrence in the Indian ocean and the Palk Bay there is a high likelihood of it occurring in the Gulf of Mannar.

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Appendix 3

A significant variation in coloration between mainland and island individuals of *Cerberus rynchops*

***Cerberus rynchops* from Manoli Island, Gulf of Mannar**

***Cerberus rynchops* from the mainland Indian coast**

Colour comparison in specimens of *Cerberus rynchops* collected from the islands of the Gulf of Mannar Marine National Park and those examined from other parts of mainland India.

Body part	Colour in island individuals	Colour in mainland individuals
Head	Black streak on either side of the head, that passes through the eye is poorly developed or absent.	Black streak usually prominent and passes through the eye and onto the neck.
Body (Dorsum)	A uniform pale grey, rarely with sporadic black spots and speckling.	Grey or brown with large black spots, becoming confluent giving individuals a banded appearance.
Body (Venter)	Black ventral markings are almost absent, or if present, in the form of paired black spots at either end of each ventral scale.	Prominent black ventral markings appear in the form of black crucifixes attached end to end.
Tail	Usually speckled with black spots	Usually banded in appearance

Appendix 4

Education & Outreach

As part of the conservation initiative of the Government of Tamil Nadu, a Gulf of Mannar Biosphere Reserve Trust (GOMBRT) has been formed with the support of Global Environmental Facility (GEF). Throughout the course of my research, the Trust and the Forest Department, especially the Wildlife Warden, Mr. V. Naganathan have greatly facilitated the outreach component of this project, right from developing educational material to helping with the organization of my presentations. Some of the outreach activities undertaken as part of this project included:

Making a presentation titled 'Sea snakes of India – Rough Seas ahead' made at the Indian Institute of Science, Bangalore, based on some of my initial findings in the Gulf Of Mannar. The Institute is among the largest and the most prestigious scientific institutions in the country and the talk was attended by a large audience which included the general popular audience and scientists alike.

I also presented my findings through a power point presentation at the conference hall of the GOMBRT in a presentation titled "Sea snakes of the Gulf of Mannar". The talk was attended by Park Managers, officers working with GEF, fishermen and scientists from various national institutions which included the Wildlife Institute of India, Madurai Kamraj University and the Central Marine Fisheries Research Institute.

During the course of this work my assistants and I presented several educational talks at the fishing companies and in all the fish landing sites in the Gulf of Mannar. These were general talks in Tamil about various aspects of the Gulf of Mannar's incredible marine biodiversity.

A collared photographic, sea snake species identification poster title "Sea snakes of the Gulf of Mannar" was designed, 1500 copies printed and with the aid from the Tamil Nadu Forest Department the poster has been distributed at all the fish landing sites in the Gulf of Mannar Marine National Park. The poster has also been distributed to various educational institutions, government departments of forest fisheries and museums in the state of Tamil Nadu as well as in other parts of the country. The poster has also been put on display at the herpetological section of the British Natural History Museum.

I provided images and species descriptions which went into the design of a booklet titled "Sea cucumbers and Sea snakes of Gulf of Mannar" produced by the Tamil Nadu forest Department. 2000 copies were printed and distributed in various parts of the state.

The Gulf of Mannar Marine National Park is among India's most biodiverse marine habitats. While a large quantum of research has been carried out on several marine taxa in this area, the sea snake fauna in the region has remained largely undocumented. Sea snakes are among the few apex predators in nearshore coastal ecosystems and play a crucial role in their functioning. This study is a detailed, pioneer account of sea snakes occurring in this region and provides insights into the ecology and the threats these creatures face. The study also makes a case for the conservation of these marine reptiles