

# ESTIMATING SEA SNAKE DIVERSITY USING TRAWLER BYCATCH ALONG THE COAST OF GOA

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*By*  
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## Certificate

This is to certify that Sh. Aaron Savio Lobo of the Wildlife Institute of India, Dehradun has carried out an original research work titled '**Estimating sea snake diversity using trawler bycatch along the coast of Goa.**' in partial fulfillment of the MSc. (Wildlife Science) degree of Saurashtra University, Rajkot. The study was conducted under our supervision from November 2002 to June 2003. We also certify that this research work has not been submitted for the award of any other degree to any other university.

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## SUMMARY

The sea snake community off the coast of Goa was studied using trawler bycatch. To obtain a fair idea of species richness other fishing crafts such as shore seines and sluice nets were visited at regular intervals to check for snakes that were opportunistically caught in them. Catch per unit effort was calculated to compute the sea snake abundance. Food habits of sea snakes were studied using a gut content analysis, where in the fish families commonly fed on by sea snakes were recorded. An attempt was made to understand the causes of mortalities in sea snakes. This was done relating the magnitude which was the number of dead sea snakes and intensity which was the proportion of dead sea snakes with the duration of the trawl, weight of the catch and mean depth in meters. Sea snakes were measured for several parameters and length-weight relationships were computed. A total of six species were encountered of which four were caught through systematic sampling using trawlers while the remaining two were obtained through opportunistic searches using shore seines and sluice nets. The total catch per unit effort calculated for the entire study was  $1.28 \times 10^{-5}$  sea snakes per net hr and the catch per unit efforts calculated for the individual bases varied significantly. The sea snake diversity was seen to be the highest for Vasco followed by Malim, Chapora and Betul. A cluster analysis with complete linkage showing similarities across the four different fishing bases showed that Vasco is most similar with Malim and Betul with Chapora. The composition of sea snake species varied with depth. The proportion of *Lapemis curtus* increased and *Enhydrina schistosa* decreased with an increase in depth. The proportion of male and female snakes per trawl were similar in all three depths for *L.curtus*. In *E.schistosa*, however males did not occur in depths greater than 15 m. In *L.curtus* most individuals contained food in the stomach. The species was found to feed on five fish families of which families Clupeidae and Cynoglossidae dominated. The consumption of clupeids decreased with increase in the length of the snake. Consumption of prey families varied slightly with the time of the day and this was mainly with the change in the proportion of Cynoglossids consumed.

The mortality of sea snakes was found to be strongly related with the number of individuals caught. The magnitude and intensity of mortality were found to increase with the duration of the trawl, weight of the catch and mean depth. Mortalities of sea snakes varied with species, *L.curtus* having a larger proportion of dead than live individuals and *E.schistosa* having a larger proportion of live as compared to dead individuals, thus showing that *L.curtus* is more susceptible to mortalities due to trawling as compared to *E.schistosa*. Betul recorded the highest mortalities and the mortality of sea snakes was found to be significantly influenced by the time of the day and season. Bruises were found to vary significantly in live and dead sea snakes and were higher in dead snakes. Morphometric studies in *L.curtus* and *E.schistosa* found that snout vent length bore a strong relationship with the weight and tail length. No sexual dimorphism in terms of size was recorded in both the species which was similar to previous studies in the case of *L.curtus*. However, it was found that the heaviest and lightest individuals in both species are females.

# 1. INTRODUCTION

## General Introduction

Sea snakes are known to form an important constituent of the fauna in the tropical and the sub-tropical seas of the world (Heatwole, 1999). Sea snakes possess several adaptations that enable them to survive in the marine environment. Some of these characters include an elongate, laterally compressed body with an oar shaped tail, which helps them in efficient swimming. They possess dorsally located nostrils, which are opened by valves (Heatwole, 1978). Sublingual salt glands help them maintain an osmotic balance with the seawater (Dunson, 1975). The presence of an elongated right lung and cutaneous respiration enable them to spend long periods under water (Heatwole and Seymour, 1975). Reproduction through viviparity and highly toxic venom are other unique adaptations (Heatwole, 1999). Sea snakes are known to feed almost entirely on fish (Wall, 1921). They are comprised of several lineages that separately have become adapted to living in the sea (Heatwole, 1999).

Various families of snakes contain marine forms that are collectively termed as sea snakes. Of the 15 living families of snakes four contain marine species viz. Colubridae, Acrochordidae, Laticaudidae and Hydrophiidae (Heatwole, 1999). There are 73 species of marine snakes of which 57 are hydrophiids, 9 homalopsines, 3 natricines and 3 acrochordids (Heatwole, 1999). There are 23 species of marine snakes known from India (Murthy in Heatwole, 1999). These include *Acrochordus granulatus*, *Laticauda colubrina* and *Laticauda*

*laticaudata*), eighteen species belonging to seven genera under Hydrophiidae and two species of homalopsines (*Cerberus rynchops* and *Gerarda prevostiana*). There are 11 species belonging to six genera occurring in the Arabian sea along the West coast of India (Ahmed, 1975).

India is probably the only country, which has the single longest coastline supporting a large diversity of sea snakes within a political boundary in Asia. The fishing industry looms high along the coastal states of the country with millions of people depending on it as the sole source of their livelihood. In India, trawling is one of the major and most effective fishing methods along the coast (Ravindran, 1998). Sea snakes are often caught as bycatch during trawl fishing. The conservation status based on the IUCN categories has been assigned only to four out of 23 species known from the Indian waters. All the four species were placed in 'data deficient' category (Anon, 1998). The habitat of these sea snakes frequently overlaps with the trawl grounds and thus they run at a great risk of dying either due to drowning in the net or being killed by the boat crew once on board (Milton, 2001).

It is estimated that 27 million tonnes of trawl bycatch is discarded globally each year (Alverson et al., 1994). This large quantity of discards and the increasing knowledge on the impacts of trawling has resulted in worldwide concern since it might threaten the viability and profitability of trawl fishing (Pauly, 1979; Sainsbury, 1987). An increasing human population has greatly increased the demand and thus placed a severe stress on these marine resources. Besides the depletion of the commercially important forms other

non-commercially important species like sea turtles and sea snakes are unintentionally killed during these various fishing activities.

The state of Goa has a coastline of 105 km along the west coast of India. Like any other coastal state the marine resources here are being exploited rapidly. There are 1143 operational trawlers in Goa, which contribute to approximately 60% of the total fish landing (Shirodkar, Fisheries dept, Goa, pers. com). Sea snakes are commonly encountered in trawl nets in Goa, however the extent of mortality and the ways to reduce such bycatch has not been studied. The present study was undertaken to assess the sea snake population and mortality occurring along the coast off Goa.

### **Objectives**

The present study was carried out with the following objectives:

- (i) To estimate diversity and describe the community of sea snakes occurring along the coast of Goa.
- (ii) To quantify the diet of few species of sea snakes.
- (iii) To quantify mortality and injury to sea snakes in trawl fishing.
- (iv) To study the morphometry of sea snakes.

### **Review of literature**

#### ***Diversity***

There are several factors limiting sea snake distribution that are unique to the respective group they belong (Minton, 1975). Sea snakes live in coastal and marine waters and are distributed in the Indian Ocean, southwest Pacific

Ocean, Arabian Sea and South China Sea (Voris, 1977). Sea snakes are not known to occur in the Atlantic Ocean. A species *Pelamis platurus*, had been known to stray to the Atlantic ocean (Heatwole, 1999). Studies in the Gulf of Carpentaria, Australia documented seasonal shifts in the sea snake population, which coincided with winds, currents and possibly food supplies (Shuntov 1971; Redfield et al., 1978). Similar observations were made in the Gulf of Siam, Tonkin Gulf and the region around Karachi (Minton, 1975).

The greatest diversity of sea snakes are known to occur in the waters of Australia (37 species) and 36 species occurring in the waters of the Malaysian and Indonesian archipelago (Heatwole, 1999). Waters along the coast of Australia have several endemic and primitive genera such as *Hydrelaps* and *Ephalophis* (Cogger, 1975).

Initial studies on sea snake diversity in the Indian ocean documented 13 genera containing 30 species (Wall, 1921). Ahmed (1975) documented 19 species of sea snakes belonging to eight genera with information on their systematics, ecology and distribution in the Indian ocean, this work was however based on the collections made earlier by the Zoological Survey of India. There were several studies on the occurrence of sea snake species occurring in the Madras waters and the Chilika lake, Orissa by Murthy (1977, 1986, 1992) & Murthy and Rama Rao (1988). Two new species of homalopsine snakes *Enhydris plumbea* and *Cantoria violacea* were recently discovered in the Great Nicobar Islands and Andaman Islands respectively, which are new records for India (Ghodke and Andrews, 2001). There are

certain studies on the terrestrial behaviour of *Laticauda colubrina* occurring along the coast of the Andaman Sea (Shetty and Prasad, 1996). It can be inferred that little work has been done on taxonomy, ecology and distribution of sea snakes that inhabit the Indian Ocean (Ahmed, 1975).

### **Diet**

Sea snakes are known to feed almost entirely on fish (Wall, 1921; Herre, 1942). However, there are two species of *Emydocephalus* that are known to feed exclusively on fish eggs (Voris and Voris, 1983). There have been several studies, which focussed on the specific types of fish eaten by sea snakes (Klawe, 1964; Mc Cosker, 1975; Voris, 1972, Voris et al, 1978; Voris and Glodek, 1980). A few studies on sea snake diet dealt with aspects such as diet diversity and diet overlap within snake assemblages at specific localities. McCosker (1975) identified stomach contents from snakes collected along the coast of Australia and found that prey diversity within species of sea snakes was usually low and between species overlap in diet at the species level was non-existent. Glodek and Voris (1982) collected data on the prey of 16 sea snakes and found that prey diversity is low for most of the snake species. They also found that in a particular locality there is little evidence of diet overlap among most species of marine snakes. Voris and Voris (1983) compared feeding strategies in marine snakes. They found that eels and gobies were the largest consumed prey items among sea snake species, certain species such as *Emydocephalus* were found to be specialists and were found to feed exclusively on fish eggs, certain species were found to be generalists. Voris and Voris (1983) found differences in sea snake species in

between snake neck girth and the maximum diameter of the prey; snake gape measurements and fang length to the type of prey taken; snake shape and body proportions to the prey selected. There are several modes of feeding in sea snakes; feeding in nooks and crannies in the bottom or in reefs, cruising near the bottom, and feeding in drift lines (Voris and Voris, 1983). A higher diet overlap was recorded when species coexist and vice-versa when they do not co-exist (Voris and Voris, 1983).

### ***Mortality***

Fishing activities such as trawling directly infringe upon the survival of sea snakes by depleting their food resource and by causing mortality due to incidental capture (Wassenberg et al, 2001). Sea snakes are a common by catch of the trawl fisheries in India. Many sea snakes caught in the trawl nets die due to drowning or are killed by the fishermen once on board. Studies on the impacts of trawling on sea snakes in Australia found that trawling is responsible for large scale mortality and injury of sea snakes; with certain species of sea snakes being more affected than others (Wassenberg et al., 2001; Milton, 2001). Most previous studies on sea snakes simply documented species richness in different areas, and there have been no previous studies on the effects of various fishing activities on sea snake populations

### ***Morphometry***

Studies on morphometry of sea snakes species is scanty. Body size affects many aspects of an animals life, including the types of shelters, it's diet, vulnerability to predators and reproductive success (Calder, 1984). Studies

have shown that body size can have a significant influence on the life history patterns, such as clutch size in poikilotherms (Blueweiss et al., 1978). In snakes it has been found that differences in mean body size can result in interspecific variation in their ecology (Shine, 1994). Length–Weight relationships have been studied in many species of snakes (Kaufman and Gibbons, 1975; Guyer and Donnelly, 1990; Das, 1991). In most cases it was found that female snakes were larger than males. In *Laticauda colubrina* females grow larger than the males and have longer and wider heads than their conspecific males (Shetty and Shine, 2002a). This is also the case in *Acrochordus granulatus* (Houston and Shine, 1993).

## 2. STUDY AREA

The state of Goa is located along the Central West Coast of the country, between the coordinates 14°54' to 15°48'N and 73°40' to 74°20'E. It covers an area of about 3702 km<sup>2</sup> and has a 105km long coastline (Fig. 1). The state is flanked by the Western Ghats on the east and the Arabian sea on the west. Goa has seven major rivers, which are Mandovi, Zuari, Terekhol, Chapora, Galgibag, Kumbarjua canal, Sal and Talpona. Their basin covers 69% of the total geographical area of the state (Modassir and Sanitha, 2003). These rivers are fed by the southwest monsoon and discharged from the catchment area.

The coast of Goa shows marine, fluvial and Aeolian features (Modassir and Sanitha, 2003). Erosion and accretion features indicate that the coast is degrading along the beaches and retreating along the cliffs and headlands. Based on the disposition of landforms, the present coast is neither emergent nor submergent in nature, but it is a combination of both. The continental shelf of Goa is relatively wide, with 50m contour depth at 35km, 100m at 80 km and 200m at 100 km away from the coast (Modassir and Sanitha, 2003). The area of the continental shelf (upto 100 fathoms) is 10,000 sq.km (Jhingran, 1991). The seabed consists of silty clay upto 50m water depth and sandy silt from 50 to 100m water depths. The coastline of Goa is a scenic alteration of beaches, headlands, bays, creeks, sea cliffs, promontories, pocket beaches, dunes, rocky headlands or hard wave cut platforms, estuaries and river mouths. The total inland waterways in Goa is 250 kms (Shirodkar, Fisheries dept, Panaji-

Goa). The islands of Goa are of two types: 1) the rocky islands like those of the Mormugao coast and the Piedade, right in the Mandovi which are the protrusions of a drowned topography separated from the mainland. 2) The alluvial islands like those of the Kumbarjua group created by the heavy deposition of silt by the river in their estuaries.

The oceanography of the Goa region is influenced by three seasons viz. Southwest monsoon (June- September), post monsoon period (Oct-Jan) and Fair weather period (Feb-May). The sea is usually very rough during the monsoon season. On an average, Goa receives an annual rainfall of about 1200mm. The air temperature fluctuates between 22-38°C with 80% humidity (Modassir and Sanitha, 2003).

Goa has four major fishing bases viz. Chapora, Malim, Vasco and Betul which are located along Chapora, Mandovi, Zuari and the Sal river respectively. Besides these, there are 3 other minor bases located at Baina, Chicalim and Talpona, where the boats are temporarily anchored.

The trawl base Chapora is at the mouth of the river Chapora. The river has its origin in the Ram Ghat hills of the Belgaum district in Karnataka and its length in Goa is about 31 km (Modassir and Sanitha, 2003). It has several islands in its watercourse. Down stream near the mouth, the river basin shows features of drowned topography.

The Malim fishing base is located at a distance of about 4 kms from the mouth in the river Mandovi. Mandovi is the largest amongst all rivers flowing through the state. It originates from the Parwa ghats; a section of the Western Ghats in Karnataka and it traverses about 75 kms before it joins the Arabian sea. It can be classified as coastal plain or drowned river valley estuary. Mandovi covers a basin area of 1530 sq.kms, and a catchment area of 1150sq.kms. At the mouth between the Aguada and Cabo headlands, it measures 3.2 kms, but narrows down to less than 1 km within 4 km. Water depth is about 7.5 meters at the mouth and 2.5 meters at upstream, with average depth of 3.5 meters. The tide in this area is of a mixed semi-diurnal type. The freshwater which is maximum during the post monsoon period gradually decreases during the premonsoon periods at the distance of about 14 kms. from it's mouth. Mandovi is connected to Zuari estuary by a narrow canal, Kumbarjua canal (Modassir and Sanitha, 2003).

The Vasco fishing base is located at the mouth of the Zuari river. Zuari river is about 70 kms in length with the basin area of 973 sq.km, of which the catchment area is 550 sq.km. At the mouth, the Zuari is 5.5 km wide (Modassir and Sanitha, 2003). The source of water of Zuari lies entirely within Goa. In the downstream, the tributary develops alluvial flats and marshes on either side.

The Betul fishing base is located at a distance of one km from the mouth of the Sal river. The Sal river is 24 km long (Modassir and Sanitha, 2003). It

goes through the taluka of Salcete and flows into the Arabian sea near the fort of Cabo da Rama at Betul.

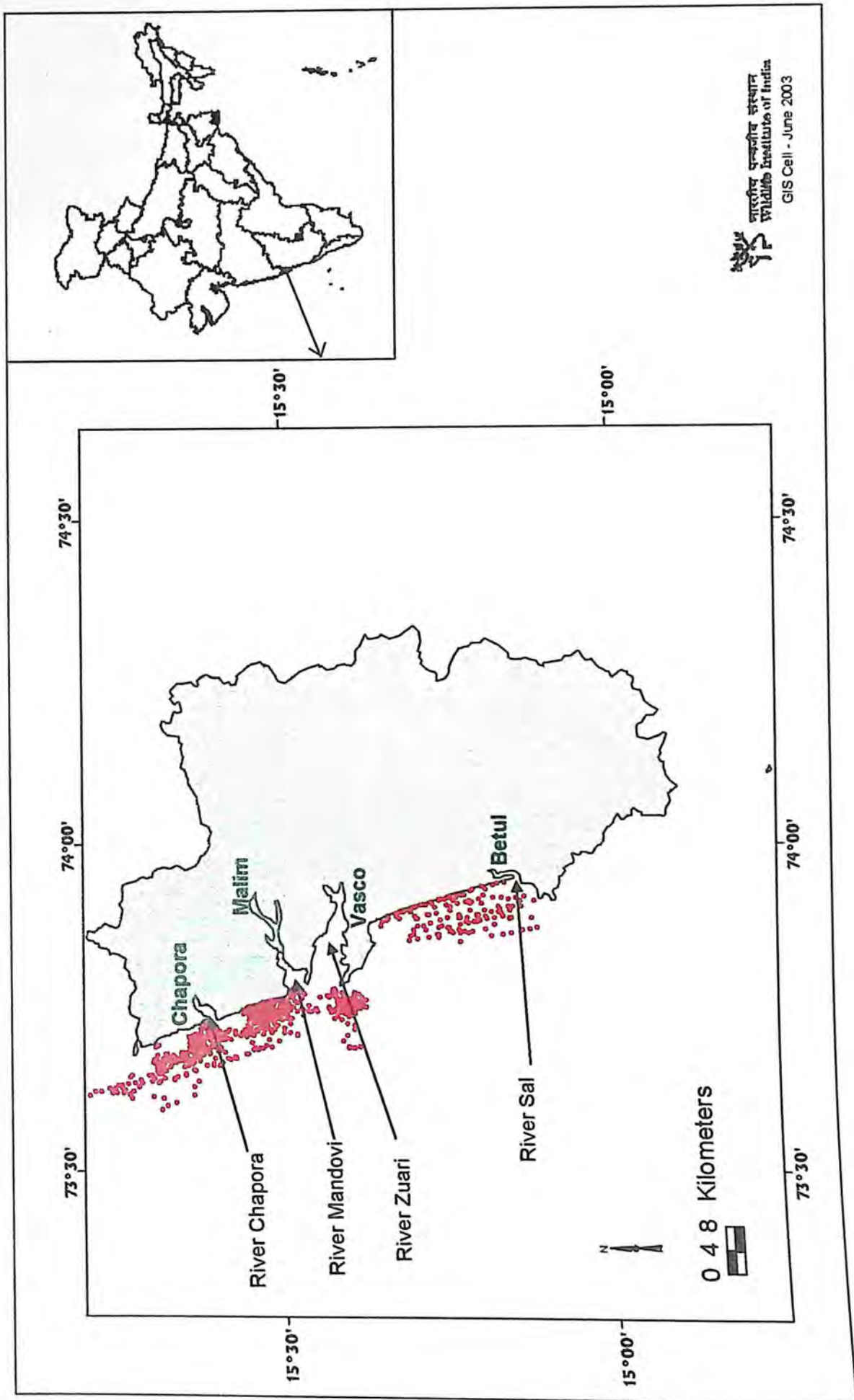
Goa has a total of eight fishing talukas and 89 fishing villages of which 42 are marine and 47 are inland (Shirodkar, Fisheries dept, Panaji–Goa). The different types of fishing gear used in Goa are Seagill net, Sea cast net, Rivergill net, Rivercast net, Rampon net, Drag net, Purse seine net, Trawl net, Barrier (Funtani), Sluicagate net, Stake net, Ormol net and Singel net. The types, number of fishing boats, nets and the landing centers have been summarized in Table 1.

Table 1. Coastal fisheries statistics for Goa

Item	Numbers
No. of mechanized trawlers	1142
No. of motorized wooden country crafts	859
No. of motorized FRP country crafts	109
No. of non-motorized country crafts	1963
No. of registered nets	5238
Fish landing centers (jetties)	5
Fish landing centers (ramps)	14

(Source: Fisheries department, Panaji – Goa)

Fig.1. Map of Goa coast with GPS locations of the area sampled during the study



### **3. METHODS**

#### **Trawler and Trawl Gear**

The trawlers used during the study were Ruston and Hornsby three cylinder engines with a maximum horsepower of 40.7. They were eight to ten meters in length, three to four meters in breadth and 1.5 meters in depth. These trawlers usually operate in shallower areas with the focus on shrimp catch.

The trawling gear used as described by Biswas, (1996) was composed of a towing rope (wire rope of 8-9 mm diameter, 300-400 m length, 3-4 times of water depth), otter board (made of wood or resin of 125 cm (length) × 60 cm (width), Rope (Nylon of 35 mm diameter), supporting pole (Iron bar), wing net (Nylon), ceiling net (Nylon), belly net (Nylon), bag net (Nylon), float (foam plastics), sinkers (iron or ceramic). The trawl net used in the study was of the low opening type (Plate 1).

The trawler net used were eight meters of wing net, ten metres of belly net and three metres of codend net. Mesh sizes used for the wing, belly, throat (part of the bellynet) and codend net were 35mm, 30mm, 28mm and 18mm respectively. For preparation of mesh of wing, belly and throat, nylon string 0.5 mm (thickness) and for codend mesh, the same string was doubled thereby decreasing the mesh size further.

## **Abundance and Diversity**

During the entire study fishing trawlers from the various fishing bases, along the coast of Goa were accompanied to obtain samples of sea snakes. The trawlers usually operate intensively in fish catch rich areas. This would be an inherent bias in the study where the data pertains to specific areas where the fish abundance is high. It is however felt that the data would be able to address the objectives stated.

On each sampling occasion net was casted at a slow speed. The net was towed at speed of 3 - 4 km hr<sup>-1</sup> for approximately 2 -3 hours in each trawl, in depths ranging from 5 - 25 m (Plate 2 A). Propulsion was stopped for net hauling, and the net was rolled up by means of a hydraulic powered net roller. The bag end was untied, and the catch was dumped out on the deck (Plate 2 B). The catch was stored in fish holds after throwing the debris and bycatch caught inside the net (Plate 3 A).

In order to quantify effort, the time at the start of the trawl was recorded. This was the moment when the trawl net was lowered and the trawling began. The start location was obtained using a Global Positioning System (GPS) at the same point. At the start point other parameters that were recorded included start depth in metres, sea state and weather conditions. The speed of the trawler was also recorded when the trawler attained a constant speed. At the end of the trawl the following information was recorded: Time of haul, haul location and haul depth. The start and end time would give the duration of trawl. The start and end locations were fed into a GIS software Arc view 3.2

where the distances were obtained. The distances were computed taking into consideration way points and verified using duration and speed of the trawler.

Besides trawlers, other commonly used fishing gears such as shore seines and sluice gate nets were also checked opportunistically for sea snakes so as to get a fair idea of the species richness in the state. The sea snake species were identified using published keys (Smith 1926;1943).

### **Diet**

To study the diet/ prey items of the snake species, the dead snakes obtained during trawling are first placed in an ice box so as to temporarily stop digestion. They were then transported to a laboratory in the icebox where they were dissected (Plate 3 B). The following variables were recorded. (i) Presence or Absence of food in the crop and intestine. (ii) Prey condition: This was done by ranking the prey as 1,2 and 3 (A rank of 1 was assigned when the prey was intact, 2 when partially digested and 3 when the prey was in the form of an unidentifiable mass of tissue).(iii) Prey identification: The fish were identified upto family level using published keys (De Bruin et al., 1995), identifications were confirmed by comparing them with museum specimens, collections of fish trawled along with the snakes was also made to aid and simplify the identification of snake stomach contents.(iv)The feeding direction of the fish within the crop was recorded as 1 when the head of the fish was ingested first and as 2 when the tail of the fish was ingested first.

## **Mortality**

Mortality of sea snakes due to trawling was studied by observing the sea snakes arriving dead on the deck on completion of a trawl (Wassenberg et al., 2001). In order to identify factors that influence within trawl mortality the following parameters will be recorded. (i) No. of snakes dead, (ii) Species identity, (iii) Morphometric measurements, (iv) Duration of the trawl in secs and (v) Approximate weight of the catch in kg, as per the information given by the trawl personnel. An assessment of the injuries to sea snakes was made by enumerating the cuts, bruises, punctures or skin loss (following Wassenberg et al., 2001). The bruises were counted on head (from tip of the snout to neck), mid body (from neck to vent) and tail (from vent to tail tip). The effect of trawling was examined using two response variables, 'magnitude' and 'intensity'. The magnitude of mortality was measured as the number of dead individuals found in the catch and the intensity of mortality was measured as the proportion of dead individuals found in each catch.

## **Morphometry**

Morphometric measurements were taken for all snakes caught in trawls. Total body length (TBL), Snout vent length (SVL) and Tail length (TL) were taken to nearest 0.5 cm with a steel tape; Gape width (GW), Gape length (GL) and girth at the thickest part of the body (G1, G2) to the nearest 0.01 cm with a dial vernier calliper (Mitutoyo <sup>TM</sup>). The weight (Wt) of all snakes was taken to the nearest gm using a Pesola Balance. Live snakes caught during trawling were released back to the sea after taking morphometric measurements, whereas dead snakes were placed in polythene bags with tags, which were

then placed in an icebox to be used for further laboratory analysis. Voucher specimens of sea snakes were preserved using standard protocol (Simmons, 1987).

### Data analysis

Abundance of sea snakes in trawlers was calculated as Catch Per Unit Effort (CPUE; Snedecor and Cochran, 1967) in Equation 1 and the 95% confidence interval of CPUE was calculated using Equation 2.

$$R = \frac{\sum Y}{\sum X} \quad (\text{Equation 1})$$

$R$  = Sum of sea snake catch in different trawls/ Sum of unit effort (CPUE)

$\sum Y$  = Total No. of sea snakes

$\sum X$  = Sum of all lengths trawled in metres/21 × Total time(mins) trawled/60

$$95\%CIofR = R \pm 1.96 \left[ \frac{1}{\bar{X}} \right] \sqrt{\sum \frac{(Y-RX)^2}{n(n-1)}} \quad (\text{Equation 2})$$

$\bar{X}$  = Mean Effort

$X$  = Effort (Standardized to 20m net hours)

$R$  = Sum of sea snake catch in different trawls/ Sum of unit effort (CPUE)

$Y$  = No. of sea snakes per trawl

$n$  = No. of tows

CPUE data from each base was tested for normality using Kolmogorov-Smirnov goodness of fit test at  $\alpha = 0.05$  for all species in each season. The Kruskal-Wallis test was used to compare the variation in the data as it did not

follow normal distribution. Man Whitney U tests were employed to test whether the CPUE at individual bases were significantly different. Rarefaction curves (Krebs, 1989) were used to compare sea snake communities across the four trawl bases. Simpson's (1-D) was used to quantify the sea snake diversity following Krebs (1989) for the different trawl bases. The dissimilarity of the sea snake communities in four bases was compared using a Euclidean distance with complete linkage in a cluster analysis (Pielou, 1984). A species accumulation curve of the fish families in the stomach of *Lapemis curtus* was made. The proportion of snakes showing presence and absence of food as well as the proportion of different fish families present in the gut of *L. curtus* and *Enhydrina schistosa* were represented using stacked bar diagrams. *Thallasophina viperina* and *Acrochordus granulatus* were excluded from the analysis as their sample sizes were represented only by two and three individuals respectively. Proportion of fish families fed upon by different size classes, sexes and time of capture of the snake were computed in case of *L. curtus* and depicted in the form of stacked bar diagrams. Pearson's and Spearman's correlation coefficient (Sokal and Rohlf, 1995) was used to depict the relationship between number of sea snakes captured and the number of dead individuals. Graphs with mean and 95% CI were used to depict the variation in the number and proportion of dead snakes with tow time, total wt of catch and mean depth. The number and proportion of dead in different class intervals of duration of trawl, weight of catch and depth of water were tested for normality using Kolmogorov-Smirnov goodness of fit test for all species in each season. Kruskal-Wallis test was employed to test for differences in the samples. Pie charts were used to depict composition of

number of trawls with only live snakes, only dead snakes, and live and dead snakes. Stacked bars were used to show proportions of live and dead in different species and then sex in each of the species. Mortality of sea snakes were tabulated for various trawl bases, time of the day, season and individuals with presence or absence of food. A Chi square test of independence was done to examine the influence of these parameters on the mortality of sea snakes. A Chi square test was also done to test if the number of bruises in live and dead snakes in *L.curtus* and *E.schistosa* varied significantly than expected.

Scatter plots were made to show the relationships between snout vent length with tail length and weight in the case of *L.curtus* and *E.schistosa*. Log normal transformation of these variables was used for the analysis. The regression equations were calculated by forcing the regression line through the origin (Sokal and Rohlf, 1995). The coefficients of variation were computed for each of the morphometric measurements taken viz. snout vent length, weight and tail length. In all tests  $\alpha$  was set at a 0.05 level. The statistical analysis was carried out using SPSS 8.0 (Norusis, 1992). Graphs and other computations were done using EXCELL 2000.

## 4. RESULTS

### Abundance and Diversity

During the study 194 trawls were sampled which spanned for a duration of 385 hrs from 22<sup>nd</sup> November 2002 to 10<sup>th</sup> April 2003. The effort yielded 231 snakes which translated to CPUE of  $1.218 \times 10^{-5}$  snakes/net.hr. The CPUE in the four trawl bases were significantly different (Fig. 2; Kruskal Wallis test,  $\chi^2 = 19.91$ ,  $df=3$ ,  $p<0.05$ ). The CPUE of Chapora however did not differ significantly in comparison with Malim and Betul (2 tailed Man Whitney U,  $p>0.05$ ). Similarly the CPUE of Malim did not differ significantly from Betul (2 tailed Man Whitney U,  $p>0.05$ ). However the CPUE of Vasco differed significantly from Chapora, Malim and Betul (2 tailed Man Whitney U,  $p<0.05$ ).

231 individuals comprising of four species of sea snakes were found during the study (Annexure 1). These were *Lapemis curtus*, *Enhydrina schistosa*, *Thalassophina viperina* and *Acrochordus granulatus*. Opportunistic searches revealed that *Cerberus rhynchops* were encountered in sluice nets and *Pelamis platurus* was recognized as an occasional species caught in shore seines. There were four species of sea snakes in the first 85 individuals that were sampled and there was no increase in the number of species till the end of the study when 231 individuals were sampled.

The rarefaction curve did not stabilize at the end of the sampling period (Fig. 3). The rarefaction curves for the three bases show a high diversity, except Betul where the number of species remained unchanged even after 45

individuals were sampled (Fig. 4). The Simpson's Index was the highest for Vasco, followed by Malim, Chapora and Betul. Thus we can conclude that Vasco is the most diverse followed by Malim, Chapora and Betul (Table 2). It is also observed that bases with higher catch per unit effort have a lower diversity which is contradictory to conventional thought (Fig.5).

Species abundances showed considerable differences across the four bases. *L.curtus* and *E.schistosa* were common to all four bases. *A.granulatus* (N=3) were caught from Vasco and Chapora. *T.viperina* (N=2) were caught from Malim only (Fig. 6). The dendrogram using Euclidian distances based species composition shows that the bases Malim and Vasco are the closest. It also indicates that Chapora and Betul are very similar to each other (Fig. 7). Vasco and Betul were the most dissimilar in terms of sea snake composition.

There was a tendency for *E.schistosa* to be found in shallower waters (5-10m) and its abundance decreased with increase in depth (Fig. 8), while *L.curtus* was found to have a lower abundance in shallower waters and its abundance increased with the increase in depth. During the study females were caught in much higher numbers than in case of males in both *L.curtus* and *E.schistosa* their percentages were 73% and 68% of the total catch respectively. The variation in the number of male and female snakes/trawl with depth followed the same pattern in both *L.curtus* (Fig. 9a) and *E.schistosa* (Fig. 9b). In both cases females were dominant all in their three depth classes. In *E.schistosa* there was a drastic reduction in their numbers beyond 15m depth and all the individuals encountered were females.

Fig.2. Catch of sea snakes Per Unit Effort in four trawl bases along the coast of Goa between November 2002 and April 2003

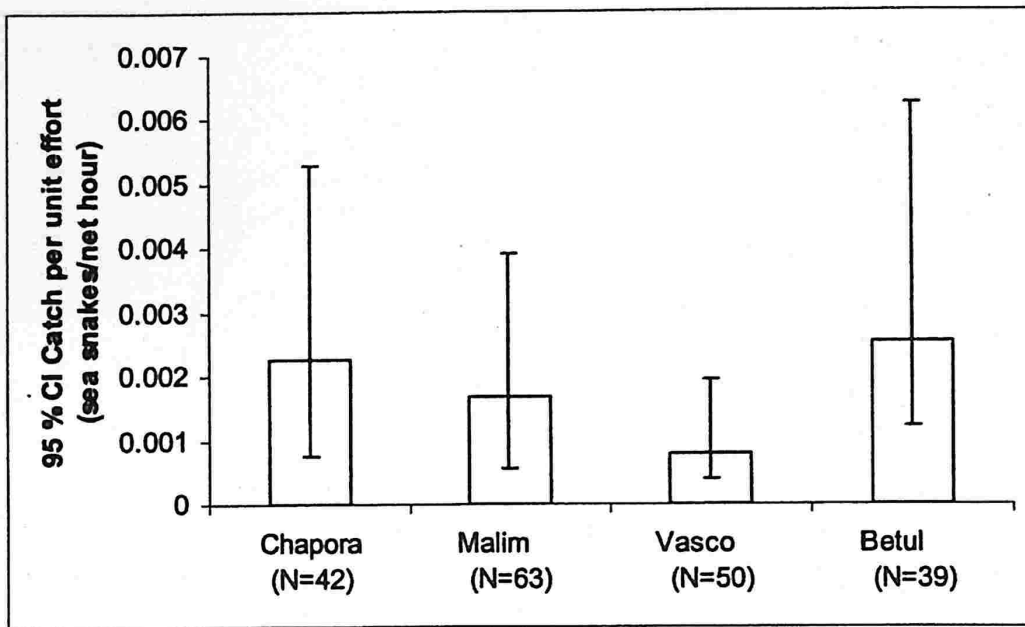


Fig. 3. Rarefaction for number of sea snakes species along the coast of Goa between November 2002 and April 2003

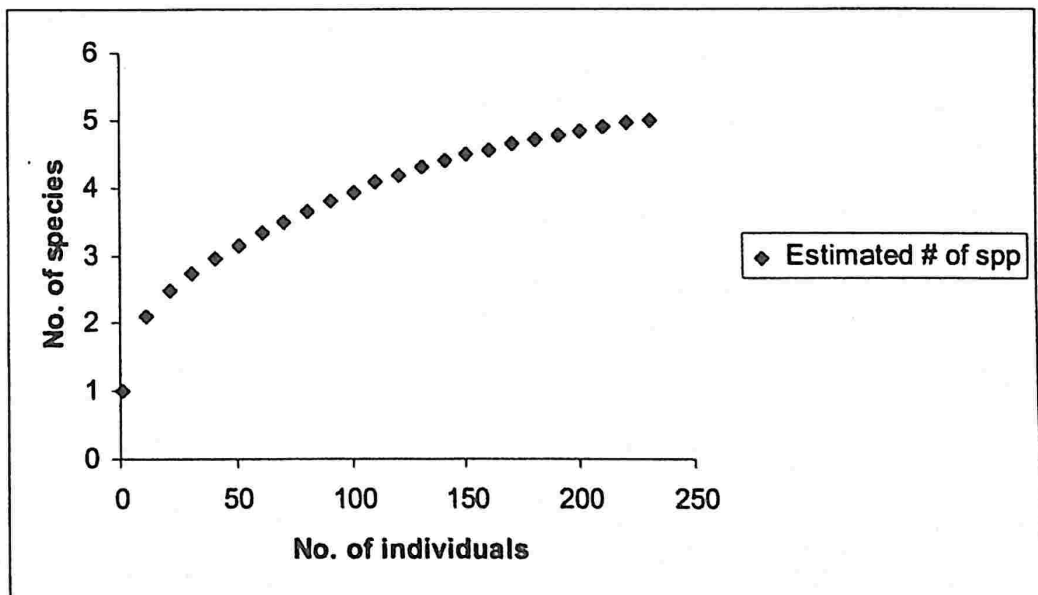


Fig. 4. Rarefaction across trawl bases for sea snake species composition along the coast of Goa from November 2022 and April 2003.

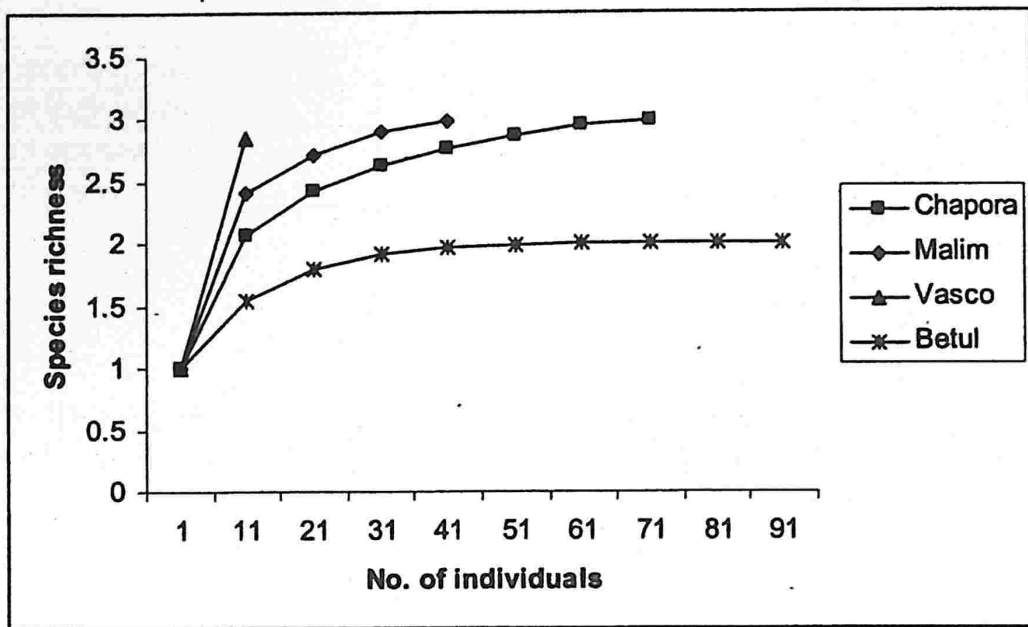


Fig. 6. Composition of sea snake species at the four different fishing bases along the coast of Goa between November 2002 and April 2003

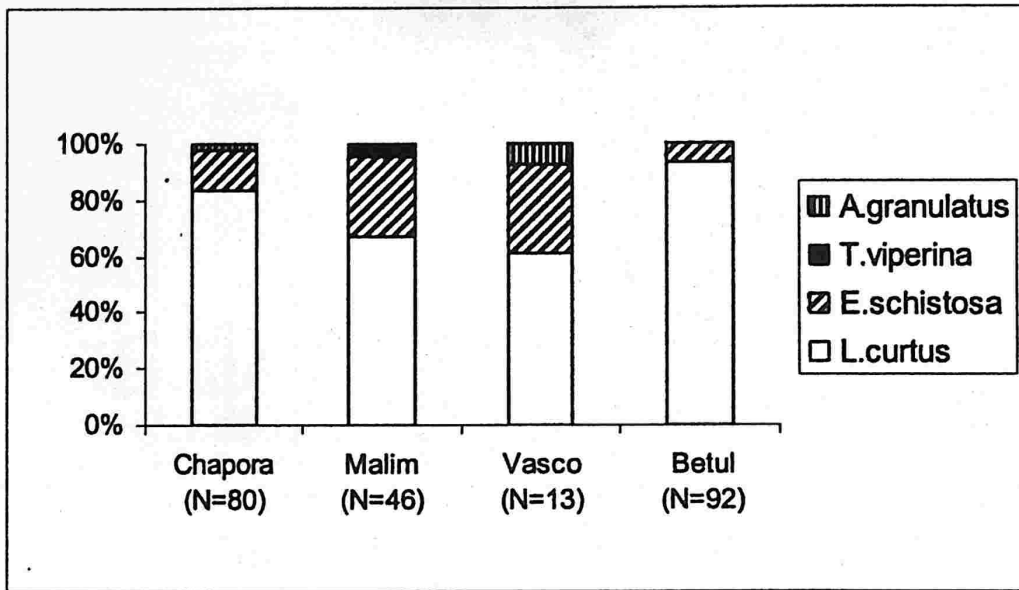


Fig. 7. Dendrogram based on Euclidean Distance cluster analysis with complete linkage showing similarities across four different fishing bases along the coast of Goa between November 2002 and April 2003

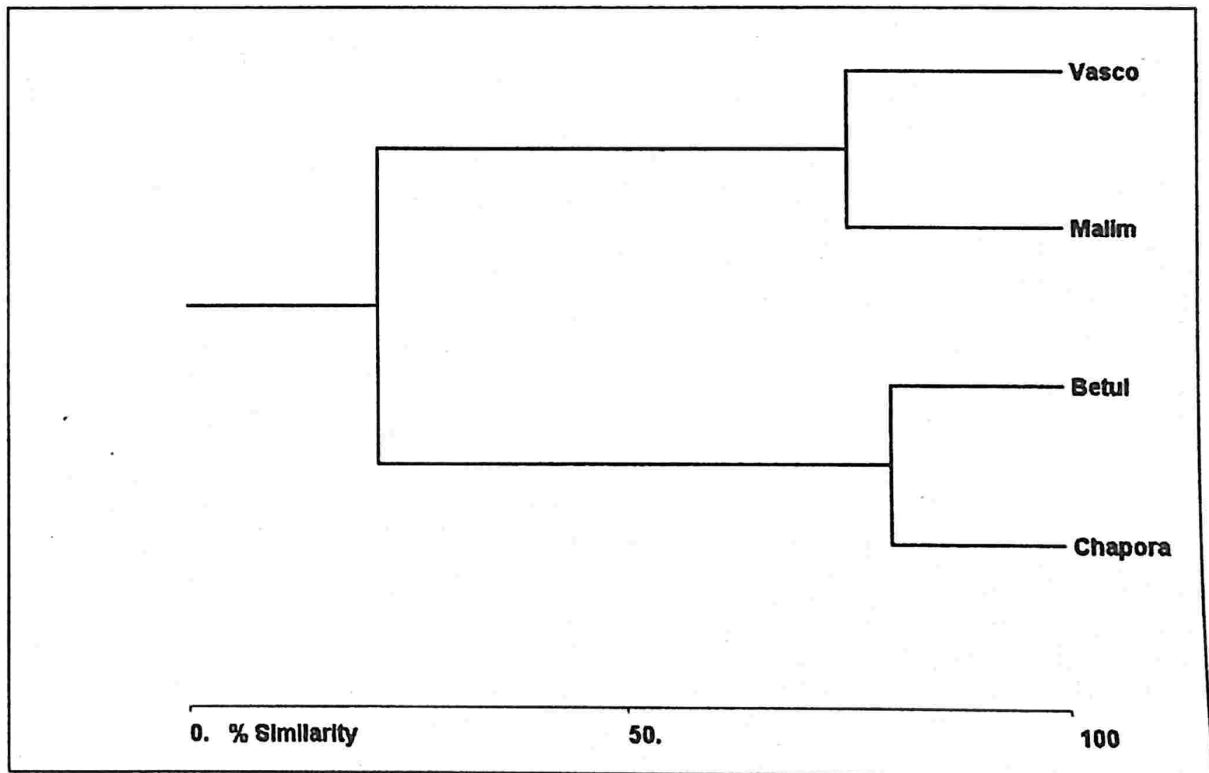


Fig. 8. Percentage composition of sea snake species occurring at different depths of the water column along the coast of Goa between November 2002 and April 2003.

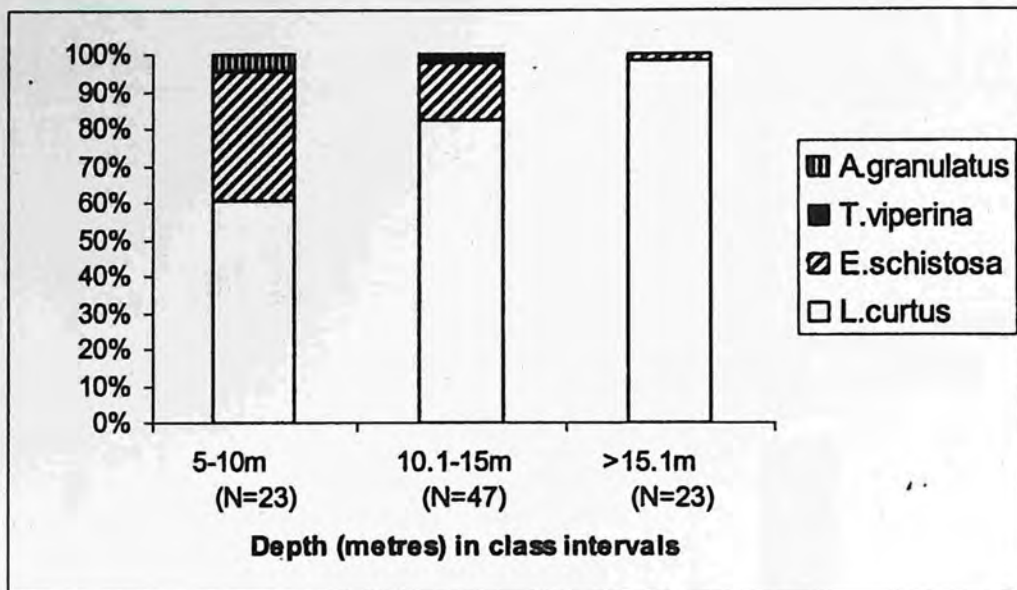
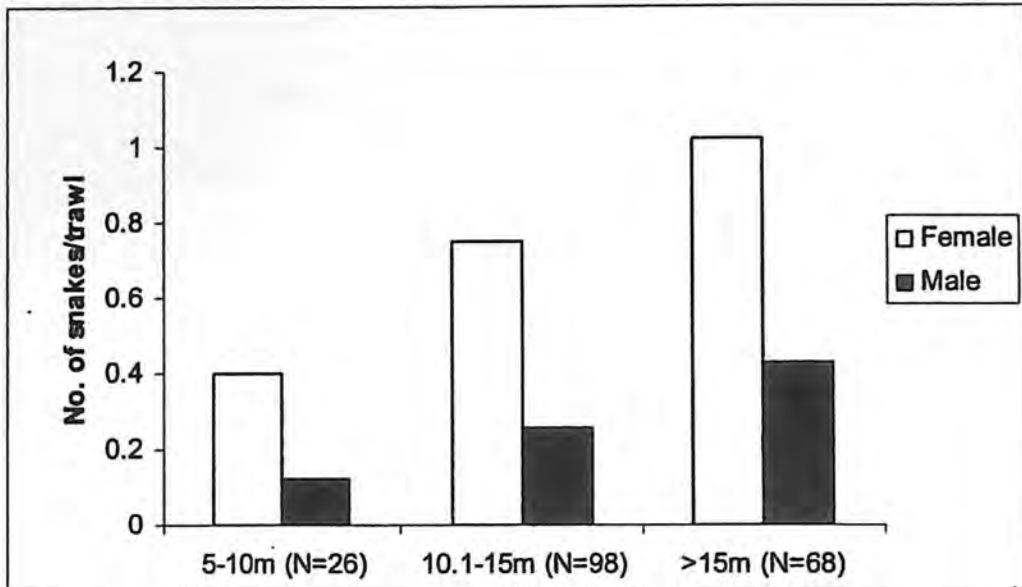
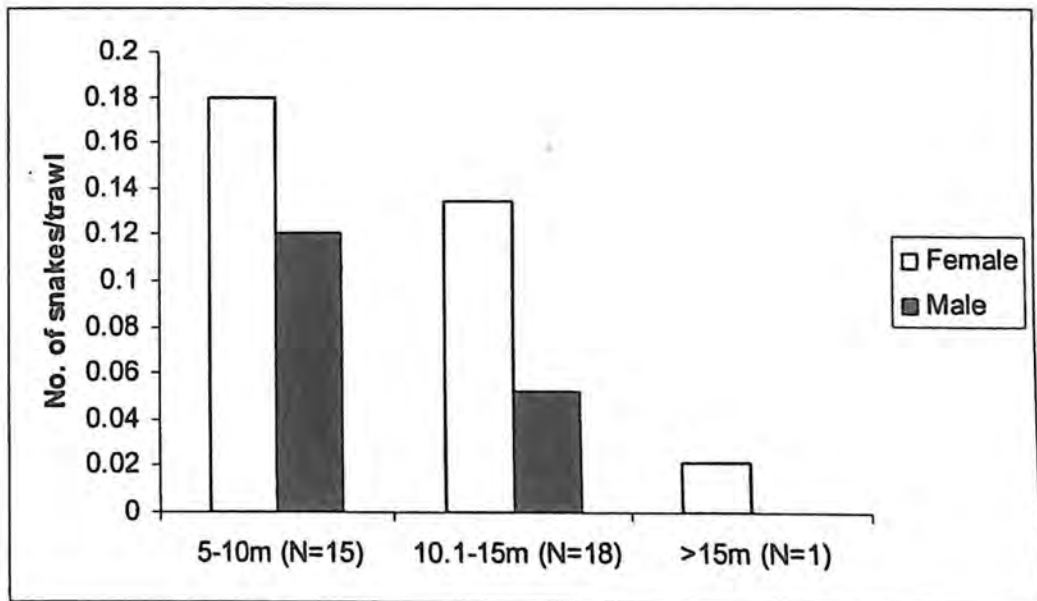


Fig. 9a. Abundances of males and females at different depth classes, along the coast of Goa between November 2002 and April 2003

a) *L.curtus*



b) *E.schistosa*



## Diet

Of the 165 individuals of *L. curtus* examined for gut contents 90% of them had food, whereas in the remainder there was no food in the stomach (Fig. 10). 56% of the 18 *E. schistosa* examined had food in their stomachs, which was mostly in an unrecognizable mass (Fig. 10). The two individuals of *A. granulatus* examined had food in their stomachs. In *L. curtus* five fish families were identified from 145 stomachs of the total of 165 individuals examined for gut contents (Annexure 2). The accumulation of fish families in the sample of snakes examined did not flatten even after sampling nearly 150 individuals (Fig. 11). The prey was ingested head first 95% of the time in *L. curtus* while the remaining 5% were ingested tail first. The prey was identifiable in only 59 occasions upto family level. Clupeidae (57%), dominated the diet of *L. curtus* along with Cynoglossidae (34%), Terapontidae, Trichiuridae and Sciaenidae constituted a small fraction of the diet in the species ( Fig. 12). In *E. schistosa* three fish families were obtained from a sample of 18 snakes examined for gut contents. The fragments of food items found in the stomach of this species were from fish belonging to families Ariidae, Sciaenidae and Clupeidae.

When the composition of fish families in the gut in relation to the size class of the snake was examined, Cynoglossidae, Clupeidae and Terapontidae occurred in all three size classes (Fig.13). Trichiuridae was found only in size class 471 – 570 mm and family Sciaenidae was represented only in >570mm size class (Fig. 13). Clupeidae, followed by Cynoglossidae were found to dominate all three size classes, however their proportions varied. It was also

found that the consumption of Clupeids was the highest in the size class 370 – 470mm and decreased in the larger size classes of snakes (Fig. 13). On the other hand Cynoglossids were consumed in lower proportions in the size class 370–470mm and this increased slightly in the higher size classes (Fig. 13).

The families Clupeidae, Cynoglossidae and Terapontidae were represented in the diet of both sexes. The families Sciaenidae and Trichiuridae were only represented in the diet of female snakes (Fig. 14). As expected there was overlap in the diet of male and female snakes in *L.curtus*. The fish families found in the diet of sea snakes overlapped by 92% with the assortment of commercially valuable catch of fish.

The families Clupeidae and Cynoglossidae were represented in the diet of *L. curtus* at all of the three time intervals of the day. The family Terapontidae occurred during the noon and afternoon but was absent during the morning hours. Trichiuridae was only represented during noon hours and Sciaenidae only during afternoon hours (Fig. 15). The variation of the family Clupeidae in the diet of *L.curtus* over the three times of the day is not much, however the variation in the Cynoglossids is remarkable (Fig.15). The consumption of Cynoglossids was seen to be highest in the morning, it decreased dramatically during Noon and there was a slight increase in the afternoon hours (Fig. 15).

Fig. 10. Presence /Absence of food in the stomach of sea snakes examined along the coast of Goa between November 2002 and April 2003

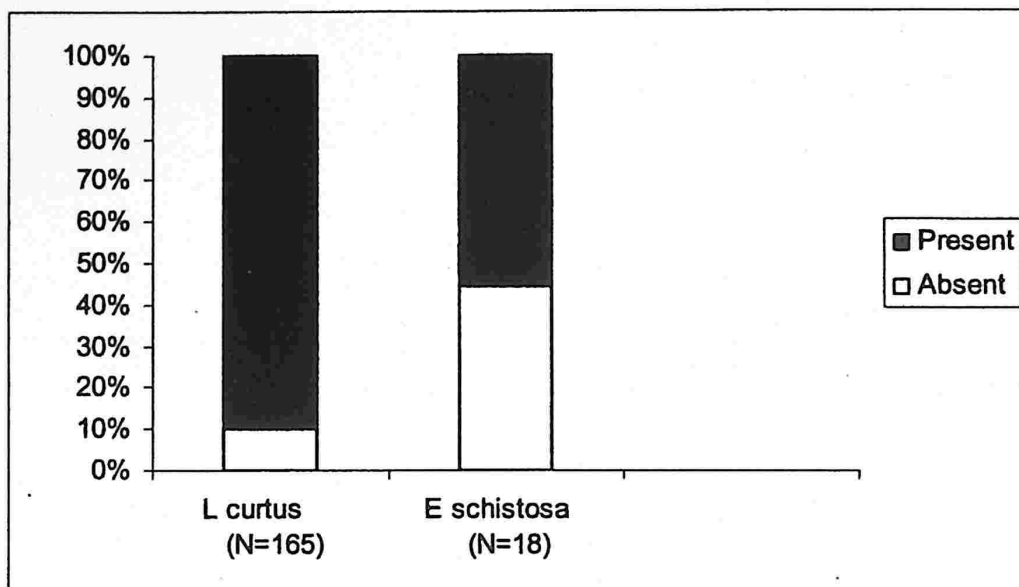


Fig.11. Species accumulation curve for fish families found in the gut of *L. curtus* along the coast of Goa between November 2002 and April 2003

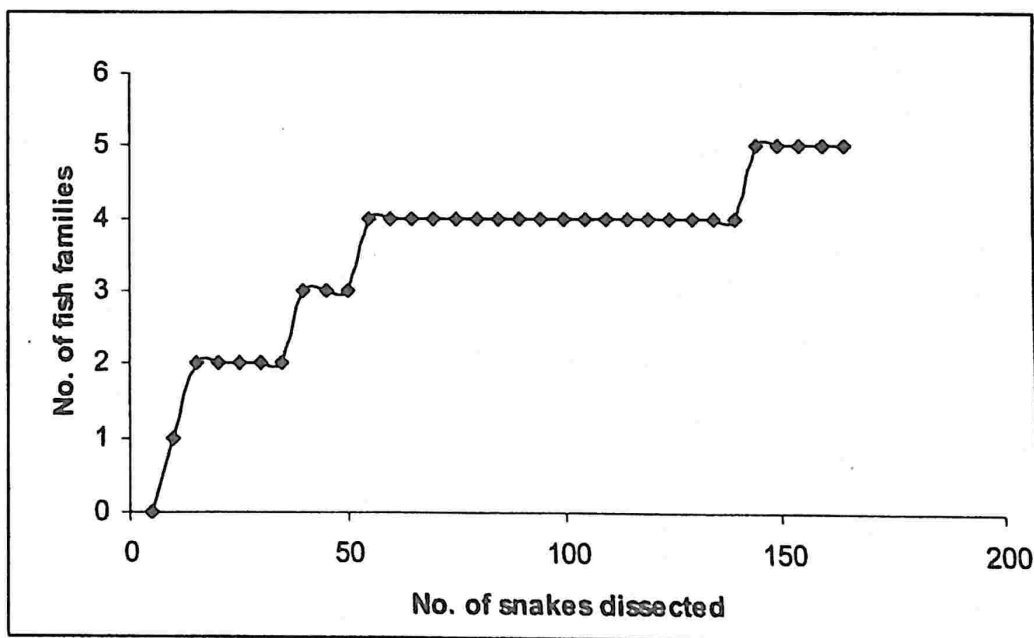


Fig. 12. Percentage composition of different fish families in the diet of *L.curtus* (N = 59) along the coast of Goa between November 2002 and April 2003.

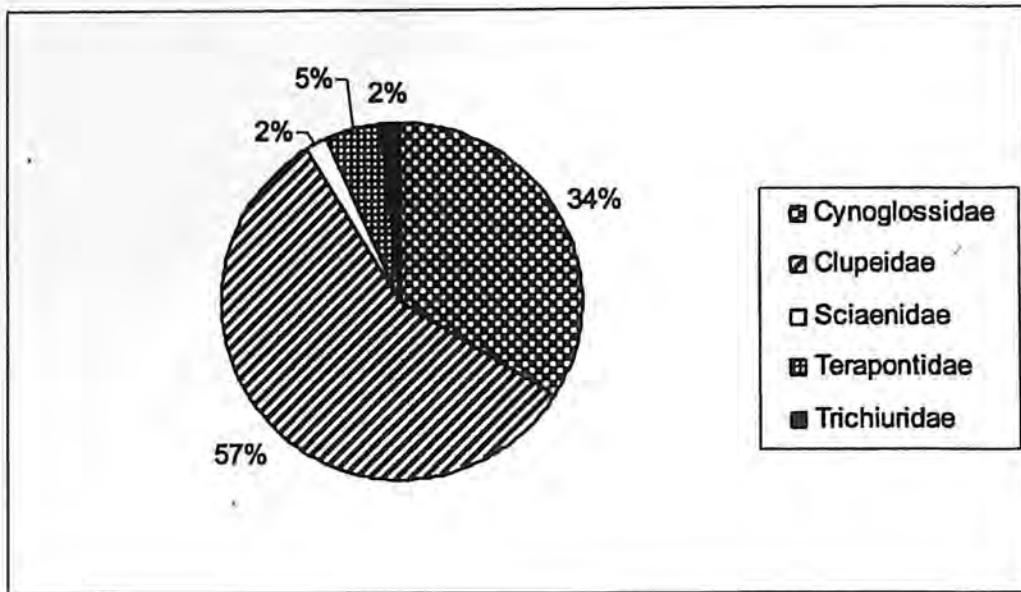


Fig. 13. Percentage composition of fish families in the diet of different size classes of *L.curtus* along the coast of Goa between November 2002 and April 2003

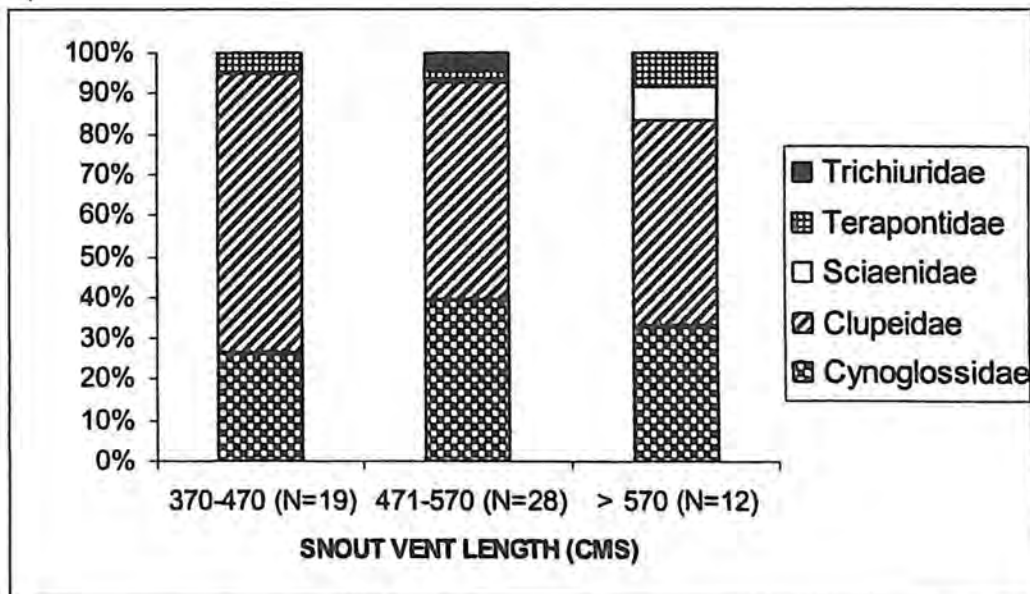


Fig. 14. Percentage composition of fish families in the diet with respect to sex in *L.curtus* along the coast of Goa between November 2002 and April 2003.

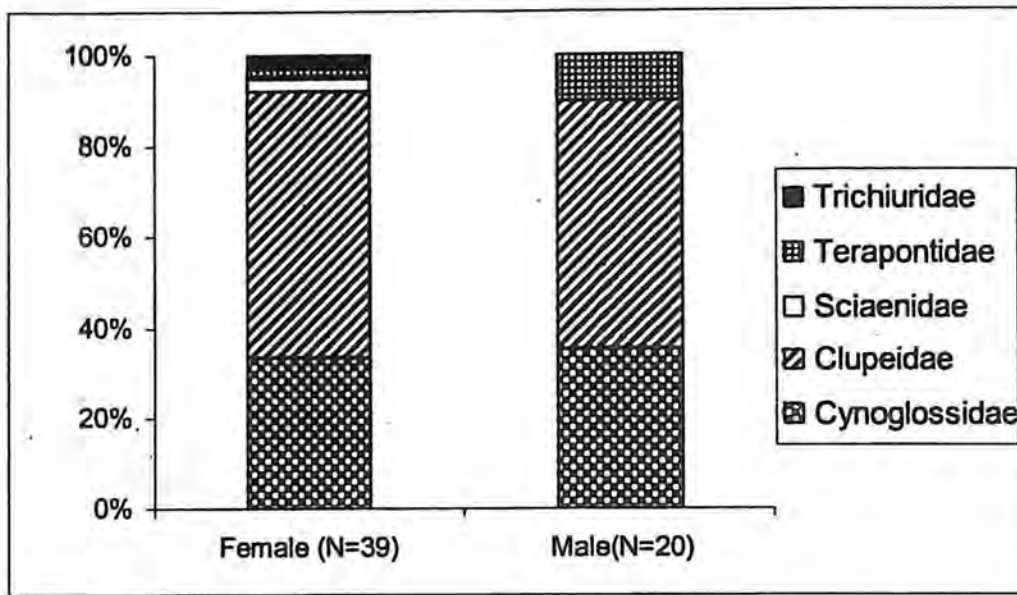
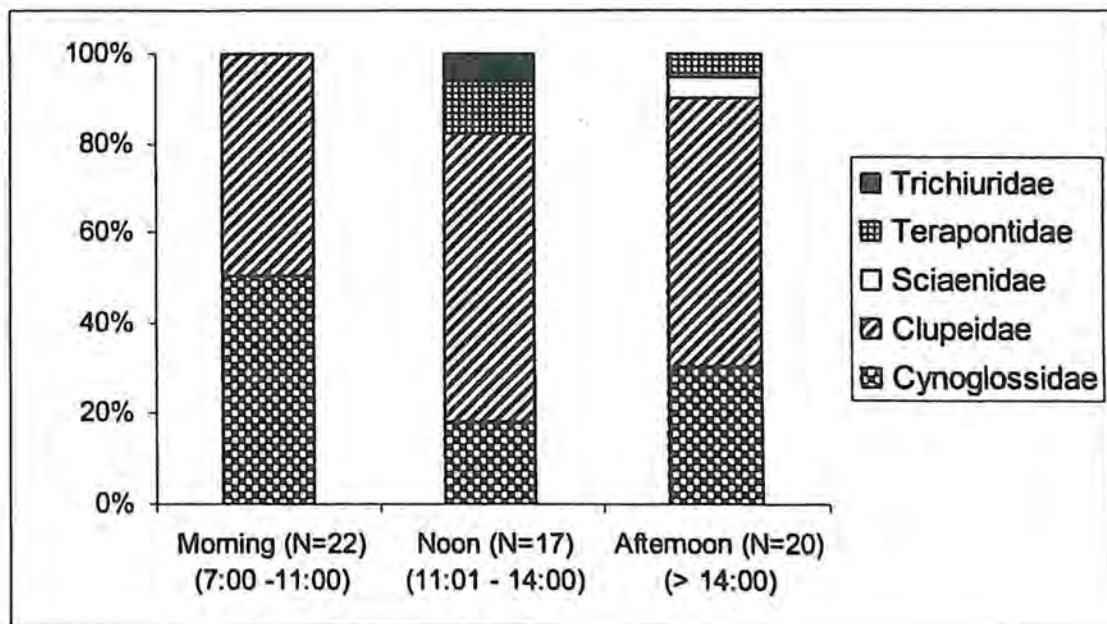


Fig. 15. Time of snake capture vs percentage composition of fish families in the diet of *L.curtus* along the coast of Goa between November 2002 and April 2003



## **Mortality**

There was a positive correlation between the number of sea snakes captured and the number of dead sea snakes (N=194,  $r = 0.881$ ,  $p < 0.01$ ;  $r_s = 0.687$ ,  $p < 0.01$ ; Fig. 16). In other words trawls with greater number of sea snakes also had a greater number of dead individuals.

The number of dead snakes in the three different trawl duration class intervals were significantly different (Kruskall Wallis test,  $\chi^2 = 14.146$ ,  $df=2$ ,  $p < 0.05$ ; Fig. 17). Trawls of longer duration had a greater magnitude of mortality leading to a greater number found dead (Fig.17). The intensity of mortality measured as the proportion of dead snakes in the three different duration class intervals were also significantly different (Kruskall Wallis test,  $\chi^2 = 8.488$ ,  $df=2$ ,  $p < 0.05$ ; Fig. 18). There was a slight increase in the intensity of mortalities from trawl between the first and the second duration class intervals. The increase in the intensity of mortalities was dramatic for trawls having durations greater than 10,000 seconds.

The number of dead snakes in the three different weight of total catch class intervals were significantly different (Kruskall Wallis test,  $\chi^2 = 7.309$ ,  $df=2$ ,  $p < 0.05$ ). There was a slight increase in the magnitude of mortality with the increase in the catch weight (Fig. 19). The proportion of dead snakes in the three different total catch class intervals were significantly different (Kruskall Wallis test,  $\chi^2 = 10.711$ ,  $df=2$ ,  $p < 0.05$ ). The trawls with weight of catch greater than 90kg had the highest intensity of mortality (Fig. 20).

The number of dead snakes in the three different mean depth class intervals were significantly different (Kruskall Wallis test,  $\chi^2 = 16.355$ ,  $df=2$ ,  $p < 0.05$ ; Fig. 21). There was a steady increase in the magnitude and intensity of mortality with the increase in the mean depth at which the sea snakes were trawled from (Fig.21-22). The proportion of dead snakes in the three different mean depth class intervals were also significantly different (Kruskall Wallis test,  $\chi^2 = 19.686$ ,  $df=2$ ,  $p < 0.05$ ; Fig. 22)

In the 194 trawls that were sampled, in 102 (52%) trawls snakes were absent, 37 (19%) trawls had only live snakes, 36 (19%) of the trawls had only dead snakes and 19(10%) trawls had both live and dead snakes (Fig. 23).

Of the 231 snakes obtained during the 194 trawls, 60 % were dead. The intensity of mortality varied from 41–69% in the four trawl bases. The percentages of *L.curtus* and *E.schistosa* found dead on arrival aboard the trawler were 69% and 12% respectively. Three individuals of *A.granulatus* were caught of which one was dead. The two individuals of *T.viperina* which were caught were alive. The proportion of *E. schistosa* found alive was higher (88%) than *L.curtus* (31%) (Fig. 24).

In *L.curtus* the percentage of females and males found dead on arriving aboard the trawler are 65% and 82% respectively. Males tend to suffer greater mortality than do females. In *E.schistosa* females (13 %) suffer marginally higher mortality than males (9%).

The number of sea snakes dead per trawl was the highest at Betul, followed by Chapora, Malim and Vasco (Table 3a). The mortality of sea snakes was not found to be significantly influenced by the time of the day ( $\chi^2=1.07$ ,  $df=2$ ,  $p>0.05$ ) however the number of snakes dead per trawl was found to be highest during the afternoon, followed by noon and lowest during the morning hours (Table 3b). The mortality of sea snakes was found to significantly vary with season ( $\chi^2=9.88$ ,  $df=2$ ,  $p<0.05$ ) and it was found that most of the dead sea snakes per trawl was during November–December followed by January–February and the least during March–April (Table 3c). The influence of food present in the stomach on mortality was examined in *L.curtus* and *E.schistosa*. All snakes with food absent ( $N = 17$ ) were found dead. Of the sea snakes which had food present in the crop ( $N = 148$ ), 77% were dead. The mortality of sea snakes was significantly influenced by the presence or absence of food in the stomach ( $\chi^2 = 4.93$ ,  $df = 1$ ,  $p<0.05$ )

The number of bruises on the body was higher in dead snakes than in live specimens. There was a significant influence of the number of bruises on the number of live and dead snakes in *L.curtus* ( $\chi^2=153.36$ ,  $df=2$ ,  $p<0.05$ ) and in *E.schistosa* ( $\chi^2= 401.92$ ,  $df=2$ ,  $p<0.05$ ).

Fig. 16. Relationship between No. of sea snakes captured and No. of dead seasnakes along the coast of Goa between November 2002 and April 2003.

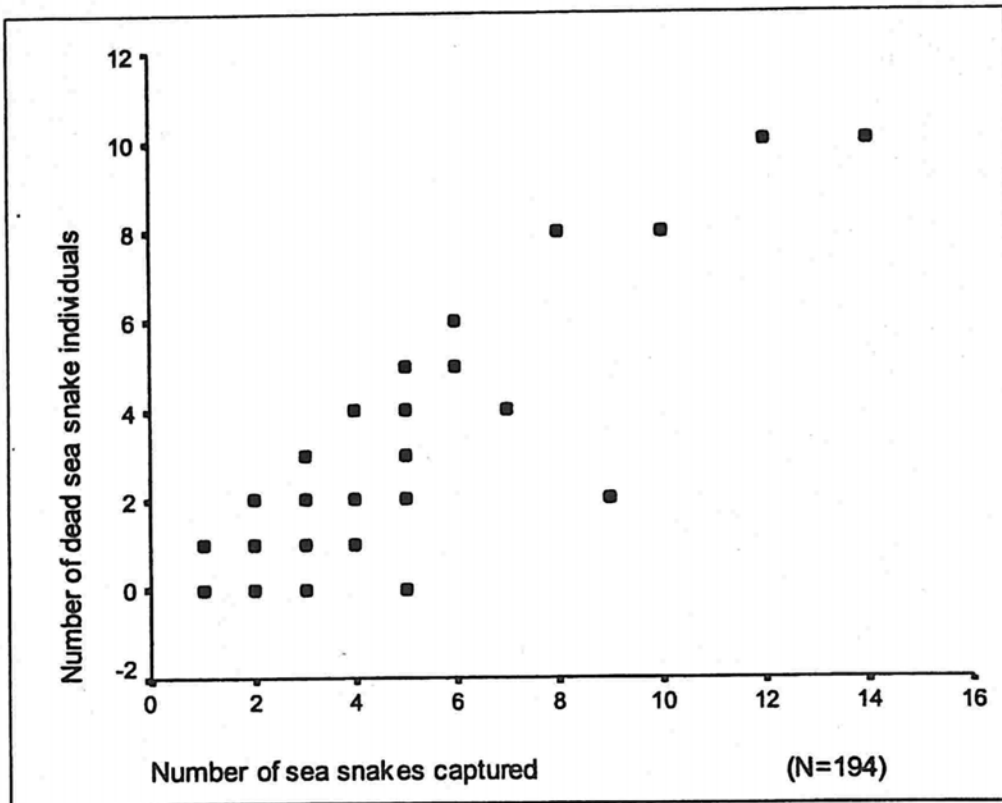


Fig. 17. The variation in the number of dead sea snakes with duration of trawl, along Goa coast between November 2002 and April 2003

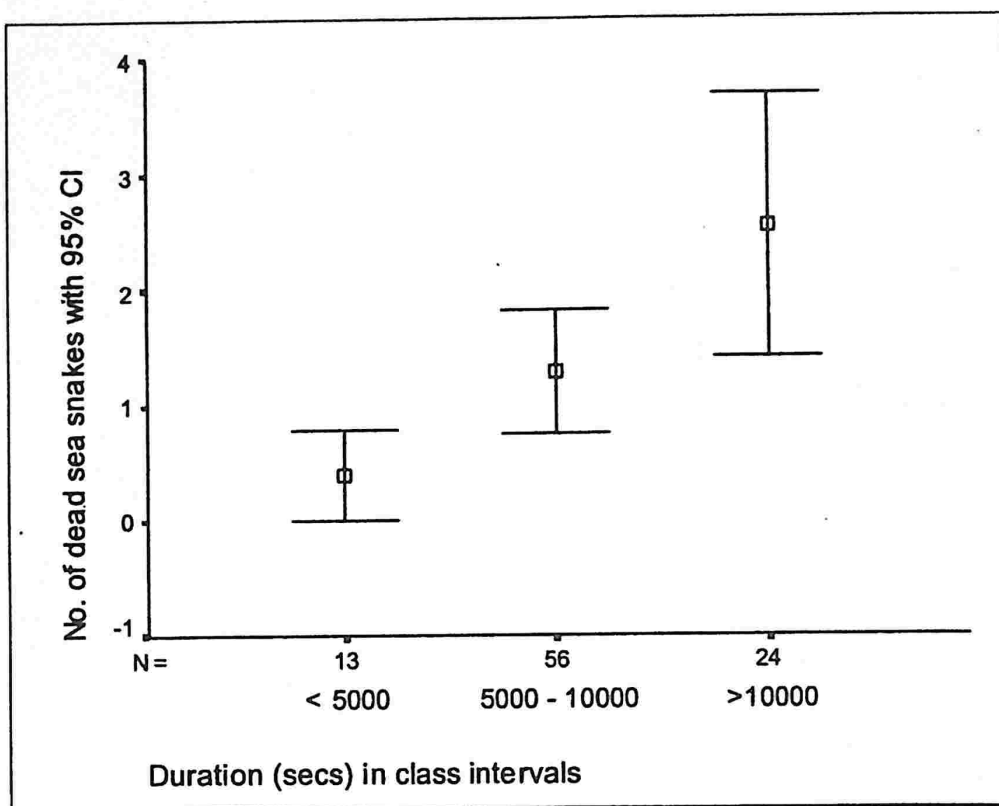


Fig. 18. The variation in the proportion of dead sea snakes with duration of trawl along Goa coast between November 2002 and April 2003.

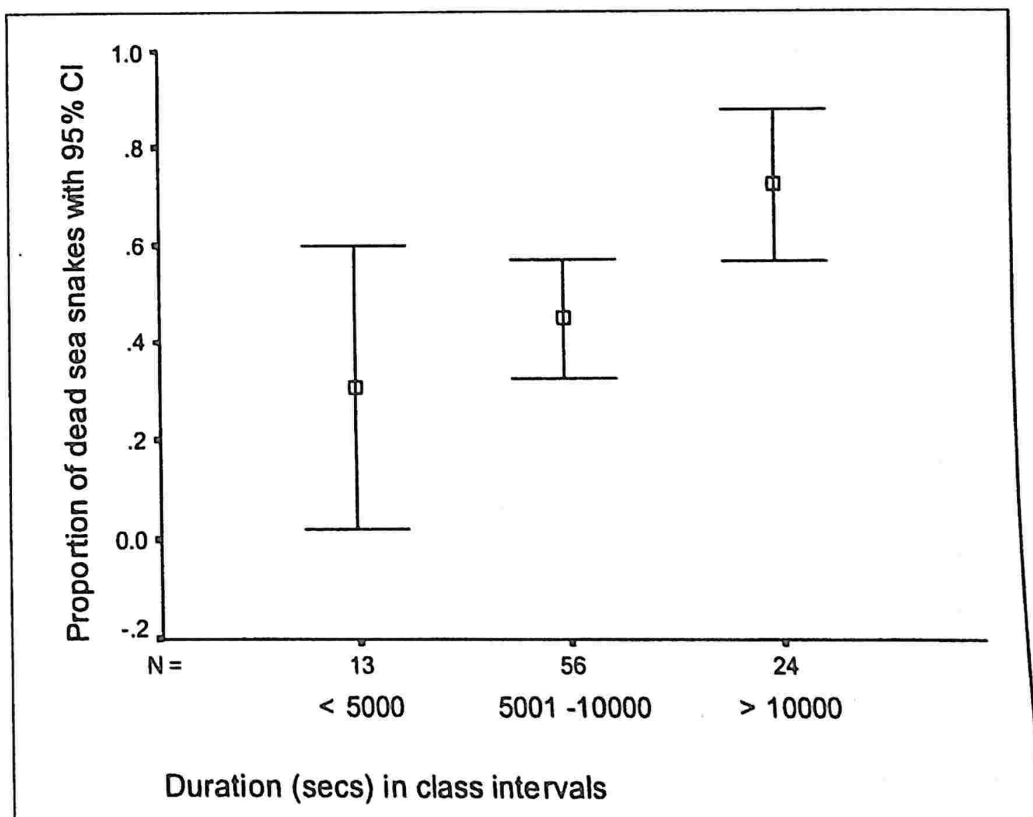


Fig. 19. The variation in the number of dead sea snakes with the weight of the catch along Goa coast between November 2002 and April 2003.

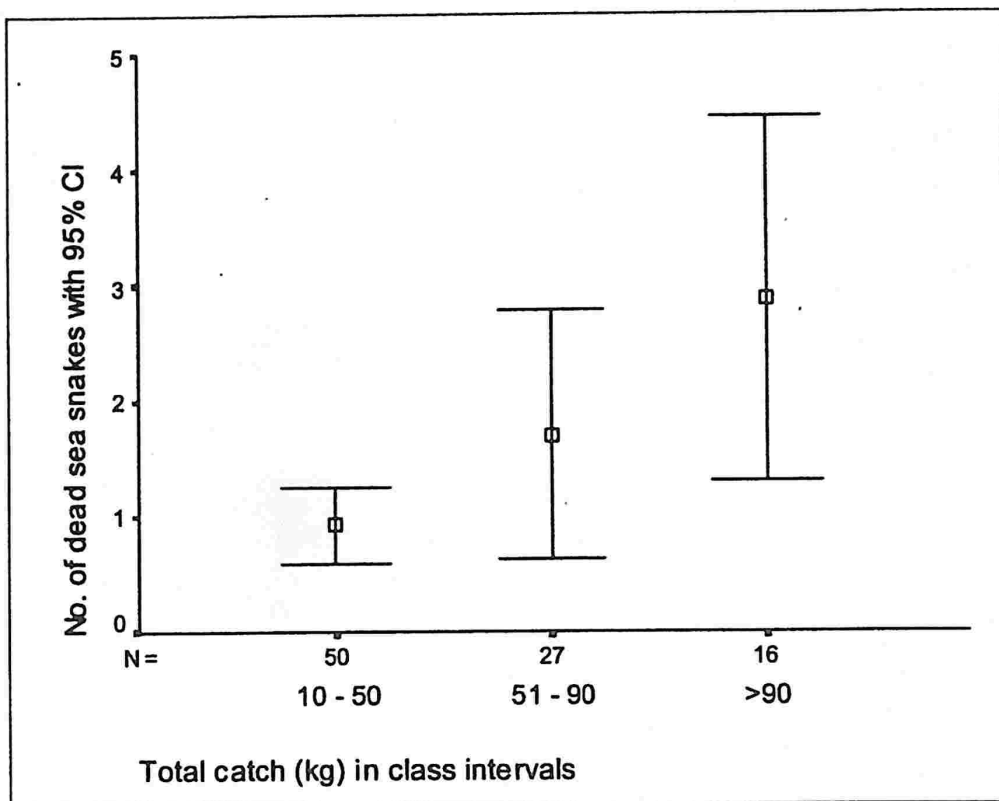


Fig. 20. The variation in the proportion of dead sea snakes with the weight of catch along Goa coast between November 2002 and April 2003.

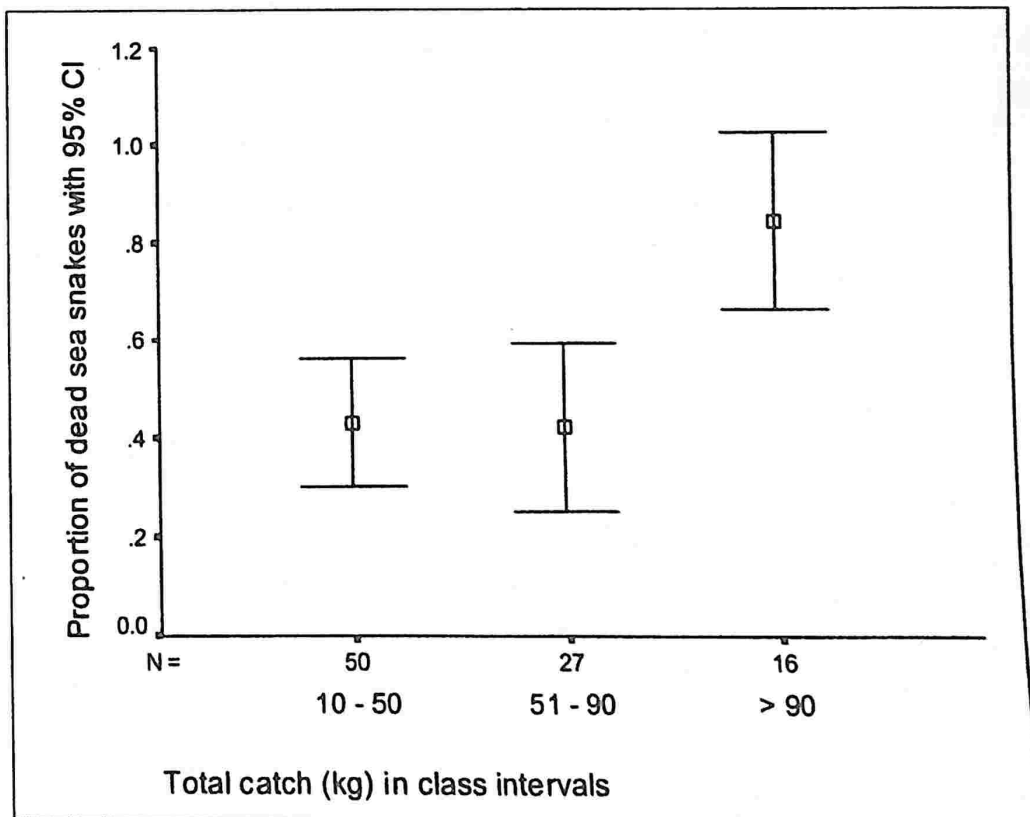


Fig. 19. The variation in the number of dead sea snakes with the weight of the catch along Goa coast between November 2002 and April 2003.

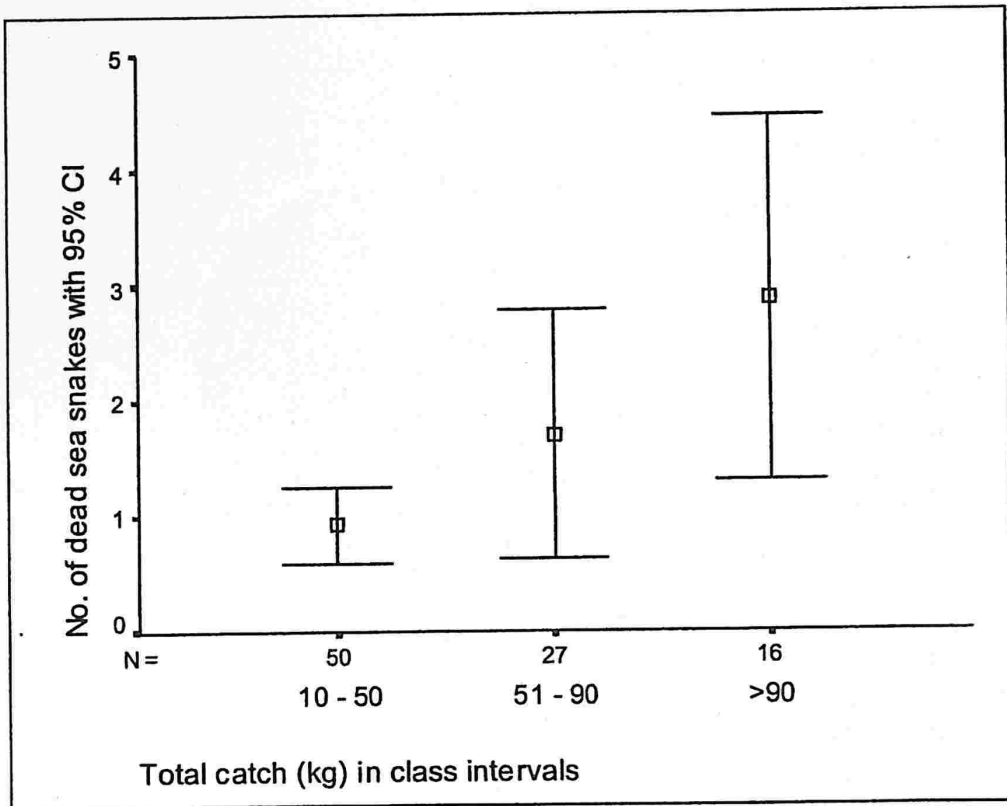


Fig. 20. The variation in the proportion of dead sea snakes with the weight of catch along Goa coast between November 2002 and April 2003.

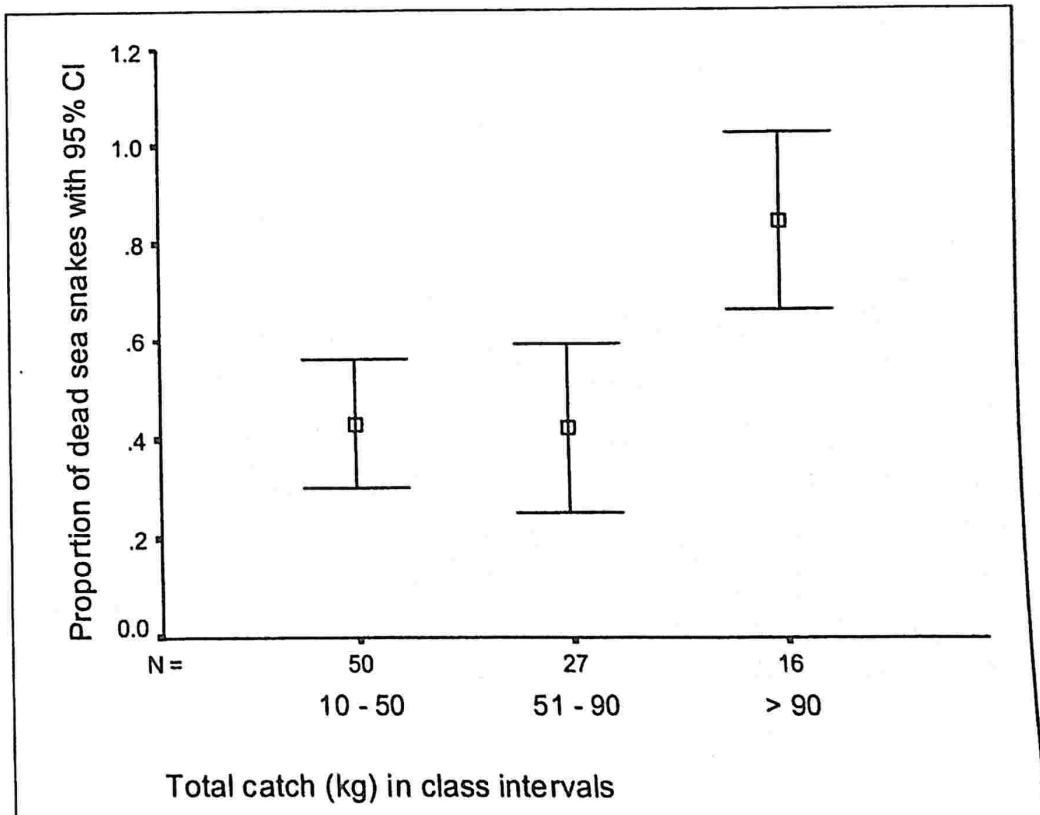


Fig. 23. Composition of trawls based on sea snake presence/absence and the condition in which they were found along Goa coast between November 2002 and April 2003.

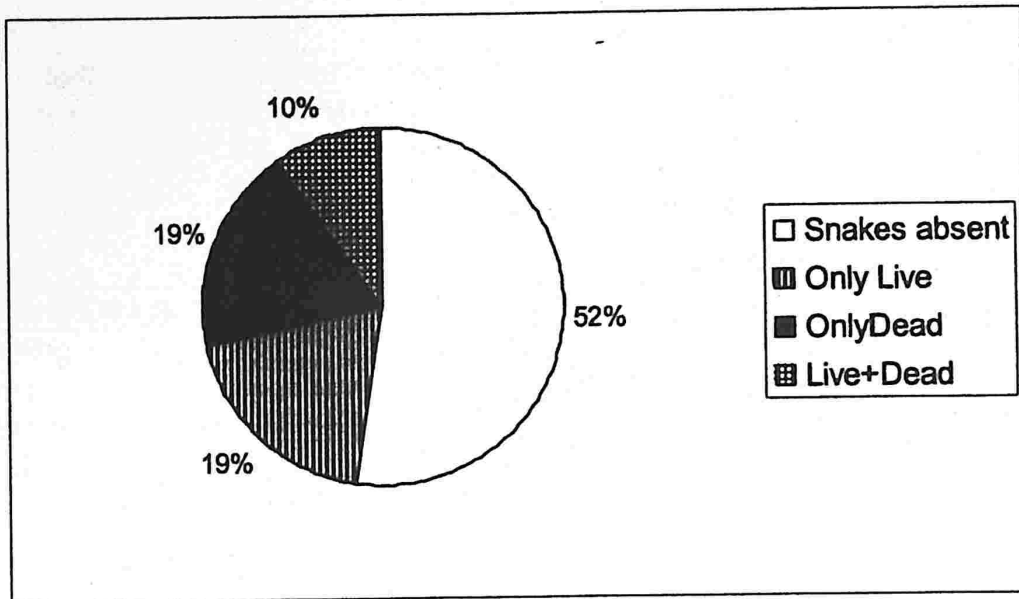


Fig. 24. Proportion of live and dead sea snakes of different sea snake species in trawls along the Goa coast between November 2002 and April 2003.

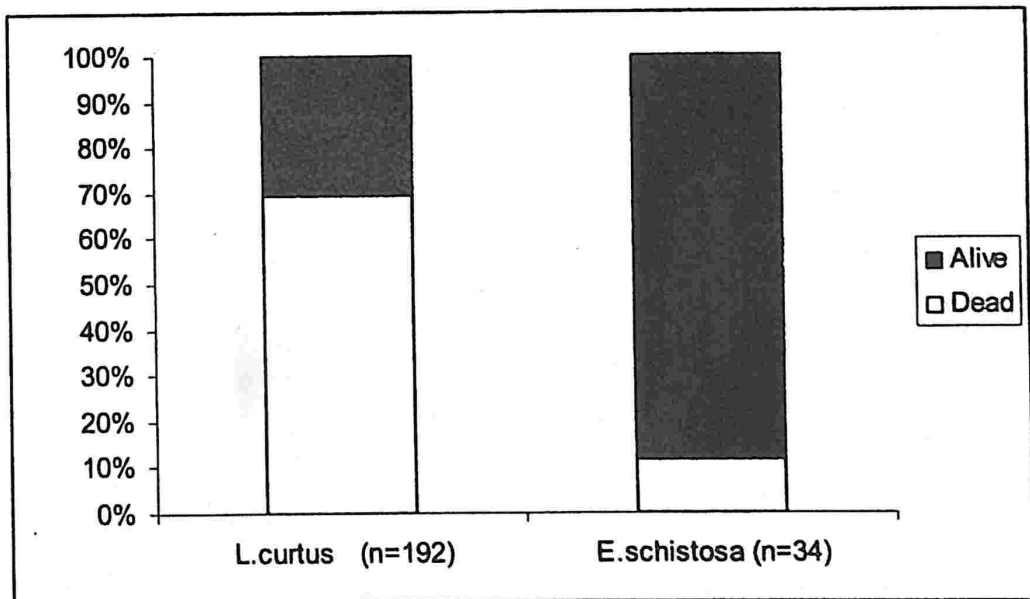


Table 3. Summarised data on mortality of sea snakes in trawls along the coast of Goa between November 2002 and April 2003.

	No. of trawls	No. Caught	No. Dead	Proportion Dead	No. Dead/Trawl
<i>a. Mortalities across different trawl bases</i>					
Chapora	42	80	50	0.63	1.19
Malim	63	46	19	0.41	0.30
Vasco	50	13	9	0.69	0.18
Betul	39	92	60	0.65	1.54
Total	194	231	138	0.60	0.71
<i>b. Mortalities across different times of the day</i>					
Morning	75	78	43	0.55	0.57
Noon	62	80	49	0.61	0.79
Afternoon	57	73	46	0.63	0.80
Total	194	231	138	0.60	0.71
<i>c. Pooled mortality for seasons across bases</i>					
Nov - Dec	56	97	68	0.70	1.21
Jan - Feb	92	95	53	0.56	0.58
Mar - Apr	46	39	17	0.43	0.37
Total	194	231	138	0.60	0.71

## Morphometry

In *L.curtus* and *E.schistosa* it was observed that the snout vent length (SVL) bears a strong positive relationship with the body weight and tail length (Table 4) . There was no obvious sexual dimorphism observed in the species, however it was seen that in both cases the largest and the smallest individuals were females (Fig. 25). The coefficient of variation of morphometric variables such as weight were much higher in case of females was than in case of males in *L.curtus* and *E.schistosa* .

Table 4. Data on regression of Snout Vent length (SVL) to Body Weight (Wt) and Tail length (TIL) with regression line forced through the origin.

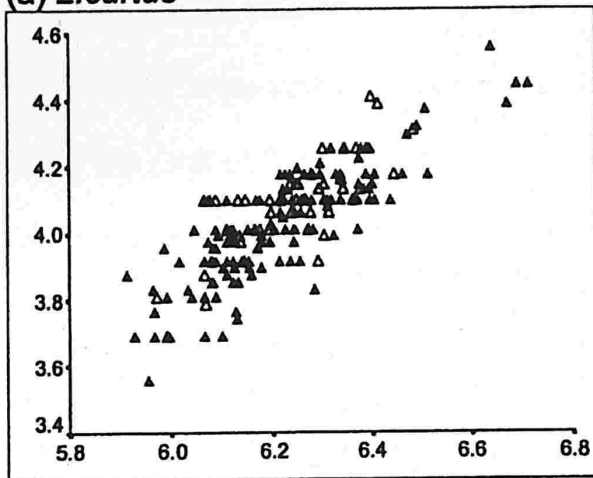
Sea snake species		R <sup>2</sup>	F	df
<i>L.curtus</i>	Wt to SVL	0.993	28990	190
	TIL to SVL	0.999	300323	191
<i>E.schistosa</i>	Wt to SVL	0.996	8621	34
	TIL to SVL	0.999	35928	34

Table 5. Mean and Coefficient of variance of different morphometric measurements along Goa coast between November 2002 and April 2003 in males and females of (a) *L.curtus* and (b) *E.schistosa*

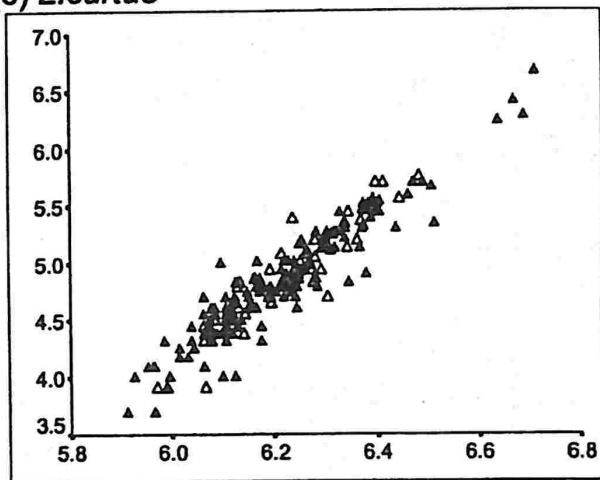
	Male (N = 51)		Female (N = 141)	
<b>a. <i>L.curtus</i></b>				
	Mean	CV	Mean	CV
SVL	512.76	11.64	504.42	16.46
Wt	148.82	43.02	145.37	69.86
TIL	59.56	13.52	56.28	17.21
<b>b. <i>E.schistosa</i></b>				
	(N=11)		(N=23)	
SVL	802.36	14.64	783.52	17.77
Wt	310	28.75	318.47	80.02
TIL	97	17.85	102.82	20.43

Fig. 25. Allometric relationship of tail length (a & b), weight of snake (c & d) with length in *L.curtus* and *E.schistosa* sampled along Goa coast between November 2002 and April 2003.

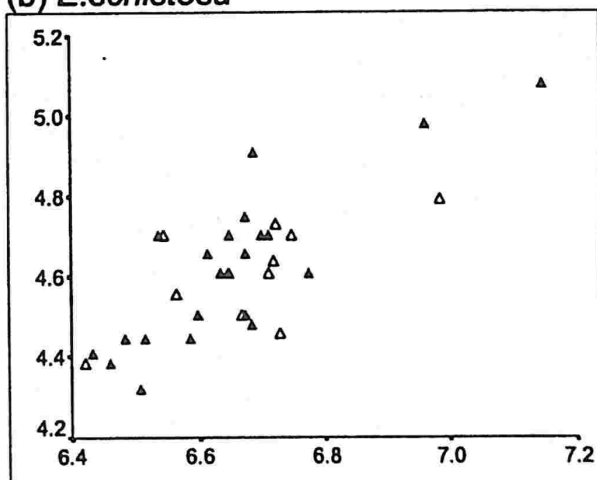
(a) *L.curtus*



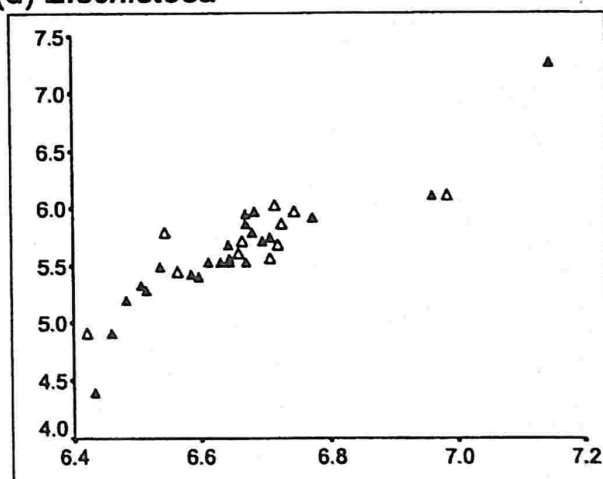
(c) *L.curtus*



(b) *E.schistosa*



(d) *E.schistosa*



ln (snout vent length)

## 5. DISCUSSION

### **Abundance and Diversity**

The total CPUE calculated during the study was  $1.218 \times 10^{-5}$  sea snakes/ net hour, which was several times lower compared to similar studies conducted along the Gulf of Carpentaria, Australia where the CPUE was 0.028 and 0.026 sea snakes/ net hour (Wassenberg et al., 1994). Waters off the coast of Australia are diverse both in terms of species and habitat. Comparison with other parts of India is not possible since there have been no studies on the similar lines conducted so far. Trawling and several other fishing activities have been present in Goa for a considerable period of time and presently the number of fishing trawlers off the coast of Goa have increased at a dramatic rate which besides placing pressure on the fish resources may have influenced sea snake populations. There is however no documented evidence of this influence.

*Pelamis platurus* was not caught in trawl nets, but was caught in shore seines probably because it is one of the only pelagic species, which is usually found floating along slicks where it lives and feeds (Kropach, 1975). Since the trawlers are demersal, i.e. they catch only bottom dwelling species, this species was probably missed out. It was however found in shore seines where the net extends from the surface of the water right to the bottom and thus such pelagic species are captured as bycatch.

The rarefaction curve for number of species along the coast of Goa did not stabilize clearly showing that a larger sample size would have yielded more species. This seems to be very likely considering the fact that 11 species have been recorded along the West coast of India (Ahmed, 1975). Some species such as *Hydrophis cyanocinctus*, *Hydrophis mamillaris*, *Hydrophis caeruleus*, *Hydrophis gracilis*, *Hydrophis cantoris* were recorded in the waters of the neighbouring states (Smith, 1943) and thus have a high likelihood of being found in Goa.

When rarefaction curves were drawn to compare species composition across bases (Fig. 4) it is seen that Betul reaches asymptote early at the 41<sup>st</sup> individual sea snake sampled. Malim and Chapora also tend to reach an asymptote slightly later. The curve for Vasco does not seem to stabilize, suggesting that the base has a diverse community of sea snakes, however the overall abundance of sea snakes was low. The decreasing diversity with increasing abundance of sea snakes found in this study is contrary to conventional thought. The reasons for such a pattern can be many and cannot be inferred through such short term studies.

The study species probably dwell in the continental shelf at the mouths of large estuaries. In terms of species composition Vasco and Malim appear to be most similar. The two rivers Mandovi and Zuari on which the bases Malim and Vasco are located open into the Aguada and the Mormugao Bays respectively which lie adjacent to each other. The sediment profile, salinity and temperature at the mouths of these two rivers are similar. The

hydrographical features of Mormugao Bay are similar to Aguada bay but there is a clear seasonal variation in the biological properties of these two estuarine bays (Ansari et al, 1995). The combined size of this large area could have a bearing on the diversity of sea snakes found in them. Wider estuaries have a greater heterogeneity and therefore support a greater diversity of fish and consequently more sea snake species.

It is known that most species of sea snakes dive to the depths in the areas they are found (Heatwole and Seymour, 1975). The results from this study pertaining to the depths at which sea snakes dived is similar to previous studies where it was found that different species of sea snakes dived to different depths (McCosker, 1975). According to McCosker (1975) this zonation of sea snakes with depth was mainly because of dietary specializations of sea snakes. Heatwole and Seymour, (1975) grouped sea snakes into pelagic and non pelagic species, which were further grouped into shallow water, intermediate and deep water species based on the depth at which they dive. Even though different species were found to occur at different depths, sexual segregation with respect to depth in *L.curtus* and *E.schistosa* was not pronounced. In studies conducted on sea snake species such as *L.colubrina*, females were known to venture into greater depth as they feed on large conger eels which generally inhabit greater depths, males on the other hand were found to remain in shallower waters as they feed on moray eels which were known to inhabit shallow waters (Shetty and Shine, 2002a). In *L.curtus* both males and females were found to occur at similar depths, in *E.schistosa* however no males were found to occur in depths

greater than 15 m. The results could be similar to studies in *L.colubrina* (Shetty and Shine, 2002a), however the sample was too small to arrive at any conclusions.

### **Diet**

There had been no studies on the diet of sea snakes in India. The diet of *L.curtus* was composed of a wide range of fish families. The families Clupeidae and Terapontidae are pelagic, usually shoal living species whereas Trichiuridae (Ribbon fish) are found at a wide variety of depths, Sciaenidae (Croakers) and Cynoglossidae (Tongue soles) are generally bottom dwellers (De Bruin et al., 1994) . The diet of *L.curtus* suggests that it feeds on different families of fish from a wide range of depths. Previous studies in Australia (McCosker,1975; Glodek & Voris, 1982) had shown that another species *Lapemis hardwickii* had a very diverse diet and fed on a wide variety of prey which inhabit different depths of the water column. These findings are also similar to those of McCosker (1975) and that of Glodek and Voris (1982), where they have termed *L. hardwickii* to be a generalist feeder unlike many other species of sea snakes which are highly specialized. From this study it can be inferred that *L.curtus* is also a generalist feeder. Presently *L.hardwickii* has been synonymised to *L.curtus* (Heatwole,1999). Thus, the feeding habits of *L.curtus* in Australian waters and off the coast of Goa are very similar.

In terms of feeding direction *L.curtus* behaved like most other snakes in that it was found to ingest it's food 95% of the occasions head first. There are a few species such as the *Erythrolamprus bizonus* that seize their prey as they

crawl away and thereby ingest them tail-first (Greene, 1997). In previous studies on sea snake diet it was found that *E.schistosa* always fed on its prey head-first. The prey of *E.schistosa* primarily constitutes catfish which have sharp dorsal and pectoral spines which are erected if prey was ingested from the opposite direction and could inflict fatal wounds (Voris et al., 1978). Species such as Swampsnakes (*Regina alleni*) swallow dragonfly naiads headfirst, so as to direct backward the spines, hooks, and other protuberances on those insects, adults of the same species are however known to ingest crayfish tailfirst, thereby folding the crustaceans' appendages and immobilizing their dangerous claws (Greene, 1997). Similarly *L.curtus* fed head first on certain species of fish belonging to family Terapontidae which have sharp dorsal spines which are erected when the fish is captured or agitated, in order to prevent injury. In *E.schistosa* examined for diet it was always found that the prey was always ingested head first.

Food was present in 90% of the individuals of *L.curtus* analyzed for diet suggesting that it might be an ambush feeder or sit and wait predator. Sit and wait predators invest little time and energy searching for prey. They remain stationary and attack mobile prey that move within their field of vision (Gerritsen and Strickler, 1977), it is because of their sluggish habits that food remains in the crop for longer periods. Studies on the feeding habits of *Lapemis* in Australia, yielded similar results where it was found that the capture of fast moving prey such as members belonging to families Carangidae, Engraulidae and Clupeidae has been accomplished through

cautious stalking and rapid lunging behaviour and not by coursing after prey (McCosker, 1975).

*E. schistosa* is known to be an active forager, feeding in 3-5 m depth in turbid waters (Voris et al., 1978). It had been found that tactile rather than visual perception played a role while foraging in this species (Voris et al., 1978). Their food items are mainly composed of fast moving species such as catfish (Tachysuridae). It was probably because of its active habits that food was absent in 45% of the individuals or it was found in an unidentifiable form. Active foragers move widely in search of their prey where in they expend considerable amounts of energy, food in their stomachs will thus pose a hindrance while foraging (Huey and Pianka, 1981). They thus have a higher metabolism and therefore food is digested at a faster rate than their more sedentary counterparts.

Separation of size class of sea snakes based on diet has been reported previously in *L.colubrina* (Shetty and Shine, 2002). It was found that larger snakes fed on conger eels (Congridae), while smaller individuals fed on the smaller moray eels (Muraenidae) (Shetty & Shine, 2002). There was a slight change in the composition of the diet in *L.curtus* with the increase in size. Individuals greater than 570 mm had a greater proportion of families Sciaenidae and Terapontidae in their diet, but the proportion of these two families is too small to conclude anything about this change in diet. There have been no studies on size based difference in diets in this species.

Sex-based divergence in diet has been reported from several snake species such as American water snakes (Mushinsky,1987), Australian file snakes (Houston and Shine, 1993) and sea kraits (Shetty and Shine, 2002). It has been found that female Arafura file snakes (*Acrochordus arafurae*), Diamond-backed watersnakes (*Nerodia rhombifer*), and Yellow-lipped Seakraits (*Laticauda colubrina*) reach greater size than males and consequently add to their diets larger fish species not taken by the other sex (Greene, 1997).

Sex-based divergence in diet was not very well pronounced in *L.curtus* wherein both females and male snakes fed on similar prey items which mainly composed of Sardines (Clupeidae) and tongue soles (Cynoglossidae). However female snakes were found to consume members of two more families Sciaenidae and Trichiuridae. Members of family Sciaenidae (croakers) and Trichiuridae (ribbon fish) are generally larger and more bulky as compared to the clupeids and tongue soles. It was also found that the largest individuals of *L.curtus* which fed on members of these two families were indeed females.

In Goa many of the marine fish caught in fishing trawlers are of commercial value. This value/price varies with the season, taluka etc (Shirodhkar, Fisheries dept, pers.com.). It is however not only the commercial species that are caught in the nets of commercial trawlers, catch is also composed of several species of smaller fish and several other life forms of little or no commercial value called bycatch. These species die during the process of sorting commercial from non-commercial forms. In most cases this bycatch is

just dumped back into the sea, in some cases it is dried, ground and used as poultry food. This dead (bycatch) will then have little use to sea snakes as there have been no records of species belonging to hydrophiidae to scavenge unlike species such as *Acrochordus arafurae*, *Nerodia sipedon* and *Helicops modestus* have been known to scavenge on dead fish (Shine, 1986; Browder et al., 1995 and Sazima and Strussmann, 1990).

### **Mortality**

Studies on mortalities of sea snakes due to trawling focused on specific species (Wassenberg et al, 2001; Milton, 2001). Sea snakes like all other reptiles need air to breathe, which means that they have to surface at regular intervals. As the trawl nets are dragged along the sea floor it prevents the animals from surfacing for a considerable length of time. This, along with the stress the animals undergo while trying to escape cause them to consume all the oxygen in their blood and they drown, the intensity and magnitude of mortality would naturally and was greatly found to increase with the trawl duration.

Weight of the catch was found to contribute significantly to the mortality of sea snakes. Heavier catches exert a greater pressure on the bodies of the sea snakes causing them to get crushed. Moreover, the fact that the trawler is moving causes the sea snakes to get pressed to one corner of the net and heavier catches would thus result in a greater mortality.

Heatwole (1999) found that the voluntary submergence time was upto half an hour in most species. It has been found that measurements of the change in

oxygen content of the blood of snakes diving in the laboratory showed that they usually have enough oxygen to sustain aerobic metabolism, even after dives as long as, or longer than those occurring naturally in the sea and they rarely need to depend upon anaerobic respiration (Heatwole, 1999).

An increase in depth decreases the lung volume and also the rate at which oxygen is consumed from the blood. Sea snakes that dive to greater depths will be able to remain there for shorter intervals of time than at shallower depths (Heatwole and Seymour, 1975). There was a dramatic increase in the magnitude of mortality as the depth increased from 5- 10m to 10.1 – 15m, it was however not very different in 10.1 -15m to >15m class intervals of depth.

The trawl duration and weight of catch of the 3 cylinder trawlers is consistently smaller than the larger 6 cylinder trawlers, which will surely lead to an increase in the death toll of sea snakes. Most large 6 cylinder trawlers along the coast of Goa, trawl in waters greater than 20m where sea snake abundances are low and thus they run at a lower risk of being caught in the trawl nets. However, this is not the case in the northern coast of Goa which has a large number of six cylinder trawlers, that trawl in shallow waters where prawn densities are known to be higher and thus place the sea snakes at a higher risk in this zone.

The results of the study augments with the findings of Wassenberg et al.(2001) which showed that duration of trawl and total weight of catch had

significant positive effects on within-trawl mortality of sea snakes. Wassenberg et al.(2001) however did not look at the mortalities caused due to differences in the depth.

It is likely that *E.schistosa* and *L.curtus* experience varied mortalities due to trawling. In *L.curtus* it is clear that males are more susceptible to the effects of trawling than females however it may not be true in the case of *E.schistosa*.

Mortalities of sea snakes were found to be a function of the number of individuals caught and there was seen to be a general trend of increasing mortalities with the increase in the number of snakes caught. While comparing mortalities across trawl bases it was obvious that Betul having the highest CPUE also had the highest mortality followed by Chapora, Malim and Vasco. A similar case was found when comparing mortalities across seasons where in the mortalities decreased steadily from November-December to March-April which was due to the decrease in the CPUE of sea snakes caught. A comparison of mortalities across the three different times of the day were not found to differ significantly and this was due to a similarity in the number of sea snakes across the three different times of the day.

Many species of snakes become relatively inactive soon after they have fed, as movement would probably cause them to feel great amounts of discomfort, moreover body parts of the prey such as antlers and bones in large snakes and in the case of prey of sea snakes sharp spines could inflict injury. Even though all of 17 snakes in which food was absent were dead a much larger

sample of 148 had 77% and the presence of food in the stomach might have contributed to the mortality in the species.

Bruises in dead snakes were higher than as compared to live snakes and could be one of the reasons for their mortality. However, most of the bruises were in the form of minor punctures, pokes and reddish blotches rather than lacerations suggesting that the main cause of death was due to drowning. These results were similar to those carried out by demersal trawlers in Northern and Eastern Australia (Wassenberg et al., 2001). Bruises on the head and tail regions were few in number and were not really a useful indicator for assessing sea snake mortalities, this was contrary to the work carried out by Wassenberg et al.,(2001) where in a large proportion of bruises were constituted on the head region.

### **Morphometry**

The snout vent length varied proportionately with weight and tail length, as seen in many other species of snakes (Das, 1991; Kaufman and Gibbons, 1975; Guyer and Donnelly, 1990). There was no sexual dimorphism in *L.curtus* with respect to the snout vent length which is similar to previous findings (Heatwole, 1999), similarly there was no sexual dimorphism seen in the tail lengths which is unlike that of several other snake species such as *L.colubrina* (Shine and Shetty, 2001) and *Thamnophis sirtalis sirtalis* (Burt, 1928) in which males have longer tails than females. There was no sexual dimorphism in *E.schistosa* in terms of length which is contrary to previous studies that have been done on sexual dimorphism with respect to length, tail

length and weight where it has been found that female snakes are larger than males (Voris and Jayne, 1979; Heatwole, 1999). However, in both species *L.curtus* and *E.schistosa* it has been found that the largest and the heaviest individuals were all females. This could have resulted as the population of sea snakes was skewed towards females in both *L.curtus* and *E.schistosa*, in this context it could be possible that larger males were possibly occupying different areas were thus being missed out.

An animal's body size may influence its fitness via a variety of pathways involving sexual selection (mating success), fecundity selection (reproductive output), and natural selection (shelter-site availability, thermoregulatory biology, food requirements, vulnerability to predators, etc.) (Shine and Shetty, 2001). Some traits in animals may favour the mating success of a species but decrease their survival (Krebs and Davies, 1987). Detailed morphometric studies have been carried out on species such as *L.colubrina* where the females are larger than males and have longer and wider heads (Shetty and Shine, 2002). It was however found that the tail in male snakes were longer than those of the females and males with longer tail had a greater chance of survival and finding mates (Shine and Shetty, 2001). Females are known to spend much more energy as compared to males in reproduction. Hence, a larger body size would result in the production of a larger clutch as compared to the smaller individuals (Andrews and Rand, 1974).

## 6. CONCLUSION

Six species of sea snakes were recorded during the study. However, as the data from the present study suggests, occurrence of more species in the coastal waters off Goa is not ruled out. This is more likely to happen since previous studies have documented different species from the neighbouring states (Karnataka and Maharashtra). The species diversity in Vasco didn't reach an asymptote, suggesting that it would have to be sampled still further. Vasco and Malim were most similar in terms of species diversity and this was because they have a common mouth opening into the Arabian sea and both these rivers are governed by similar biotic and abiotic factors. There was a slight variation in the composition of sea snake species with depth where in *E.schistosa* was found in shallow waters with maximum abundance in waters between 5-10m, *L.curtus* was found to prefer deeper waters. There was no sexual segregation with respect to depth in both these species. Food habits of *L.curtus* indicated that the species could possibly be an ambush feeder. In terms of diet *L. curtus* is a generalist as it feeds on fish families from a wide depth range. Dietary analysis of *E.schistosa* revealed empty stomachs in most cases this was probably because of its active foraging habits. Sex based divergence in diets was not pronounced in *L.curtus* and there appeared to be a large overlap on the fish families they fed on, however it was seen that the diet in female snakes was more diverse than in males. There was a slight change in the diet of *L.curtus* with the increase in size. Even though there was a great overlap in the diet of the three size classes, individuals greater than 570 mm had a greater proportion of families Sciaenidae and Terapontidae in

their diet. Sea snakes were found to feed on commercial fish in most occasions. This seems to be a concern because of the fact that the fisheries resources of Goa is being intensively exploited at present. Depletion of the food species of sea snakes in future may affect their population. In this context the present study can be considered as a bench mark, one based on which further comparison on the effect of trawling on sea snakes in the future can be made. The magnitude and intensity of mortality increased with the increase in the duration of the trawl, weight of the catch and the mean depth. Mortalities of sea snakes were found to be a function of the numbers caught. A higher CPUE of sea snakes also resulted in higher mortalities. The length of sea snakes varied with the weight and tail length. No sexual dimorphism was seen in terms of length in both species. However it was found that the heaviest and lightest individuals were all females, this could however be simply an artefact of the sample size in that females were captured more frequently than males and larger males inhabited other areas. This is not conclusive and needs to be investigated further.

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*Note: The references marked in \* were not referred in original*

Annexure 1: A photographic catalog of sea snake species found along the coast of Goa during the study.

a) *Lapemis curtus* (Shaw, 1802)



b) *Enhydrina schistosa* (Daudin, 1803)



c) *Thalassophina viperina* (Schmidt, 1852)



d) *Acrochordus granulatus* (Schneider, 1799)



e) *Cerberus rhynchops* (Schneider, 1799)



(Photo: S.Shetty)

Annexure 2: A photographic catalog of fish species found in the diet of sea snakes during the study

Family : Clupeidae



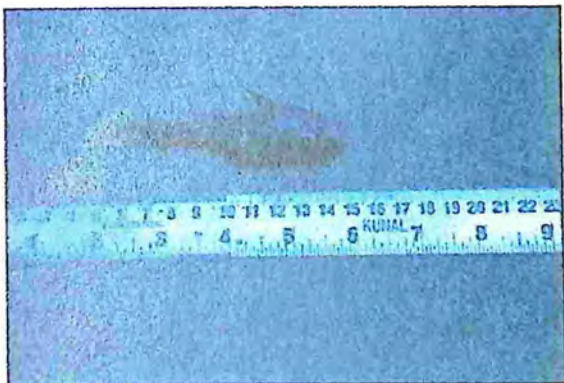
Family : Cynoglossidae



Family : Sciaenidae



Family : Ariidae



Family : Terapontidae



Plate 1. Diagrammatic representation of trawl net used during the study depicting various parts with their dimensions .

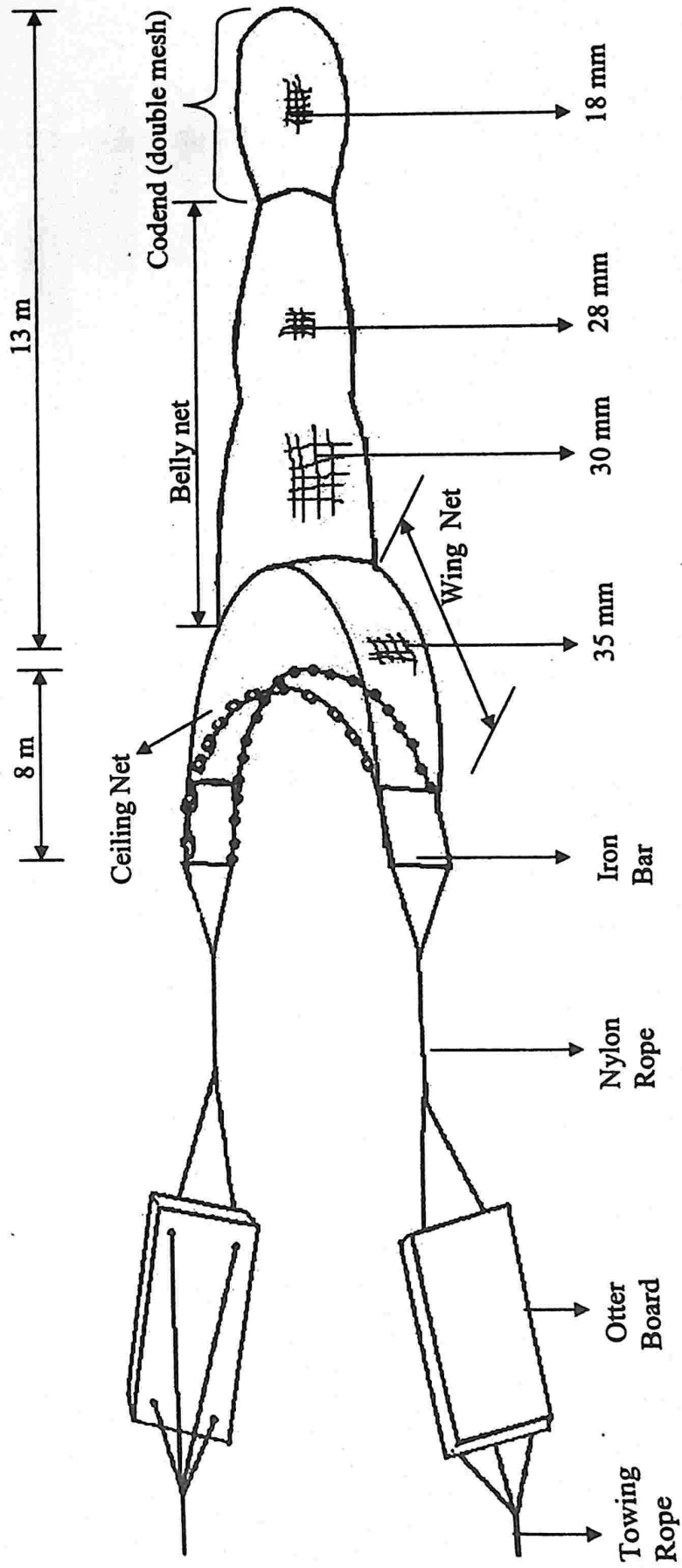


Plate 2

(A) A demersal trawler towing the net along the Goa coast



(B) Catch from a three cylinder demersal trawler with a sea snake



Plate 3

(A) Common constituents of Bycatch in a normal catch along the coast of Goa. (Sps include sea snake, mantis shrimp, echinoderms, young cuttlefish and other juvenile fish of no commercial importance)



(B) Dissected *L.curtus* depicting partially digested *Cynoglossus* one of it's major prey species in the crop.

