Effect of fishing practices on species assemblages of sea snakes off the Sindhudurg coast of Maharashtra, India

Final report

Submitted by:

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About Dakshin Foundation:

Dakshin Foundation is a registered not-for-profit, non-governmental organization. Since its establishment in 2008, we have undertaken a range of projects that deal with conservation. Dakshin works with an understanding that challenges of conserving our environment is one that necessitates an active engagement between the natural and social sciences where conservationists accommodate expertise that transcends disciplinary boundaries. Dakshin's applied scientific research aims at filling some of the critical gaps in our current knowledge of marine ecosystems. Through long-term monitoring of select ecosystems and taxa, our research aims to advance our understanding of the patterns and processes that maintain ecosystem function and resilience to anthropogenic stress and climate-induced changes.

Introduction: Taxonomy and Distribution

Sea snakes are venomous snakes that are specialised to inhabit marine ecosystems (Voris 1977; Heatwole 1999, Ineich and Laboute 2002) and have evolved independently from terrestrial snakes of family Elapidae (Voris 1977). Further taxonomic divisions have categorized sea snakes into two subfamilies: the oviparous sea kraits; *Laticaudinae* and the viviparous 'true sea snakes' *Hydrophiinae* (Lukoschek 2007). There are ~65 species of sea snakes reported from the modern oceans. Morphological and genetic variations have been reported in ubiquitous species such as the hook-nosed or beaked sea snake (*Hydrophis schistosus)* and Shaw's sea snake (*Hydrophis curtus)* (Ukuwela et al. 2013, 2014) due to discontinuous distributions despite being widespread. Molecular analysis has revealed that all hydrophid snakes fall under the genus *Hydrophis* (Sanders et al. 2013). However, the taxonomy and classification of the *Hydrophis* group is still work in progress and further detailed examinations from other parts of its range need to be conducted to fully understand such variations. Despite the differences in natural history traits between *Laticaudinae* and *Hydrophiinae*, both subfamilies are collectively known as 'sea snakes'.

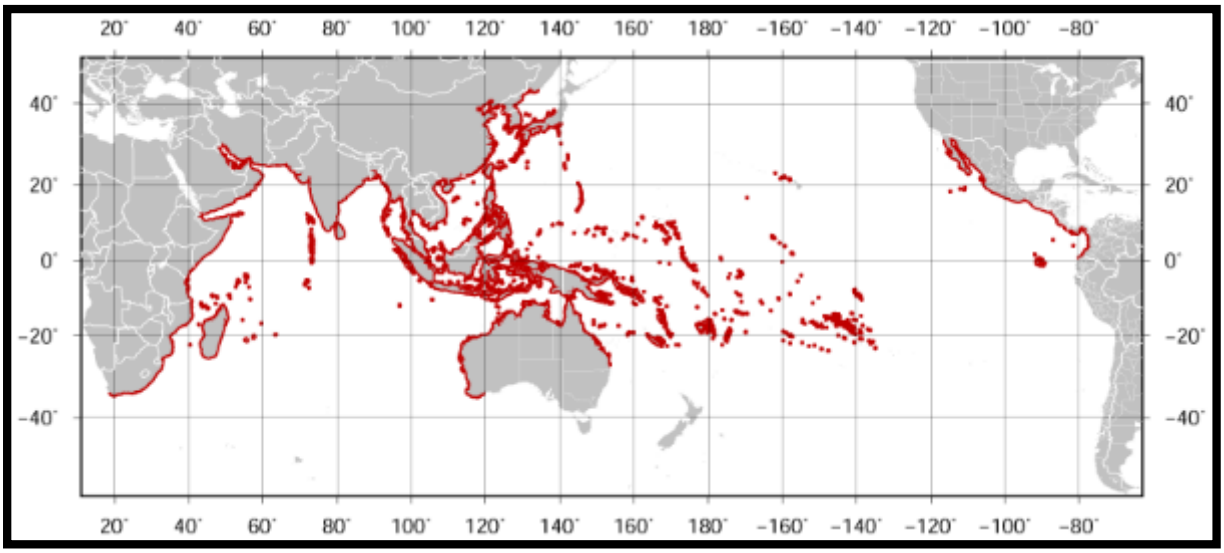


Figure 1: Global distribution of sea snakes (Map courtesy of IUCN Red List Spatial Data)

Sea snakes are reported largely from the Indian Ocean (Rasmussen et al. 2014), with the exception of the yellow bellied sea snake (*Hydrophis platurus*) which also occurs in the Pacific Ocean (Figure 1). Their diversity is noticeably higher in Northern

Australia (Great Barrier Reef) and South East Asia (Thailand, Indonesia and Vietnam) with >25 species reported from each region (Rasmussen et al. 2013, 2014). There are about 20 species of sea snakes reported from the coast of India (Das et al. 2003; Whitaker and Captain 2004). Most of the literature on sea snakes in India is from the pre-independence era (Smith 1943) which dealt with identification and basic ecology. Other information available is based on opportunistic collections made from a few scattered localities along the coast (Ahmed 1975; Murthy 1977; Palot 2009)

Sea snakes inhabit shallow waters and have been observed in depth ranges from 10 to 40 m. Their diet consists of a wide range of vertebrate and invertebrate marine organisms and the dietary preference may vary in different parts of their range. There is limited interspecies competition even in highly speciose areas (Voris et al 1983). Since these animals feed on a wide range of prey, they act as important bio-indicators of healthy marine ecosystems.

Globally, sea snakes are threatened with overfishing, pollution and coastal development activities among many others. Populations have been reported to be on the decline in species rich areas of Northern Australia (Lukoschek 2013), Gulf of Thailand (Van Cao et al 2014) and offshore waters of Vietnam (Rasmussen et al 2011). Sea snakes are commonly encountered across the Indian coast as bycatch in fishing nets (Lobo et al 2005). The impact of fishing practices on sea snakes has been studied to some degree in Australia (Milton 2001, Wassenberg et al 2001, Guinea 2003, Lukoschek et al 2013, Sanders et al 2013, Rasmussen et al 2014), Vietnam and Southeast Asia (Rasmussen et al 2011); however, little is known about the situation in India. These studies have shown dramatic reduction in sea snake populations from certain areas due to uncontrolled fishing from disruptive fishing practices such as fish and shrimp trawling.

Sea snakes are protected under Schedule IV of the Indian Wildlife Protection Act, 1972. Despite their protected status, limited scientific research has been undertaken to understand existing species assemblages and diversity in the backdrop of increasing fishing practices, pollution and other anthropogenic pressures. Studies have so far been conducted in Goa (Lobo 2004, 2006; Padate 2009), Kerala (Palot et al 2010), Odisha (Murthy et al and Rao 1988; Tripathy 2006) and Tamil Nadu (Murthy 1977; Lobo 2006; Karthikeyan et al 2007, 2008 Chandrashekhar et al 2013; Muthukumaran et al 2015).

Study area

Sindhudurg (Figure 2) is the southernmost coastal district of Maharashtra bordering Goa. This survey took place in the coastal town of Malvan, where there is high fishing activity from shrimp and fish trawlers which operate from areas as far as Kerala and Gujarat. The shallow coastline (<30 m) interspersed with river mouths and large swathes of mangroves makes this region very productive for fish spawning and acts as important breeding and nursery grounds for other marine fauna. This fact also makes it an important fishing area in the region. Fishing activities in Malvan are basically classified into Trawling, Gill net fishing and Rampan net fishing. Survey of sea snakes was conducted in Malvan in two phases: Phase 1, from January to March 2016 and Phase 2, from November 2016 to March 2017.

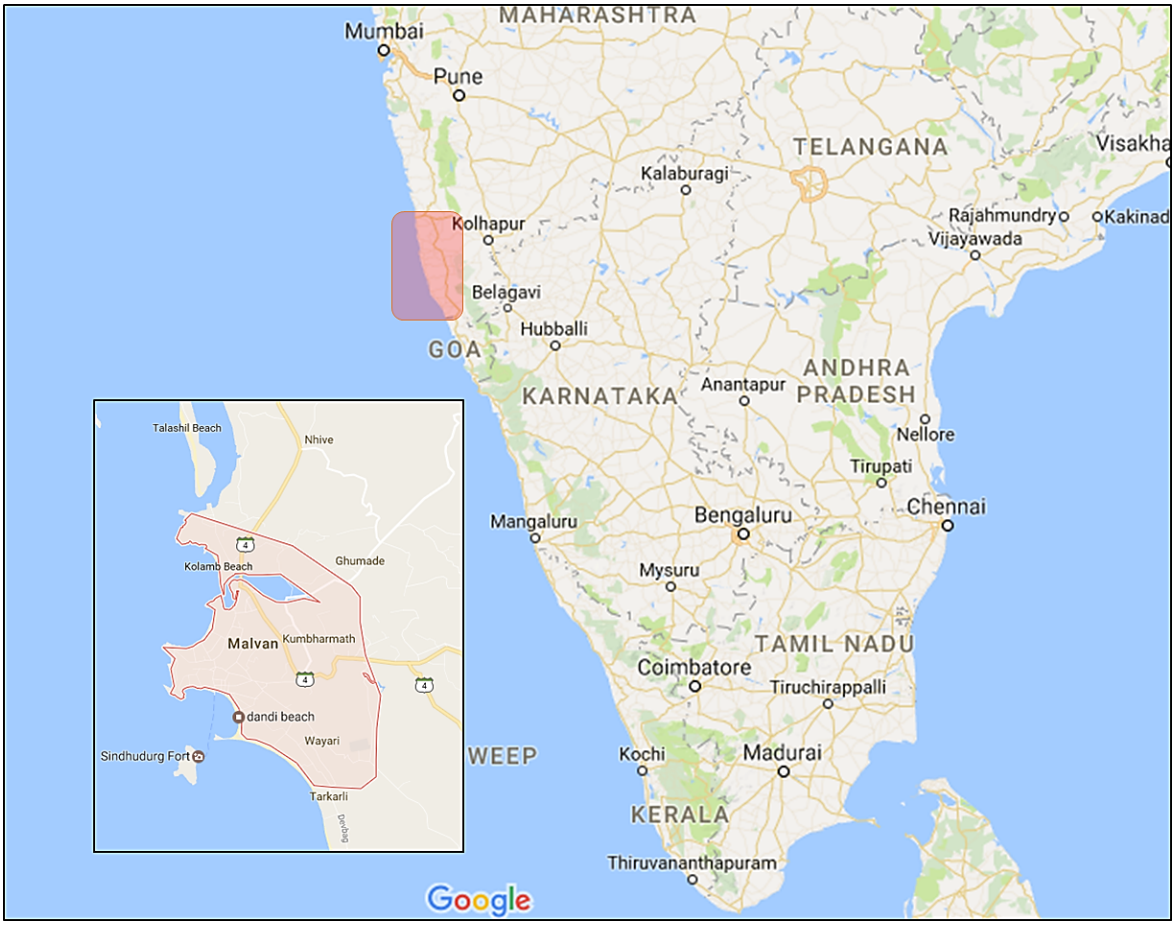


Figure 2: The study area

Fishing practices in Sindhudurg district:

Trawler fishing:

Trawl fishing in Malvan targets prawns (Family: Penaeidae) (bottom trawling) and ribbon fish (Family: Trichiuridae) (demersal trawling) and trawling operations range for 12 hours to 3 nights as per catch, traveling distances north and south of Malvan. The distance and duration depended upon catch availability and is highly variable. Catch is sold in the local fish auction at the end of each day (Picture 2).

Gill net fishing:

Gill net fishing in Malvan occurrs daily from 0300 hours to 0900 hours. The target catch are sardines (*Sardinella spp.*) and mackerel (*Rastrelliger kanagurta*). The fishermen sort their catch on beach stretches of Dandi in Malvan; The fishing takes place 1-10 km offshore (avg. depth range of 9 - 27 m; avg. span to 3-5 hours) (Picture 3).

Rampan net fishing:

Rampan nets are deployed based on intuition of the fishermen of a probable catch. The nets in Dandi beach are deployed daily for 3-4 hours, 5 days a week. *Rampan* nets are also deployed on beaches in Tarkarli, Tondavli and during the monsoon (post August) in Vengurla (Picture 1).

Picture 1: Fishermen pulling in a Rampan net on Dandi beach, Malvan. (Pic: Trisha Gupta)

Picture 2: *H. schistosus* (centre) caught in a mechanised trawler, Vengurla, 2016. (Pic: Chetan Rao)

Picture 3. Left: Fishermen sorting the catch from a gill net in Malvan (Pic: Trisha Gupta).
Right: *H. schistosus* caught in a gill net in 2016. (Pic: Chetan Rao)

Methods:

To document the existing species diversity of sea snakes, the following methodology was followed (Ward 1996; Fry 2001):

a. Trawlers: Sampling was carried out in a trawler that usually operated daily from 0700 hours to 1600 hours. Trawling was carried out at 4-8 km offshore, within a depth range of 16-22 m. Snakes caught in nets were identified, weighed and measured during every haul of the operation. Information on depth, location of the catch using GPS (Garmin GPS 60); mortality data (whether the caught snake was alive or dead) and gear details such as type of net, net length and mesh size were recorded. Sampling effort for trawlers was much higher in phase 2 as compared to phase 1.
b. Gill nets: Traditional/artisanal boats on Chivla and Dandi beach were surveyed daily at 0800 hours to check for snakes caught in fishing nets. Caught snakes were identified, measured and checked for mortality. Gear details, target catch, fishing duration, depth etc. were noted. Fishing paths of a few of the sampled boats were recorded using GPS.
c. Rampan nets: Rampan nets were surveyed whenever they were deployed and snakes caught in the nets were checked, identified, measured, weighed and nets were checked for dead snakes.

Post-capture Survival:

Sea snakes captured in fishing nets face the threat of stress and injury. During phase 2 of the sampling duration (November 2016 to March 2017), we initiated an experiment to observe post release survival of sea snakes caught in fishing nets. Live snakes from fishing nets were kept under observation for 24 hours, following the methodology by Wassenberg et. al. (2000). The snakes were placed in large plastic tubs of seawater, segregated by species and age (size class). No food was provided. Snakes were observed every 3 hours, and at every observation dead snakes, if found, were removed and the time of death noted. Dead individuals were measured (body weight and length, snout to vent length, tail length, head size and width) and preserved as biological specimens in 3% formalin. At the end of 24 hours, live snakes were measured (body weight and length, snout to vent length) and subsequently released.

Diet data: Prey identification

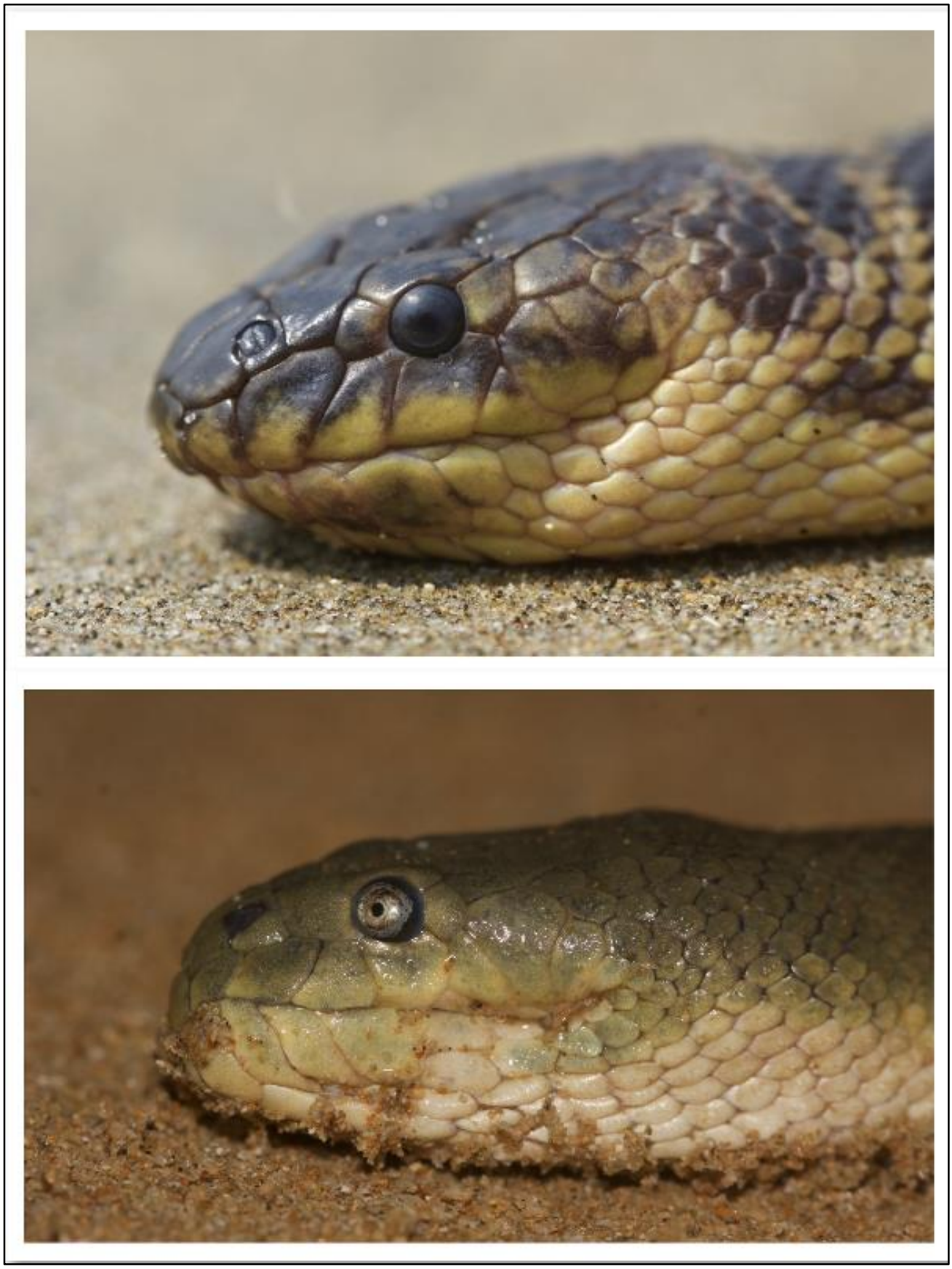
Gut content was removed from dead specimens whenever possible to obtain information on their diet. Prey items were also occasionally obtained from live individuals on regurgitation. Based upon state of digestion, prey species were identified up to family level. Intact specimens were measured and weighed. All prey items were preserved for future reference.

Questionnaire surveys:

To understand perceptions of fishermen towards sea snakes, the following methodology was followed (Lobo 2006):

a. Through a questionnaire survey containing a mix of closed and open-ended questions (See Annexure 4), fishermen were interviewed to understand their general perception and knowledge of sea snakes in the area. All interviews were conducted in private to minimize peer influences on their responses. The interviews were restricted to one fisherman per vessel at the fish landing sites.
b. To understand perceptions on whether trawl fishing has brought about changes in sea snake numbers and abundance of the target catch of shrimp and fish, fishermen were questioned on the catch rates of target and non-target species and specifically on the catch rates of sea snakes (present and past) to determine if they observed a change in the catch rates of sea snakes in trawlers.

45 fishermen in Devgad, Malvan and Vengurla were interviewed regarding general perception, diversity of snakes caught, bycatch handling, mortality, snakebite and health management. We chose the fishing jetty in Devgad, fishing villages in and around Malvan and Vengurla for our questionnaire surveys. All respondents interviewed were males between the ages of 25 to 40 years.



Picture 4: Lateral view of the head of *Hydrophis curtus* (top) and *Hydrophis schistosus* (bottom)

(Pic: Chetan Rao)

Picture 5: Full body view of *Hydrophis curtus* (top) and *Hydrophis schistosus* (bottom)

(Pic: Chetan Rao)

Results:

Species of sea snakes caught in fishing nets:

263 sea snakes were sampled from the fishing nets during phase 2 of the project, making it a total of 478 snakes sampled over the two sampling phases. Two species were commonly encountered; hook-nosed sea snake (*Hydrophis schistosus,* previously *Enhydrina schistosa*) (n=379) and Shaw's sea snake or short sea snake (*Hydrophis curtus,* previously *Lapemis curtus*) (n=98) (Pictures 4 and 5). A single individual of a third species, the little file snake (*Acrochordus granulatus*), was also encountered from a trawler net (Picture 6). The number of *H. curtus* encountered during phase 2 of the project was far fewer (n=34) than the number encountered during phase 1 (n=64) (Table 2).

A large proportion of the captured sea snakes were found in trawlers (n=169) this sampling season, with a fewer individuals encountered in gill nets (n=97). Only 5 sea snakes were encountered in Rampan nets (Figure 7). This is a shift from phase 1, where gillnets represented the larger proportion of sampled sea snakes (n=170) (Figure 7). This can be attributed to differential sampling effort during phase 1 – gillnets were sampled more frequently than trawlers.

Picture 6: Little file snake (*Acrochordus granulatus*) encountered in a trawler (Pic: Shawn Dsouza)

Morphometry of sea snakes:

The average body length of *H. schistosus* sampled over two seasons was 88.26 cm (± 0.86, Min: 45.6, Max: 134.62, N: 351) and the average weight was 375.08 g (± 9.73, Min: 85, Max: 1090, N: 343). Caught individuals of *H. curtus* measured an average of 65.72 cm (± 1.06, Min: 39.5, Max: 93.98, N: 98) and weighed an average of 305.47 g (± 11.98, Min: 40, Max: 690, N: 96).

The average size of encountered individuals during phase 2 is lower than phase 1, with more juveniles and sub-adults being caught in the former. The mean body length of *H. schistosus* is 83.48 cm (± 0.98, Min: 45.6, Max: 125, N: 227) during the phase 2 sampling season, whereas mean length during phase 1 was higher at 97.04 cm (± 1.33, Min: 68.58, Max: 134.62, N: 123) (Figure 3). Similarly, for *H. curtus*, mean body length during the second phase (59.56 ±2.08 cm) was lower than that of the first phase (69.0 ±0.97 cm) (Figure 4).

Seasonal differences in size of caught individuals was observed in *H. curtus*. Smaller individuals were caught in November, and the average size of caught individuals increased till March. For *H. schistosus*, size of caught snakes did not appear to vary much across the sampling period, during either of the sampling phases (Figure 5).

Mortality Index:

The mortality of sea snakes caught in fishing nets was calculated as the percentage of snakes that were encountered dead. Mortality rate of all species during the second phase, in all types of fishing gear, was found to be 22.43%. Mortality of *H. curtus* (64.71%) was much higher than that of *H. schistosus* (16.23%). This is a considerable increase from the first phase, where the overall mortality was found to be 13.95%, with the mortality of *H. schistosus* at 7.95% and that of *H. curtus* at 28.12%.

The overall mortality rate of sea snakes per fishing gear was higher in trawlers (29%) in comparison to gill nets (12.4%). This is the opposite of the trend observed in the first sampling phase, where mortality in gill net-caught snakes (11.57%) was higher than that of the trawlers (2.31%). No dead individuals were found in Rampan nets. The mortality rates are summarised in Tables 1 and 2.

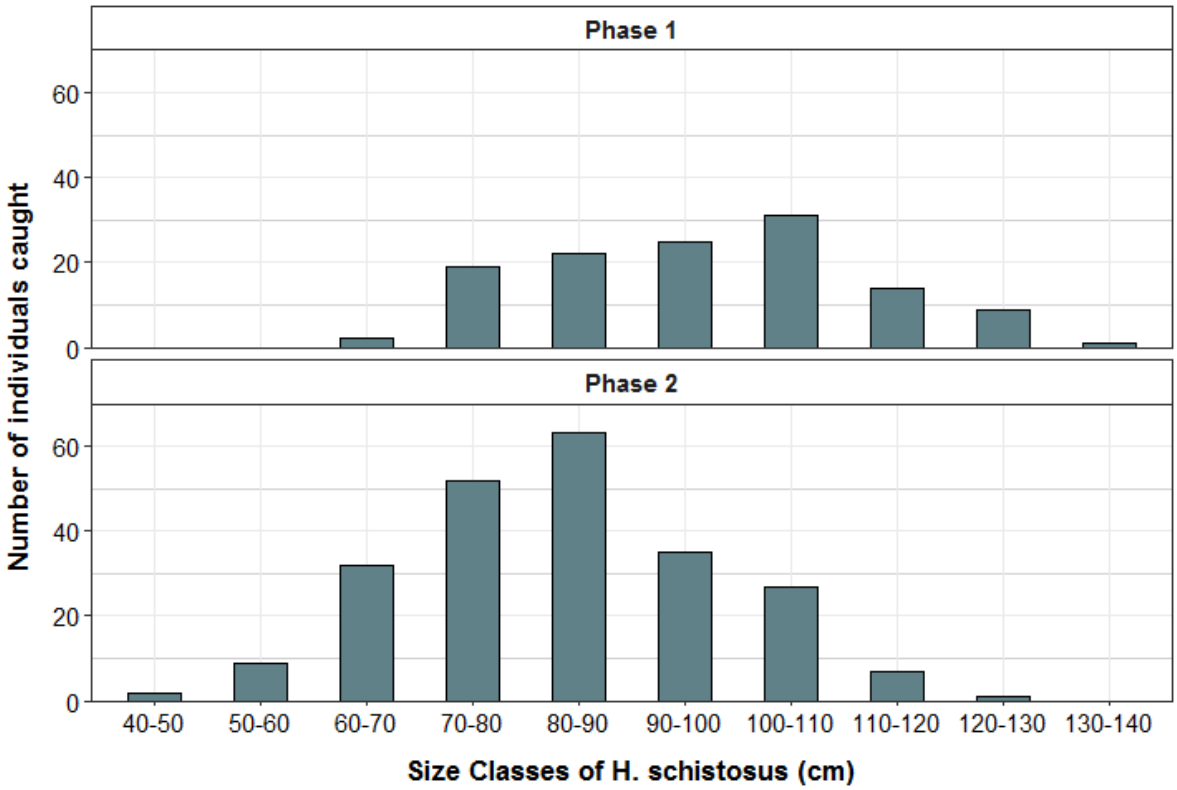


Figure 3: Size class of individuals of *H. schistosus* caught in nets during phase 1 (top) and phase 2 (bottom) of the project

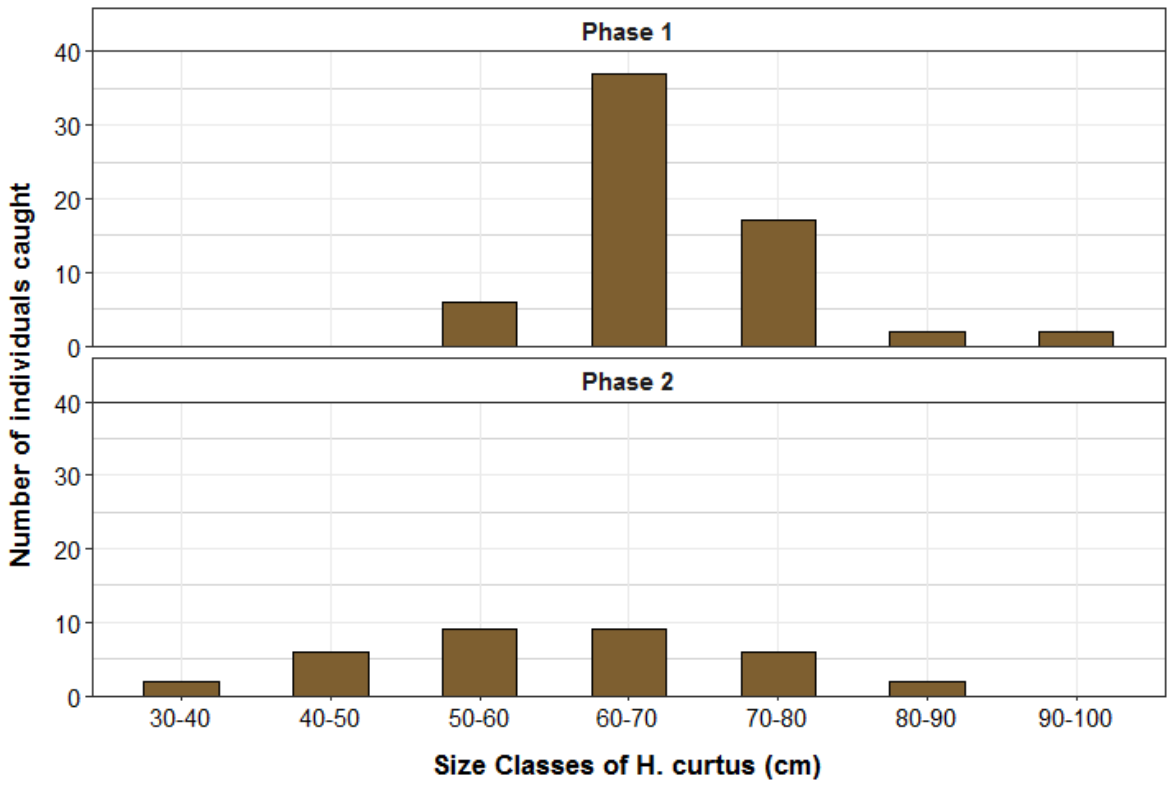


Figure 4: Size class of individuals of *H. curtus* caught in nets during phase 1 (top) and phase 2 (bottom) of the project.

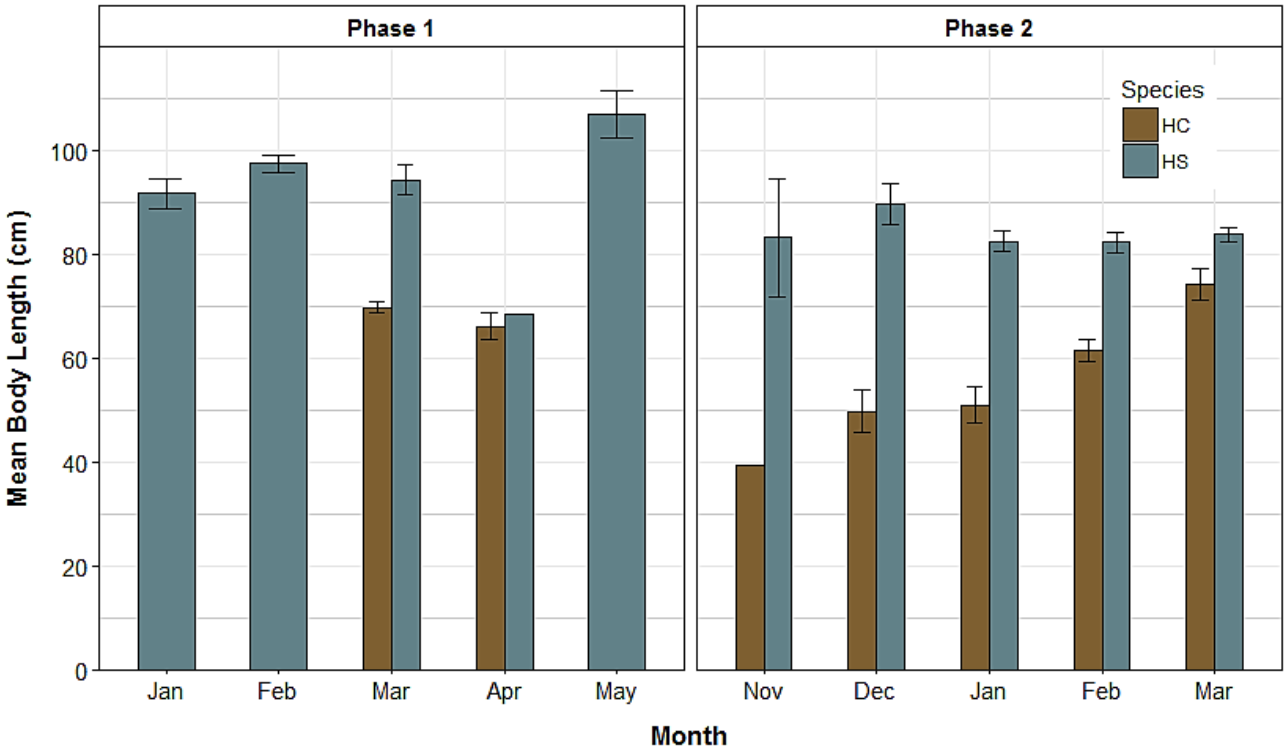


Figure 5: Average body length of *H. schistosus* (HS) and *H. curtus* (HC) caught per month, for phase 1 (left) and phase 2 (right) of the project. Error bars represent standard error.

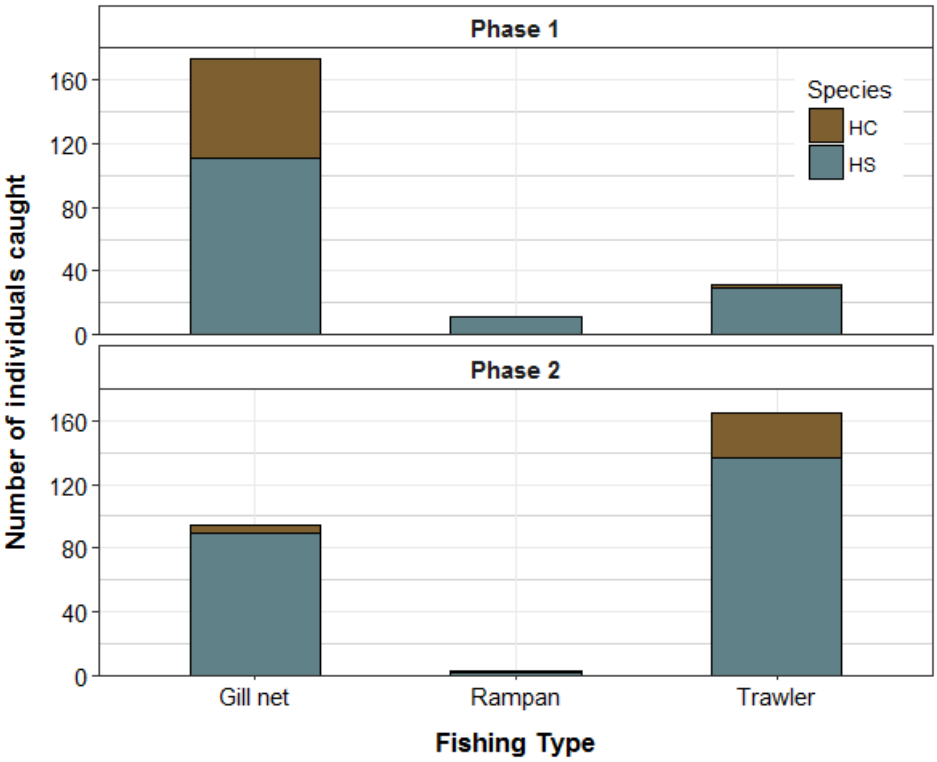


Figure 6. Number of individuals of *H. schistosus* (HS) and *H. curtus* (HC) caught in each type of fishing net during phase 1 (top) and phase 2 (bottom) of the project.

Table 1: Summaries of species and averages of morphometries and mortality observed in sea snakes with respect to fishing hours of each practice during phase 1 and 2 of the study. HS - *Hydrophis schistosus,* and HC - *Hydrophis curtus*

		Bottom Trawl Fishing	**Gill Net Fishing**	**Rampan Fishing**
No. of individuals	HS	166	200	13
	HC	30	67	1
	All Species	197	267	14
Average haul/tow/ deployment duration (Hours)		8.65	3.8	2.9
Average body size (cm)		79.97	85.51	86.42
Average body weight (g)		311.68	390.34	449.44
Mortality Rate (%)		29	12.4	0

Table 2: Number of snakes encountered in fishing nets and their mortality rates observed during both phases of the study.

Phase	**Species**	**Number of individuals encountered**	**Mortality Rate**
Phase 1	*Hydrophis schistosus*	151	7.95%
	Hydrophis curtus	64	28.12%
	All Species	215	13.95%
Phase 2	*Hydrophis schistosus*	228	16.23%
	Hydrophis curtus	34	64.71%
	All Species	262	22.43%

Post-capture Survival

Of the encountered sea snakes, 162 individuals (153 *H. schistosus* and 9 *H. curtus)* were kept under observation for 24 hours during phase 2. A total of 28 individuals were found dead during this observation period, of which 26 were *H. schistosus* and 2 were *H. curtus*. In trawlers, the long-term survival rate was 76.4% (i.e. 76.4% of the snakes survived the 24-hour observation) whereas in gill nets, the long-term survival was 91.9% (Figure 7).

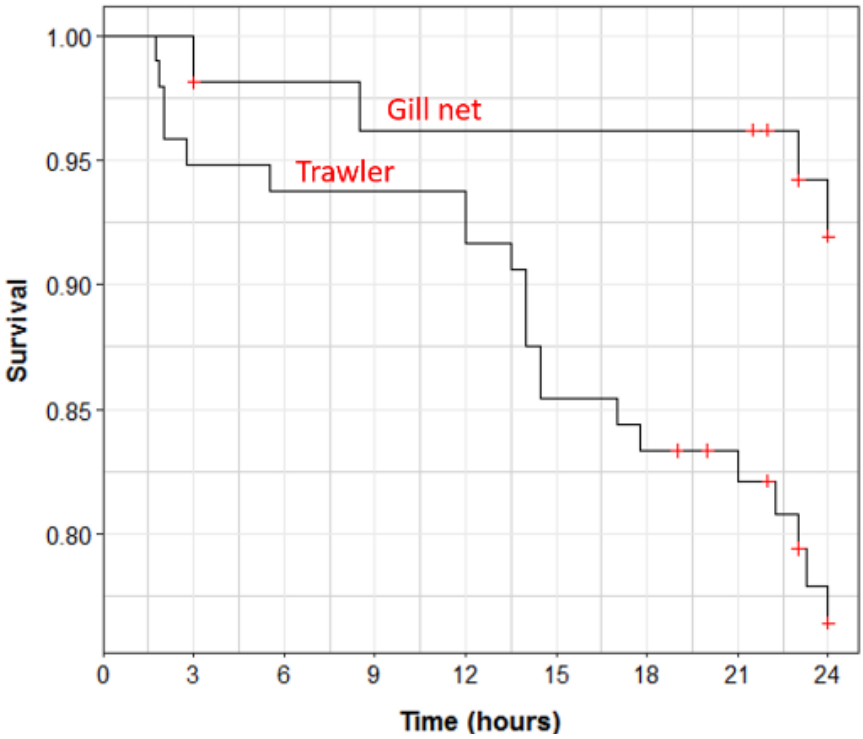


Figure 7: Survival rate of sea snakes caught in gill nets (upper line) and trawlers (lower line) over a 24-hour observation period. Red crosses represent snakes that were released alive before 24 hours.

Picture 7: Top: Dead *H. curtus*, with head injuries, caught in a trawler. Bottom: *H. schistosus* with a dislocated jaw encountered alive in a gill net, which died shortly after. (Pic: Trisha Gupta)

Diet and Reproductive Biology

41 sea snakes caught over the two sampling seasons (19 in phase 1 and 22 in phase 2) had dead prey inside them upon encounter, of which most was obtained as regurgitates from live snakes while some had been obtained from dissection of dead snakes. All prey items were obtained from *H. schistosus* (n=37) and *H. curtus* (n=11). The prey items are presently being identified to family level wherever possible, depending on the state of digestion and completely digested prey materials were discarded. So far, Clupeidae (n=13) has been found in the highest number, with sardines being the most commonly found fish. This is followed by followed by Carangidae (n=4), Elopidae (n=4) and Sciaenidae (n=4) (Pictures 8 and 9). Non-fish species such as mantis shrimps (Order: Stomatopoda, n=2) have also been found. All prey was consumed head first as observed in many other species (Lobo 2005). A full list of prey items identified during the preliminary survey is listed in Table 3.

We also encountered 5 dead gravid females of *H. schistosus* during our sampling (1 in 2016 and 4 in 2017). Dissection of these specimens produced a total

of 36 embryos from five females, in clutch sizes of 12, 9, 7, 4 and 4 respectively. The embryos were in various stages of development (Picture 10).

Table 3: Families of prey items found in caught sea snakes over the two sampling phases. Number of items found in each family (n) and common names of the species found, if possible to identify, are also given. Data is based on the preliminary analysis only; remaining prey items are to be identified.

Family	**Species Found (Common name)**
Clupeidae	Sardine
Carangidae	-
Elopidae	Ladyfish
Sciaenidae	Silver Croaker
Cynoglossidae	Sole
Tetraodontidae	Pufferfish
Polynemidae	Rawas (Indian Salmon)
Ophichthidae	Snake Eel
Synodontidae	Bombay duck
Serranidae	Grouper
Trichiuridae	Ribbon fish
Stomatopoda (Order)	Mantis Shrimp
Siluriformes (Order)	Catfish

Picture 8: Prey species found in the gut of *H. schistosus*: Left: Sardine (Family: Clupeidae). Right: Grouper (Family: Serranidae). (Pic: Shawn Dsouza)

Picture 9: *H. schistosus* regurgitates a fish (Pic: Chetan Rao)

Perception of fishermen towards sea snakes:

Fishermen from Devgad, Malvan and Vengurla could identify sea snakes caught in nets. A few mentioned eels getting caught in their nets and sometimes confused those

with snakes. They could identify *H. schistosus* from the other sea snakes. *H. schistosus* seemed to be the most predominant species to have been caught in nets. All respondents mentioned that snakes are caught throughout the year in their nets. When asked if their numbers in bycatch are constant, fishermen in Malvan and Vengurla mentioned that snakes are caught abundantly during the months of October, November, December, April and May. Fishermen responded positively by stating that nets with meshes between 45 - 60 mm caught snakes in them. These are nets used to target commercially important fish such as Indian oil sardines (*Sardinella spp.*) and Indian mackerel (*Rastrelliger spp.*). Fishermen in Vengurla believe that the catch rates of sea snakes and fish in general have come down in the past 5 years. There have been a few occasions, especially during rough windy weather, when no snakes were caught in fishing nets. Fishermen get dead snakes occasionally and most said live snakes caught in the nets, and that, irrespective of species, they are released in the sea once the nets were hauledAll fishermen were aware of the fact that sea snakes were venomous. However, fishermen tend to believe that the *H. curtus* is more venomous than *H. schistosus* due to its nature to bite more frequently when encountered/caught in a net. Only one mortality out of a snakebite has been reported in the last five years in the region.

Picture 10: *Hydrophis schistosus* embryos in different stages of development, dissected from dead females encountered in trawlers (top and middle) and a gill net (bottom). (Pic: Trisha Gupta)

Discussion:

Mechanised fishing, particularly trawling, has a significant impact on marine ecosystems and species (Kumar and Deepthi, 2006). The results of this study show that, of the two sea snake species commonly encountered, *H. curtus* appears to be highly susceptible to fishing mortalities (Table 2). Higher mortality of this species may be due to a lower threshold to the physical stress of being caught in nets such as desiccation and dehydration. High mortalities may explain why very few individuals of this species were encountered (Figure 6) as compared to previous surveys. Lobo (2005), for example, found that *H. curtus* predominated sea snake bycatch in fishing nets in Goa. More recent studies, however, have also reported *H. curtus* in fewer numbers (Padate 2009).

On the other hand, *H. schistosus* was found in higher numbers in fishing nets, contrary to Lobo's (2005) surveys. This species also had a lower overall mortality rate (Table 2), indicating a higher resilience to fishing-related stress. *H. schistosus* dominated the sea snake bycatch and was encountered during all months of the sampling. Individuals of all sizes and ages, from small juveniles to larger adults, of this species were found in the fishing nets throughout the sampling period (Figures 3 and 5). In contrast, smaller individuals of *H. curtus* were initially encountered (in November and December), and adults appeared in the nets only from late February/early March (Figure 5). This pattern suggests a seasonal variation of habitat use between adults and juveniles for this species. However, the sample size is not large enough at present to confirm this hypothesis.

The gut content of the snakes revealed the presence of various finned fishes and one invertebrate represented by 12 families (Table 3). Based upon the gut content in *H. schistosus,* this species may be foraging throughout the water column and may also frequently move between intertidal and open water habitats to forage. Presence of benthic species (Cynoglossidae) and snake eels (Ophichthidae) suggest their benthic foraging abilities as well. Being widely distributed, *H. schistosus* and *H. curtus* are generalists and able to thrive on a wide range of prey species (Voris 1979, 1983; Lobo 2005; Lukoschek 2010).

Our study also revealed information on the reproductive habits of these snakes. Dead gravid females of *H. schistosus* were encountered in the months of February and March (one from a gill net and four from trawlers), with a total of 36 embryos at various stages of development (Picture 10). Live, potentially gravid females were also

encountered during February and March, measured and released. Previous studies on other sea snake species have found that mating usually occurs towards December, with the young born in March (Fry et. al. 2001). Our findings suggest that this may hold true for *H. schistosus*. Gravid females are also more vulnerable to fishing nets (Fry et. al. 2001), as well as to fishing-related mortalities, which could have a significant negative impact on sea snake populations. A few encountered individuals of *H. schistosus* were in poor health during the warmer months of April and May. The poor body condition of these snakes might indicate a post parturition period. More studies can shed light on reproductive biology of these animals and their subsequent habitat use.

Comparing the impact of different fishing gears, we find that sea snake bycatch is observed in both trawlers and gill nets (Table 1, Figure 6). Mortality rate of sea snakes was higher in trawlers (Table 1). Post-capture survival experiments found that only 76.4% of individuals encountered alive in trawlers survived the first 24 hours, as compared to 91.9% in gillnets (Figure 7). Trawl fishing, therefore, appears to be a significant threat to sea snakes and other non–commercial marine biota.

Fishermen are aware of sea snakes being highly venomous. But handling them on a regular basis was viewed as an 'occupational hazard'. Despite the number of snakes caught in nets, few snake bite incidents have been officially reported from the region. Fishermen believed that there has been a decline in fish catch but not in sea snake numbers. They stated that there are more species encountered during post monsoon during the months of October, November and December when fishing is at its peak. It should be noted that none of the fishermen killed the snakes caught in their nets. All sea snake deaths were accidental in nature.

In summary, data collected over two sampling seasons indicate trends in incidental captures of two species of the sea snakes. High mortality and fewer incidents of capture of *H. curtus* may be indicative of a declining population. However, large information gaps still exist on their habitat use, feeding ecology, breeding patterns, population ecology, etc. Continued, long-term monitoring and active sampling may shed more light on these questions, which can help understand sea snake interaction and their vulnerability to different fishing practices. The occurrence of adult *H. curtus* in fishing nets during the months of March and April indicate some sort of seasonality in catch patterns of these snakes. More sampling opportunities would help elucidate patterns.

Outcomes:

Some of the outcomes of our study are:

a. Publication of a guide to the sea snakes of Sindhudurg district (in prep)
b. Preparation of three manuscripts based on this project, tentatively on the incidental catch of sea snakes in fishing nets, their diet and their reproductive biology (in prep)
c. A manuscript highlighting results from Phase 1 has been submitted to the Maharashtra Forest Department journal.

Future Work:

Further insight of sea snake diversity and ecology on the Maharashtra coast will fill information gaps that still largely persist from this region. The major aims for any future work would be to initiate similar studies on ecology and long-term monitoring of sea snakes and to assess current conservation threats in other parts of the state. Monitoring populations of *H. schistosus* and *H. curtus* using mark recapture technique and passive telemetry would help test for their habitat use and site fidelity, their conservation status (mortality assessment) through continuous monitoring of bycatch and understand their ecological role in marine ecosystem.

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Appendix 1: List of Tables

Appendix 2: List of Figures

Appendix 3: List of photographs

Cover: *H. curtus* being released at Dandi beach, Malvan (Pic: Chetan Rao)

Picture 1: Fishermen pulling in a Rampan net on Dandi beach, Malvan. (Pic: Trisha Gupta)

Picture 2: *H. schistosus* caught in a mechanised trawler, Vengurla, 2016. (Pic: Chetan Rao)

Picture 3: Left: Fishermen sorting the catch from a gill net on Dandi beach, Malvan (Pic: Trisha Gupta). Right: *H. schistosus* caught in a gill net in 2016. (Pic: Chetan Rao)

Picture 4: Picture 4: Lateral view of the head of *Hydrophis curtus* (top) and *Hydrophis schistosus* (bottom) (Pic: Chetan Rao)

Picture 5: Picture 5: Full body view of *Hydrophis curtus* (top) and *Hydrophis schistosus* (bottom) (Pic: Chetan Rao)

Picture 6: Little file snake (*Acrochordus granulatus*) encountered in a trawler (Pic: Shawn Dsouza)

Picture 7: Top: Dead *H. curtus*, with head injuries, caught in a trawler. Bottom: *H. schistosus* with a dislocated jaw encountered alive in a gill net, which died shortly after. (Pic: Trisha Gupta)

Picture 8: Picture 8: Prey species found in the gut of *H. schistosus*: Left: Sardine (Family: Clupeidae). Right: Grouper (Family: Serranidae). (Pic: Shawn Dsouza)

Picture 9 *H. schistosus* regurgitates a fish (Pic: Chetan Rao)

Picture 10 *Hydrophis schistosus* embryos in different stages of development, dissected from dead females encountered in trawlers (top and middle) and a gill net (bottom). (Pic: Trisha Gupta)

Appendix 4: Questionnaire for determining perception of fishermen about sea snakes

Area	Question
Identification	Can you identify sea snakes?
	Can you tell the difference between sea snakes and eels?
Numbers	Do any snakes get caught in your nets?
	What are the numbers in which snakes get caught?
	What is the maximum number of snakes that get caught?
	Have you noticed any difference in the number of snakes caught in the past and now?
	Have you seen no snakes at all in your nets at times?
	If yes, then during which months?
Bycatch:	How often do you go fishing?
	How do you deal with non-target species/non-commercial animals in your catch?
	How often do you encounter dead snakes in the nets?
	Are sea snakes caught for consumption or any other purpose?
Perception	Did you know sea snakes are venomous?
	Do you know anybody who has been bitten by a sea snake?
	Was the person bitten given proper medical attention?
	Has anybody died due to a snake bite?