

## By-catch mortality of beaked Sea Snake *Hydrophis schistosus* (Daudin, 1803) by entanglement in shore-seine operation in Goa-India

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**Abstract** *Hydrophis schistosus* (Daudin, 1803) commonly known as beaked sea snake occurs in shallow marine and estuarine habitats of India. The population of *H. schistosus* has been frequently noted in the shore-seine net as By-catch. Only a few studies are available about By-catch of sea snakes in Indian coasts. Being a top predator, their mortality and ecological consequences are largely unknown. The present study was conducted along the Caranzalem-Miramar coast of Caranzalem bay, Goa during monsoon (August-September, 2017 and 2018) to focus on the by-catch mortality of *H. schistosus* and their feeding preferences. Observations indicated that the fishing activities, particularly during every shore-seine operation, results in a significant by-catch of sea snakes where approximately 20–60 individuals get entangled in the fishing net. The study indicated a large number (90%) of juveniles being caught in the shore-seine. Gut content analysis of *H. schistosus* revealed that 80% of snakes preferred catfish *Arius jella* as the desired prey species. Sea snakes being top predator play a vital role in checking the local catfish population. Hence, in concern to save *H. schistosus* population and sea snakes, in general, the fishing methods, as well as awareness towards conservation of sea snakes among fishermen, should be raised.

Śmiertelność węża morskiego *Hydrophis schistosus* (Daudin, 1803) w sieciach typu niewód w Goa – Indie

**Słowa kluczowe** wąż morski, *Hydrophis schistosus*, *Arius jella*, sum morski, przyłów, Goa, Indie

**Streszczenie** Wąż *Hydrophis schistosus* (Daudin, 1803) występuje powszechnie w płytkich wodach morskich i estuariach na wybrzeżu Indii, gdzie często jest łapany jako przyłów w sieciach typu niewód.

Do dzisiaj niewiele wiadomo na temat wielkości przyłowy tego gatunku na wybrzeżu Indii. Ponieważ wąż ten jest drapieżnikiem znajdującym się wysoko w piramidzie troficznej ekosystemu wód przybrzeżnych Indii, jego dodatkowa śmiertelność może mieć znaczący wpływ na funkcjonowanie całego ekosystemu. W artykule zawarto dane dotyczące wielkości przyłowy i preferencji pokarmowych *H. schistosus* z wybrzeża Caranzalem-Miramar zatoki Caranzalem (Goa) w czasie monsunu (sierpień–wrzesień, 2017 i 2018 r.). Obserwacje wskazują, że aktywność rybacka, a szczególnie używanie sieci typu niewód, powodują znaczną śmiertelność węży (20–60 osobników zaplątanych w jednej sieci). Młode osobniki stanowią 90% przyłowy. Analiza żołądków *H. schistosus* wykazała, że 80% węży preferowała suma morskiego *Arius jella* jako zdobycz, co powodowało częste zaplątywanie się węży w sieci używane do połowu suma morskiego. Konieczne jest rozważenie alternatywnych metod połowowych, aby uniknąć przyłowy węży.

## Introduction

Sea snakes are an integral part of coastal ecosystem in the tropical Indo-Pacific region and they comprise about 86% of living marine reptile species (Rasmussen, 2011). They inhabit the soft bottom shallow coastal seas to lagoons, estuaries and mangrove areas (Limpus, 1975; Sharma, 2007). Sea snakes are active migrants in the sea but they are less efficient on land and die usually if stranded on the beach for a longer duration (Whitaker et al., 2004; Duarte, 2009).

Sea snakes are protected in Australia under the Environment Protection Biodiversity and Conservation Act 1999, but they are listed as Least Concerned (LC) in the IUCN Red list of threatened species (IUCN, 2018). The beaked sea snake *Hydrophis schistosus* (= *Enhydrina schistosa*) (Daudin, 1803), is a well-distributed Indo-Pacific species and reported as most common species from the Indian coast (Lobo et al., 2004). This species is known for its highly potent neurotoxin as the venome more toxic than those of land snakes; nevertheless, they are found to be rarely aggressive (Chippaux, 1998; Senanayake et al., 2005) despite it, most of the fatalities due to sea snake's bite are associated with *H. schistosus* around the globe (Reid, 1975). The occurrence of this species has been well reported from the entire Indian coast (Lobo et al., 2004; Karthikeyan, Balasubramanian, 2007; Zacharia, 2008; Walmiki et al., 2012; Muthukumaran et al., 2015; Hatkar, Ramesh, 2016). Studies indicate that estuaries comprise a suitable habitat for this species during pre-monsoon and monsoon season to provide ample food or bearing young (Shantov, 1971; Wassenberg et al., 1994). *H. schistosus* is a piscivorous species preferentially feeding on Catfishes and Pufferfish (Voris et al., 1978; Garrett et al., 1982; Jeyabaskaran et al., 2015) but also forage on species of Clupeidae and Engraulidae and fish eggs (Lobo et al., 2005; Emilie et al., 2010).

In India, this species is also impacted by coastal pollution (Mote et al., 2015) and commonly encountered as a trawl by-catch and other fishing operation (Rao et al., 2017). The commercial fishing operation appears to be the foremost threat to this sea snake species due to high volume by-catch (Padate et al., 2009). Due to sporadic reporting of this species mainly as a product of by-catch associated mortality, a significant knowledge gap exists about the population ecology (Hatkar, Ramesh, 2016) and feeding preferences from Indian waters. The aim of the present study was to know the sea snakes by-catch fate and feeding preferences of these top predators. The present observation highlights the ecological importance of *Hydrophis schistosus* wherein we hypothesize that as mega-benthic predators they profoundly influence the local estuarine benthic food chain.

## Materials and Methods

### Study area

The present study was carried on the central west coast of India at Caranzalem-Miramar coast (3.5 km stretch, Lat. – 15°28'09.75"N; Long. – 73°47'40.01"E), located at the mouth of Mandovi estuary (Figure 1). This place is known for fishing by artisanal fishing by local community and also a popular tourist beach in Goa.

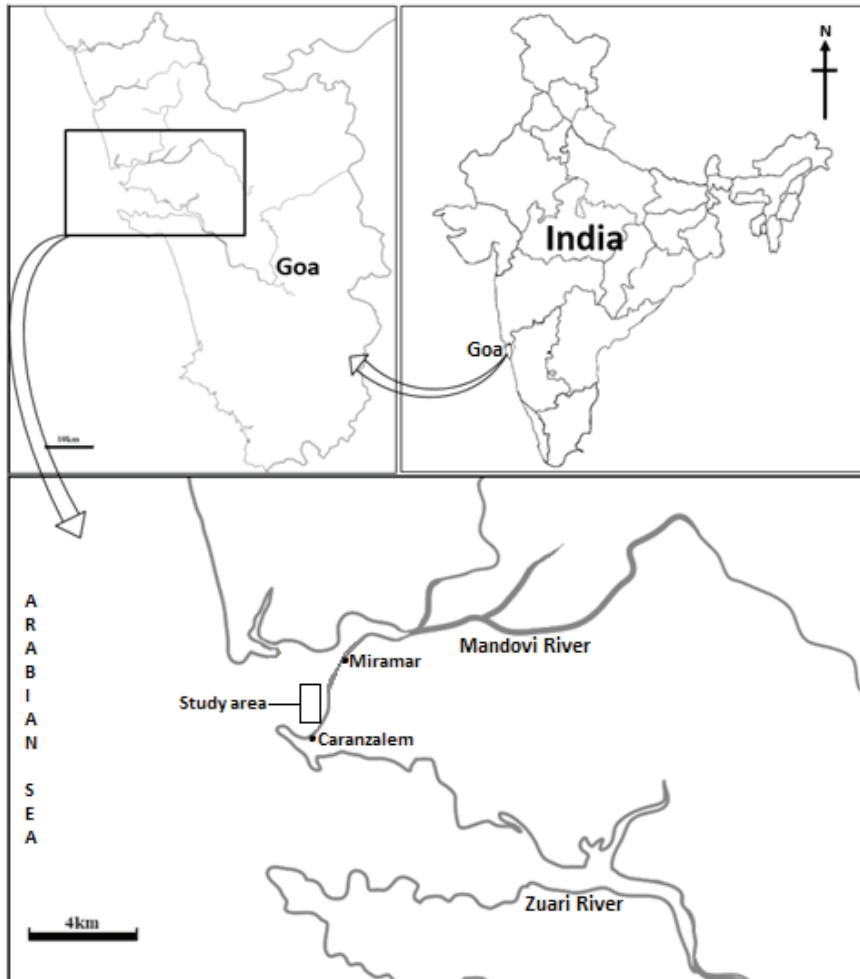


Figure 1. Location of the study area

## Collection of sample

Sampling was carried out twice in a week during August–September 2017 and 2018 after the annual fishing ban period (June–July, a total 61 days during the Southwest monsoon). Counts were carried out of all the sea snakes entangled in the shore-seine net and landing on the beach, followed by a count of dead and live sea snakes. Immediately, after the sorting of landed fishes live snakes were released back into the sea while the dead snakes were brought to the laboratory for further analysis. Morphological identification confirmed that the sea snake species is *Hydrophis schistosus* (Rasmussen, 2001). Fishing gears operated in study area were noted, which revealed that traditional fishing activities such as shore-seine net (locally known as ‘Rampani/Yandi’), operated at a depth of 4–5 m, covering an area of 1.5 km<sup>2</sup> at the mouth of the Mandovi estuary (Figure 2a). The mesh size varies from 10–20 mm and seine nets use sinkers at the bottom and float at the surface, and manually dragged. This traditional fishing method results in the considerable amount of by-catch along with the targeted fish species (Figure 2b). Significant by-catch of sea snakes *H. schistosus* during this fishing operation (Figure 2c) was noted. In the laboratory, measurements were conducted for length-weight of each dead snake specimen (n = 40) followed by gut content analysis (Figure 2d, e).



**Figure 2.** *In-situ* and laboratory observations during the study (a) Seine net operation activity, (b) Discard of by-catch during sorting, (c) Sorted catch after hauling and By-catch removal (note the trails in the foreground made by stranded snakes), (d) Sea snake species *Hydrophis schistosus*, (e) Dissected *H. schistosus* showing gut content, (f) Specimen from the gut (indigested *Arius jella*)

The species gut content confirmed as *Arius jella* using standard literature (Fischer and Bianchi, 1984).

## Results

A total of 1,448 individuals (ind.) of *H. schistosus* were landed as by-catch during the study period. In 2017, 920 ind. were counted in by-catch (695 live and 225 dead), among those 89 were adults (9.67% of total catch; Mean  $5.6 \pm 1.59$  SD) and 831 juveniles (90.3% of total catch; Mean  $51.9 \pm 11.82$  SD). While in 2018, total 528 ind. of *H. schistosus* were recorded, among them 56 were adults (10.6% of total catch; Mean  $3.5 \pm 1.90$  SD) and 472 juveniles (89.4% of total catch Mean  $29.5 \pm 12.69$  SD), among those 407 were alive and 121 were dead (Table 1). Other by-catch species along with sea snake *H. schistosus* were Bamboo sharks, Stingrays, Guitarfishes, Puffers, Catfish and other pelagic juveniles of fishes.

Table 1. Account of *H. schistosus* by-catch during the study period

Year		Total no. of <i>H. schistosus</i>	Adults	Juveniles	Live	Dead
2017	total	920	89	831	695	225
	mean	57.5	5.6	51.9	43.4	14.1
	SD	12.61	1.59	11.82	11.74	4.55
	percentage	–	9.7	90.3	75.5	24.5
2018	total	528	56	472	407	121
	mean	33	3.5	29.5	25.4	7.6
	SD	14.13	1.90	12.69	10.09	4.47
	percentage	–	10.6	89.4	77.1	22.9

The length-weight ratio of *H. schistosus* indicated the presence of juveniles and sub-adults with an average length of 43 cm and weight 35 g (Figure 3). Among the dead specimen collected for laboratory analysis, only one adult was noted with length 97 cm and weighing 359 g. Generally, *H. schistosus* attain maturity at a length of 66–73 cm (Voris, Jayne, 1979; Rasmussen, 2001; Jeyabaskaran et al., 2015). The gut content analysis of *H. schistosus* revealed presence of catfish *A. Jella* in 80% of snake specimens (Figure 2f) and the remaining 20% guts were empty or with the semi-digested or completely digested material (identification of prey items was not possible). The length of *A. Jella* in snake gut varied between 4.32–11.68 cm (Mean  $5.94 \pm 1.65$  SD) and weighed between 0.11–11.79 g (Mean  $1.42 \pm 1.89$  SD).

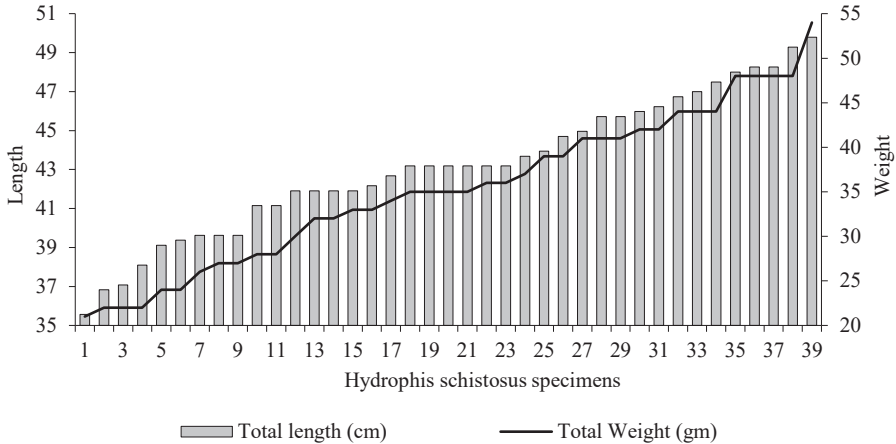


Figure 3. Length-weight ratio of *H. schistosus* sampled at the study location

## Discussion

The mortality of sea snake *H. schistosus* was found to be high in this part of the Arabian Sea. Rao et al. (2017) recorded a total 379 species of sea snakes as by-catch at Vengurla, Devgarh and Sindhudurg districts of Maharashtra within 100 km of present study area. Whereas, Padate et al. (2009) encountered 43 individuals of *H. schistosus* in 70 trawl operations. While on the east coast of India, Muthukumaran et al. (2015) reported the occurrence of 234 entangled sea snakes in trawling nets and seine nets. Several studies revealed that most of the specimens were juveniles and sub-adults (Dell et al., 2009). Use of traditional shore-seine nets is widespread in the Indian coast and known for its by-catch discards where in sea snakes are usually discarded on the shore (Raj et al., 2017). Out of all the sea snakes, Wassenberg et al. (1994) revealed that about 88% of *H. schistosus* being caught as by-catch in the coastal region at the Gulf of Carpentaria, Australia.

During this study, approximately 20–60 live *H. schistosus* entangled were found after hauling of the shore-seine net on the beach (Table 1). Therefore, considering their high abundance in the by-catch indicates that estuarine mouth benthic environment serves as an important habitat for the juveniles by providing ample food. By-catch related mortality of juvenile of marine species arises across the world oceans, as well as in Indian seas is a serious concern (Bijukumar, Deepthi, 2006; Lobo, 2012). A large quantity of by-catch and discard due to trawling and unregulated use of small meshed net causes loss of marine life including endangered species like sea turtle, sea horses and elasmobranchs (Shankar et al., 2004; Salin et al., 2005; Tiralongo et al., 2018).

The present study site at the Mandovi estuary is known to be highly productive area (Kumari et al., 2002; Ansari et al., 2003) and attracts a rich diversity of fishes as it also serves as a nursery ground for most of the species. The high abundance of sea snakes during post-monsoon as compared to pre-monsoon season has been reported in estuarine and inshore waters of Goa and the abundance of small-sized fish attracts more sea snakes into this habitat (Padate et al., 2009). Several mega-benthic predators including sea-snakes, mostly juveniles and sub-adults forage the

area and take refuge in the bay (Brown et al., 2013). Reportedly juveniles of *H. schistosus* may remain in estuarine and riverine habitats for protection and migrate into open water when nearing maturity (Voris, Jayne, 1979; Voris, 1985). The increased number of sea snake *H. schistosus* juveniles in the present study suggest that by-catch mortality is alarming in this area, compared to adjacent regions of Maharashtra, Pondicherry, Kerala and Tamilnadu states of India (Karthikeyan, 2007; Jeybasskaran et al., 2015; Muthukumar, 2015; Rao et al., 2017). Sea snakes are also known for their philopatry and site fidelity (Shetty, Shine, 2002); therefore, continuous by-catch allied mortality of this species in the study area could wipe out the local population and could impose broad scale effect on the ecosystem as well as the artisanal fishery in the region.

The gut content analysis revealed the catfish *A. jella* as the only prey species of *H. schistosus* indicating species specificity. Such a high preference for Ariid catfishes was also noted by Voris et al. (1978) in a feeding experiment as *H. schistosus* prefers benthic organisms as their prey items (McCosker, 1975; Voris, Jayne, 1979). Moreover, the ray finned catfish *A. jella* is a known benthic predator (Ritukumari, Rajukumar, 2007) and regionally has low commercial value as compared to the other economically important fishes. This implies that as a top predator, this sea snake *H. schistosus* controls the population of *A. jella* in the coastal subtidal benthic habitats. As a megabenthic important predator, if *H. schistosus* a natural predator of *A. jella* is removed from the habitat, *A. jella* will dominate this habitat as it is voracious feeder and an omnivore. This dominance of *A. jella* will indirectly out compete other economically important species of Carangidae, Stromateidae, Sciaenidae, Sillaganidae and Cynoglossidae families which are wellnoted from the study area (Noted from shore-siene operation). Apparently, due to reduced predatory pressure, the catfish dominance could impact the population dynamics of other benthic species in the bay and result in population reduction of other commercially important species.

Although the exact population of the *H. schistosus* in the bay region is difficult to decipher, but based on the by-catch mortality it can be said that considerable loss of population may result in ecosystem-level repercussions. Because of habitat destruction and capture a large number of non-target species and juveniles, small meshed seine nets are considered to be detrimental practice (Divakarannair, 2007). However, by-catch reduction is achievable through mesh size regulation with fixed and regulatory bans (Boopendranath et al., 2007); hence, strict implementation of mesh size regulation should be followed. Additionally, development and use of excluder devices and speedy release of the entangled snakes could help to avoid human fatalities and save the sea snake population (Steve, 2007). In addition, worldwide decline of sea snake population is alarming and the high mortality rate of these diminishing populations could threaten the ecosystem (Gibbons, 2000). A long-term monitoring program and the implementation of proper conservation strategies are required to protect this species.

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