New Perspectives on the Ecology and Natural History of the Yellow-bellied Sea Snake (*Pelamis platurus*) in Costa Rica: Does Precipitation Influence Distribution?

Harvey B. Lillywhite[1], Alejandro Solórzano[2], Coleman M. Sheehy III[3], Spencer Ingley[1], and Mahmood Sasa[4]

[1]Department of Biology, University of Florida, Gainesville, Florida 32611 USA
[2]Serpentario Nacional and Museum of Zoology, University of Costa Rica, San Jose, Costa Rica
[3]Department of Biology, University of Texas, Arlington, Texas 76019 USA
[4]Instituto Clodomiro Picado, University of Costa Rica, San Jose, Costa Rica

"... narrative accounts of rarely observed events in species' life histories sometimes have much merit and value. Even a single observation may constitute a valuable contribution and may be a break-through in understanding the species' ecology."

Henry S. Fitch, 1987

More than 60 species of sea snakes have evolved and radiated to occupy tropical oceanic habitats. The majority of these (50+ species) are entirely marine and do not intentionally leave seawater (Heatwole 1999). Nonetheless, fewer than 2.5% of all snake species live in marine environments, and the evolutionary transition from terrestrial to marine habitats is considered to be particularly difficult (Lillywhite et al. 2008a). Osmoregulatory challenges are paramount, and all marine species of snakes (indeed all marine reptiles) have evolved salt glands to assist with elimination of excess salt that is ingested with diet or incidental drinking. Water balance is a related but different issue, and the body water that is lost pas-

ALEJANDRO SOLÓRZANO

Fig. 1. *Pelamis platurus* on a Costa Rican beach. These snakes are sometimes stranded on beaches due to strong offshore winds that cause the snakes to drift toward the shore.

sively to the sea or in feces and secretions must be replenished either from freshwater sources or indirectly from food or seawater. The indirect sources involve further loading of salts and/or metabolites that must be eliminated with further losses of some water.

Recently, Lillywhite et al. (2008b) demonstrated that three species of Sea Kraits (*Laticauda* spp.) require fresh drinking water to replace body water deficits, as these snakes dehydrate in seawater in spite of the fact that they possess salt glands. Evidently, in these species, salt glands are important to ion balance but are insufficient to maintain water balance in marine environments. Based on current literature, representative species belonging to four out of five major lineages of marine snakes have been shown to require fresh water (or very dilute brackish water) for the maintenance of normal water balance (Lillywhite et al. 2008b). Therefore, changes in patterns of precipitation related to global warming may have important implications for the survival and distribution of marine snakes.

Whether so-called "true sea snakes," which are fully marine species, require fresh water for water balance remains to be determined. We are currently investigating this question, and we have some evidence for a freshwater requirement in the Yellow-bellied Sea Snake, *Pelamis platurus* (Figs. 1 & 2). Based on laboratory investigations of water and sodium fluxes in this species, Dunson and Robinson (1976) found that fasting *Pelamis* dehydrate in seawater (–0.4% body mass per day), and they documented drinking of fresh water when it was offered to dehydrated snakes. Snakes kept in seawater survive for long periods if fed on freshwater fish (Dunson and Robinson 1976; AS, pers. obs.), but whether these snakes can survive for long periods if kept in full seawater and fed on marine fish remains unclear.

Yellow-bellied Sea Snakes (*Pelamis platurus*)

This species of sea snake has the broadest distribution of any snake. It ranges from the coastal waters of eastern Africa along the southern Asian coasts to Japan, southward and eastward to Australia and islands of the western Pacific, thence eastward to the Americas. It is the only sea snake that has reached the eastern Pacific Ocean, and is the only species that is present on the Pacific Coast of Central America. This snake is entirely marine, gives birth to living young at sea, and is pelagic in habits. It is a species of small to moderate size, reaching a maximum length of about 1 m (Solórzano 2004). *Pelamis* has been regarded as a "passive surface drifter" that is often wafted by currents to latitudes at which it is not a breeding resident (Dunson and Ehlert 1971). Because of its cosmopolitan distribution and pelagic habits, this species of sea snake is of central importance to testing the hypothesis that fresh water is required for physiological water balance in marine habitats.

Observations of others and our own collecting experiences in Costa Rica indicate that *Pelamis* are found in greatest numbers in association with oceanic "slicks" (Kropach 1971, 1975; Dunson and Ehlert 1971). Slicks are smooth glassy streaks forming drift lines in the ocean resulting from the accumulation of foam, floating plant parts, and other debris (flotsam; Fig. 3). They occur in convergence zones where organic material accumulates, flattens the water, and creates zones of concentrated biological activity. Slicks may contain contaminate films of organic oils probably derived from diatoms, and they become discernible because of their damping effect on small wavelets. The convergence zones are created by a variety of physical processes and currents such as internal waves and eddies (Ewing 1950). Slicks are biologically important because plankton become concentrated in the convergence zones and create good places for zooplankton and fishes to find food. Indeed, slicks have been regarded as biological communities. They can also be harmful to sea life, however, because they also concentrate noxious debris and pollutants. Slicks can be relatively small and short-lived, but they can also form drift lines extending for hundreds of meters or kilometers. They are likely agents favoring dispersal of sea snakes, but their dynamics in this context are very poorly understood. We propose three hypotheses for why sea snakes associate with oceanic slicks. First, a very popular notion in the literature is that slicks provide improved feeding opportunities due to occurrence of fishes seeking shelter beneath the floating debris (Kropach 1975, Heatwole 1999). A second hypothesis is that convergence of waters concentrates floating sea snakes just as it does floating debris, which would be a purely passive phenomenon. In support of this idea, others have conjectured that *Pelamis* probably does not actively seek out slicks (Dunson and Ehlert 1971). A third hypothesis is camouflage, for the sea snakes resemble some of the floating parts of plants both in color and in form, often mimicking floating sticks to which fish are attracted (Hunter and Mitchell 1968). This could reduce predation on sea snakes as well as facilitate their feeding opportunities. Kropach (1975) also suggested that gathering at slicks increased mating opportunities for sea snakes, but this would seem dependent on one of the other reasons for the primary association of snakes with slicks.

The Coastal Distribution of *Pelamis* in Costa Rica

Yellow-bellied Sea Snakes are generally distributed along the entire Pacific coast of Costa Rica, and are usually found within 1–20 km of the coast (Voris 1983, Solórzano 2004). Especially dense populations have been noted at several locations in relatively close proximity to the coastline. These include Golfo de Papagayo and associated bays (Bahía Culebra and several playas immediately to its south), Cabo Blanco at the south end of the Nicoya Peninsula, waters between Bahía de Coronado and the northern end of the Osa Peninsula (Punta San Jose), and within the Golfo Dulce near the southern end of the country. These populations are known to us from the experiences of one of us (AS) or from literature. Other dense populations almost certainly occur elsewhere, but have not been brought to our attention.

We are presently exploring the hypothesis that the coastal distribution of *Pelamis* is partly dependent on the availability of fresh water. This was suggested for the euryhaline marine snake *Acrochordus granulatus* (Lillywhite and Ellis 1994) and was demonstrated to be the case where species of *Laticauda*, or "Sea Kraits," have been studied on a local scale at Orchid Island, Taiwan (Lillywhite et al. 2008b). Three species of *Laticauda* are abundant at sites with access to a freshwater spring or estuary, whereas few or no snakes are found at strictly seawater sites. Moreover, the abundance of these snakes also varies with rainfall, and fewer snakes are found during periods of drought or low rainfall. As discussed elsewhere (Lillywhite et al. 2008b), *Laticauda* spp. exhibit a patchy distribution that correlates with low-salinity tropical waters in the western Pacific and Indian Oceans. Also, a preliminary assessment of sea snake distribution in tropical south Asia and the Indo-Australian region reveals that the species diversity of all sea snake species correlates with mean annual rainfall (Lillywhite et al. 2008b).

Several sources of fresh water are potentially available to sea snakes. In addition to precipitation, these include springs, estuaries, or temporary outflows from the coast. Heavy rainfall forms a temporary freshwater lens at the ocean surface due to the density difference from seawater, and such lenses are the only source of fresh drinking water in the open sea away from the immediate coastline. The fact that *Pelamis* in Costa Rica can be found nearer to the coast during the dry season (AS, unpubl. obs.) is potentially relevant; and in Mexico, even more pronounced seasonal changes in distribution are evident (HL and CS, unpubl. obs.; see also Duellman 1961). These snakes might be moving to closer associations with coastal estuaries during periodic droughts, based on knowledge of sites with which we are familiar from our own fieldwork. *Pelamis* are occasionally reported from estuaries (Shuntov 1966). Indeed, various species of sea snakes are observed in estuaries, and they sometimes move considerable distances into rivers (Dunson 1975). Alternatively, *Pelamis* might appear to be more abundant nearer the coast due to prevailing stronger winds during the dry season, which could wash these snakes onto the shore at times (Solórzano 2004). Numerous reputable observers have described strandings of *Pelamis* on beaches, usually in association with storms (Dunson and Ehlert 1971). Slicks also might form in greater number near the coastal bays during the

HARVEY B. LILLYWHITE

Fig. 2. *Pelamis platurus* illustrating some of the variation of color pattern, which varies from mostly black to black and white or yellow to all yellow.

dry season. These hypotheses remain to be tested with the alternative explanations in mind.

Conclusion

Some marine snakes, including certain sea snakes, have been shown to be dependent on access to fresh water for water balance and occur in greater abundance near freshwater sources (Lillywhite et al. 2008b). We do not know whether the majority of sea snake species, which are entirely aquatic,

HARVEY B. LILLYWHITE

Fig. 3. Slicks seen near Playa del Coco, Costa Rica. (A) A narrow slick identified by foamy driftline. (B) Flotsam and debris associated with a slick. (C) A broader slick without debris; note the calm water in the center of the photograph.

also require fresh water. Physiological studies suggest that the pelagic species *Pelamis platurus* dehydrates in seawater and will drink fresh water in the laboratory (Dunson and Robinson 1976). Thus, one might infer that *Pelamis* requires fresh water for water balance, but this aspect of its physiology remains to be properly tested and documented. The movements of this pelagic species are largely unknown, but some features of its distribution in Costa Rica suggest that it might associate more closely with coastal sources of fresh water, such as estuaries, during times of periodic drought. The potential influence of fresh water on movements of this species might affect metapopulation dynamics in important ways that remain to be explored. We are currently investigating the physiology, distribution, and genetic structure of *Pelamis* populations in these contexts. Knowledge of the water requirements of sea snakes — and *Pelamis* in particular — will enhance our understanding of the distribution of these marine reptiles and how they might respond to future changes in the distribution, intensity, and periodicity of precipitation.

Acknowledgements

The research on which this article is based was supported by the National Geographic Society, Committee for Research and Exploration (grant # 8058-06 to HBL), the National Science Foundation (grant # IOS–0926802 to HBL), and a grant from the Explorers Club (to SI). We are grateful to Adán Barrera for assistance with boat transportation and locating of sea snakes in Costa Rica.

Literature Cited

Duellman, W.E. 1961. The amphibians and reptiles of Michoacán, Mexico. *University of Kansas Publications of the Museum of Natural History* 15:1–148.

Dunson, W.A. 1975. Adaptations of sea snakes, pp. 3–19. In: W.A. Dunson (ed.), *The Biology of Sea Snakes*. University Park Press, Baltimore.

Dunson, W.A. and G.W. Ehlert. 1971. Effects of temperature, salinity, and surface water flow on distribution of the sea snake *Pelamis*. *Limnology and Oceanography* 16:845–853.

Dunson, W.A. and G.D. Robinson. 1976. Sea snake skin: Permeable to water but not to sodium. *Journal of Comparative Physiology* B 108:303–311.

Ewing, G. 1950. Slicks, surface films and internal waves. *Journal of Marine Research* 9:161–187.

Fitch, H.S. 1987. The sin of anecdotal writing. *Herpetological Review* 18:68.

Heatwole, H. 1999. *Sea Snakes*. Krieger Publishing Co., Malabar, Florida.

Hunter, J.R. and C.T. Mitchell. 1968. Field experiments on the attraction of pelagic fish to floating objects. *Journal du Conseil* (*Conseil international pour l'Exploration de la Mer*) 31:427–434.

Kropach, C. 1971. Sea snake (*Pelamis platurus*) aggregations on slicks in Panama. *Herpetologica* 27:131–135.

Kropach, C. 1975. The Yellow-bellied Sea Snake, *Pelamis*, in the eastern Pacific, pp. 185–213. In: W. Dunson (ed.), *The Biology of Sea Snakes*. University Park Press, Baltimore.

Lillywhite, H.B. and T.M. Ellis. 1994. Ecophysiological aspects of the coastal-estuarine distribution of acrochordid snakes. *Estuaries* 17:53–61.

Lillywhite, H.B., C.M. Sheehy III, and F. Zaidan III. 2008a. Pitviper scavenging at the intertidal zone: An evolutionary scenario for invasion of the sea. *BioScience* 58:947–955.

Lillywhite, H.B., L.S. Babonis, C.M. Sheehy III, and M-C Tu. 2008b. Sea snakes (*Laticauda* spp.) require fresh drinking water: Implications for the distribution and persistence of populations. *Physiological and Biochemical Zoology* 81:785–796.

Shuntov, V.P. 1966. Distribution of sea snakes in the South China Sea and East Indian Ocean. *Zoolicheskij Zhurnal* 45:1882–1886.

Solórzano, A. 2004. *Snakes of Costa Rica*. Instituto Nacional de Biodiversidad (INBio), Costa Rica.

Voris, H.K. 1983. *Pelamis platurus,* pp. 411–412. In: D.H. Janzen (ed.), *Costa Rican Natural History*. The University of Chicago Press, Chicago and London.