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I. RUBINOFF
and
C. KROPACH

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Differential Reactions of Atlantic and Pacific Predators to Sea Snakes

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I. RUBINOFF
C. KROPACH

Smithsonian Tropical Research Institute,
Box 2072,
Balboa, Canal Zone

Predators from the Pacific made no attempt to attack the Pacific sea snake *Pelamis platurus*. Atlantic predators, however, were more inclined to attack, sometimes being wounded by their prey. This suggests that if a canal in Central America facilitated the spread of *Pelamis* to the Atlantic, the species would eventually spread throughout the ocean as selection favoured predators disinclined to attack it.

If a sea level canal is built in Central America[1,2] abundant populations of *Pelamis platurus* could reach the Atlantic Ocean from the eastern Pacific. Very little is known about the behaviour and ecology of this venomous reptile, which is widespread in tropical and subtropical waters from the east coast of Africa to the west coast of Central and South America. Known as the yellow bellied sea-snake, it reached the eastern Pacific relatively recently, presumably in the 2 or 3 million years since the rise of the Isthmus of Panama.

We have attempted to evaluate the relationships of *Pelamis* to Pacific predators and to potential Atlantic predators. We have examined the reactions of eastern Pacific predators to *Pelamis* both in the field and in the laboratory, and studied the response of naive Atlantic predators to *P. platurus*.

Search for Natural Predators

Pelamis is ovoviviporous and spends its entire life at sea. Although individuals can dive for up to 1 h they spend much time at or near the surface. In the sea it will spend more than 30 min, more or less motionless, at the surface. *Pelamis* swims relatively slowly and its yellow and black colour and behaviour make it visible and recognizable from farther away than a similarly sized stick or dull coloured animal would be. Specimens are usually easy to capture—we usually catch them from the surface of drift lines with a dip-net. The sluggish habits of the species would be likely to make *Pelamis* potentially vulnerable to a wide range of fish and avian predators.

Wetmore reports seeing *Fregata magnificens* pick up *Pelamis*, fly off, and then drop them without further interest[3]. We have occasionally captured specimens with healed wounds, shaped as though caused by bird beaks. *Pelamis* have not, however, been found in the stomach contents of any sea bird and in many hours of observations we have never witnessed an attack. Neither have we found any evidence of *Pelamis* in the stomach contents of 420 specimens, including twenty-six species of bony and cartilaginous fishes, taken in Panama Bay (between 7° 30′ and 8° 55′ N latitude and 78° 10′ and 80° 0′ W longitude) usually near drift lines containing *Pelamis*.

Reaction of Captive Pacific Predators

Several carnivorous Pacific fishes (*Ginglymostoma*, *Epinephelus*, *Lutjanus*, *Centropomus* and *Scianus*) were established in 15–70,000 gallon tanks of sea water. They were all willing to attack and feed on living anchovies and carangids and after 10 days of acclimatization they were given only specimens of *Pelamis* for 20 min each day. The predators swam to within approximately 12 inches of the snake, stopped to make an inspection and then usually showed no further interest. During more than 30 days no predatory behaviour developed towards *Pelamis*. In some cases when snakes were left in a tank with a predator the latter starved rather than attempt to feed on them. On one occasion a snapper which had become conditioned to seize live food thrown from the surface ingested a snake as it hit the water, before it could have seen or smelt the fish below the surface. It immediately spat out the snake and paid no further attention to it.

Reaction of Captive Atlantic Predators

To test the reactions of naive Atlantic predators to intact *Pelamis*, relatively large specimens of *Lutjanus* spp. were established in concrete tanks and treated in a similar manner to the Pacific predators before being presented with *Pelamis*.

Pelamis represented a new shape, pattern and smell to these fishes. On the initial encounters the Atlantic predators showed interest, swam close for examination

Table 1. SUMMARY OF TESTS OFFERING LIVE *Pelamis* TO CAPTIVE PREDATORS

	No. of species	No. of specimens	No. of trials	No. of attacks	No. of predator deaths
Pacific	10	21	316	1	0
Atlantic	9	21	383	35	3

and followed the snakes for varying periods. Usually, by the tenth trial the more aggressive of the snappers attacked the *Pelamis*. Attacks were usually directed toward the head and ingestion was rapid, being completed in less than 10 s. Two snakes were taken tail first; one of them bit the fish under the eye just before it was completely swallowed. The fish died in 20 min. On several occasions the Atlantic fishes ingested several snakes consecutively. The survival of Atlantic fishes ingesting *Pelamis* varied. Some fish ate an occasional *Pelamis* with impunity, one was killed when eating its first snake and another relatively efficient predator consumed twenty-two snakes in 31 days before succumbing to a snake bite. Table 1 summarizes the results of the feeding experiments with Atlantic and Pacific predators.

Evolution of *Pelamis* Recognition

The Pacific predators which do not eat sea snakes seem to have been selected for a strong aversion to *Pelamis*. Atlantic predators, on the other hand, will feed on live *Pelamis*, and after the first meal more are accepted without hesitation. One 18 inch snapper ingested four 12 inch *Pelamis* in less than 20 min. On one occasion an Atlantic snapper ingested two sea snakes consecutively. The fish died within 1 h, presumably the victim of an internal bite, for no biting was observed during attacking and swallowing. Both sea snakes were regurgitated after about 1 h and both subsequently survived. This may help to explain the evolution of the highly toxic venom which *Pelamis* possesses. Since the fish victim almost always dies, how then has selection produced a venom more toxic than the terrestrial snakes from which sea snakes have evolved ? The food of *Pelamis* is not usually envenomated, so that selection for trophic efficiency is probably not a primary factor. The common explanation that a predator might learn to avoid snakes after surviving a sub-lethal bite does not seem to apply in this case. But if a dying fish which has eaten a sea snake and been bitten occasionally regurgitates a snake, a selective mechanism for increasing the potency of the venom may be at work.

What will happen when Pacific predators witness successful predation on *Pelamis* by Atlantic fishes (if the canal is built through the geographical barrier) ? One of the most powerful stimuli to feeding in fish is for them to witness feeding by other fishes. When we offered sea snakes to Atlantic and Pacific fishes together, the attack and ingestion of *Pelamis* by Atlantic fishes produced excitement and close inspection by the Pacific predators, but no attempt to eat a snake was observed. Sometimes two or more Atlantic snappers fought for a single snake. A Pacific snapper might be attracted to and follow an Atlantic snapper with a partially ingested snake, but we saw no attempts to take it away.

It is possible that the brilliant and conspicuous colour pattern of *Pelamis* is aposematic and that potential predators have been selected to avoid it. In the most common pattern about 75–85 per cent of the body is uniformly black dorsally, yellow midlaterally and brownish ventrally. The lateral and ventral colour is more similar after shedding and the ventral darkening becomes more pronounced with "ageing" of the skin. The tail is covered with black spots on a yellow background; the size and distribution of the spots are individually specific as a finger print. We have examined the distribution of body pattern uniformity in 167 specimens of *Pelamis*. All degrees of intermediate conditions appear between the "standard type" (15–25 per cent of the

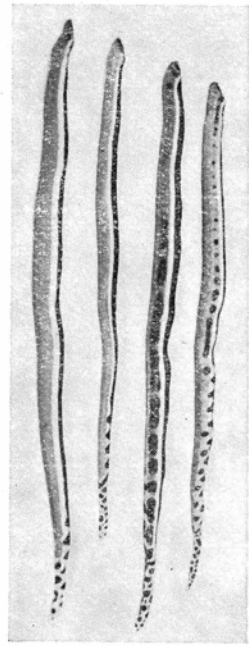

Fig. 1. Examples of pattern variability in *Pelamis platurus* from Panama Bay.

body spotted as in the left-hand specimen of Fig. 1) and spotting completely up to and including the head (as in the right-hand specimen of Fig. 1). Yellow specimens with reduced spotting have also been observed (personal communication from Dunson and Voris). The variation in pattern has been observed in all age classes, with about equal frequency, so that deviation from the "standard" does not seem to be particularly deleterious.

With few exceptions polymorphism (even conspicuous continuous variation) is uncommon in aposematic organisms[4]. The usual explanation for this is that in most circumstances it is not advantageous for aposematic organisms to have variations in pattern which may confuse predators, which if they have been selected for or have learned to avoid a particular colour or pattern may be unable to associate variations with the "standard" and may attack when they should not. If a sensory clue other than vision were important in the predator's recognition of *Pelamis* it might be possible to explain the variation in colour pattern as a relaxation of selection for the "standard" phenotype. In our aquaria two adult Pacific nurse sharks *Ginglymostoma cirratum*, which are essentially scavengers and/or olfactory predators, refused to eat living or dead *Pelamis*. In February 1970, two juvenile *G. cirratum* were captured. One was probably not more than a few weeks old, and it is unlikely that either of them had experienced contact with *Pelamis* in the inshore areas from which they were taken. No *Pelamis* had been reported there for several months. The sharks were quickly trained to accept food from forceps, and offered pieces of fresh and frozen sea snake. All were rejected. They could discriminate between similarly sized and shaped pieces of squid and pieces of sea snake. If *Pelamis* were sandwiched inside the mantle of a squid the sharks would ingest it, mouth the morsel for a few seconds then swallow the squid and expel the snake. These observations suggest that not only visual clues are used by predators to recognize *Pelamis*.

Using felt marking pens we changed the colour of specimens of *Pelamis* to all black or black and red. All of these were rejected by Pacific predators and so were freshly killed and skinned snakes. Feeding frenzies can be produced in captive predators by throwing living anchovies into the tank, but even in these circumstances

of very aggressive, competitive feeding, the fishes discriminated 100 per cent against *Pelamis*. All Pacific predators examined refused to eat living or dead (whole or cut up) *Pelamis* with skins on or off.

Our observations suggest that Pacific fishes can recognize *Pelamis* by visual, olfactory, and/or gustatory clues. The relative importance of the different modalities may, of course, vary from species to species. Aposematic visual aspects seem to be only part of the recognition criteria, although formerly they may have been more important. If conspicuously (but not similarly) coloured ophichtid eels were offered to Pacific fishes they were immediately attacked and eaten. The general serpentine shape and bright colours are thus not necessarily avoided by these predators.

Future Prospects

Pelamis platurus does not have characteristics which are universally avoided by marine fishes. Avoidance of *Pelamis* seems to be specifically selected for in organisms which have direct contact with them. In Central America the avoidance reaction has probably evolved to its present level in less than 3 million years, or rather less than the time since the rise of the Isthmus, after which *Pelamis*, presumably, arrived in the New World.

It is possible to speculate on the colonization potential of *Pelamis* if they are afforded access to the Atlantic. Large numbers of *Pelamis* are periodically stranded or appear swimming along the Pacific shores of Panama and they represent potential propagules through an unobstructed sea level canal. There seems to be no habitat requirement of *Pelamis* which could not be satisfied in the Atlantic. Drift lines of debris attracting the small fishes which constitute much of the food of *Pelamis* are found in both oceans. Drifts of Sargasso weed would probably provide ideal feeding grounds for *Pelamis*.

Invading *Pelamis* would probably be heavily preyed on so that their initial movement would be inhibited. But selection would quickly favour predators that are unwilling to attack *Pelamis* (even if only one out of twenty-two meals results in the death of the predator, this is a very high selection rate). The development of avoidance reaction in predatory species would follow. If a sea level canal were built the probability of these animals eventually colonizing the tropical Atlantic would be great, but predation by Atlantic carnivores would probably reduce the speed of this colonization.

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