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Short Note

First record of a leptocephalus larva ingested by a chaetognath

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Abstract— An approximately 17 mm *Nemichthys scolopaceus* leptocephalus was found in the gut of a 25 mm chaetognath, *Sagitta (Flaccisagitta) hexaptera*, collected in the North Equatorial Current region of the western North Pacific. The chaetognath was photographed before preservation. The leptocephalus was folded in half and was positioned deep within the hindgut. Although the chaetognath was caught during sampling for leptocephali, its location in the hindgut suggests that the leptocephalus could have been ingested prior to capture by the net. This first record of ingestion of this unique type of fish larva suggests that if contact is made with small leptocephali, it is possible for them to be ingested by relatively large sized chaetognaths that may identify them as potential prey.

Key words: chaetognath, leptocephalus, feeding, *Sagitta (Flaccisagitta) hexaptera*, *Nemichthys scolopaceus*

Chaetognaths are carnivorous zooplankton that are abundant and widely distributed in the world's oceans and often rank second in abundance only to copepods (Feigenbaum and Maris 1984). Their role in trophic interactions and ocean flux as predators of copepods continues to be the focus of much research (Sullivan 1980, Øresland 1987, Dilling and Alldredge 1993, Terazaki 1995, Froneman and Pakhomov 1998, Øresland 2000). While copepods are the major food source of chaetognaths, there have also been several reports of chaetognaths with larger items in their guts, such as fish larvae, polychaete larvae, amphipods and even other chaetognaths (Alvariño 1985, Feigenbaum 1991). We report here what may be the first record of a leptocephalus being eaten by a chaetognath to show that this unique type of soft-bodied fish larva may be captured and easily ingested by chaetognaths.

Sampling for leptocephali occurred during the KH-04-2 cruise of the R/V Hakuho Maru in the North Equatorial Current region of the western North Pacific. Tows were made using a 3 m Isaacs Kidd Midwater Trawl (IKMT) with an 8.7 m^2 mouth and 0.5 mm mesh. A chaetognath containing a leptocephalus was collected on 22 May 2004 (Stn. 20: 16° 59.8′N, 141°59.7′E), in a tow that reached a depth of 466 m. The duration of the tow was 78 min. Leptocephali were being sorted fresh from the plankton, when the chaetognath containing the leptocephalus was observed and removed. It was photographed prior to preservation in 10% formalin-seawater using a Nikon SMZ 1500 dissecting scope and a Nikon DMX 1200 digital imaging system. The chaetognath was identified later according to Alvariño (1967), and the leptocephalus was identified following Smith (1989). To avoid damaging the two specimens, the total length of the leptocephalus was estimated after fixation without dissecting it out of the chaetognath.

The chaetognath was identified as a 25 mm TL *Sagitta (Flaccisagitta) hexaptera*. The specimen is catalogued in the zooplankton collection at the University of Tokyo, Ocean Research Institute (ORI-KH-04-2 No. 205). This species has a cosmopolitan epiplanktonic distribution in temperate and warm regions of the ocean. It is distributed in the Pacific from 43°N to 44°S, in the Atlantic from 40°N to 40°S and in the Indian Ocean it extends south to about 42°S (Alvariño 1965). Bieri (1959) reported a similar range in the Pacific with a notable concentration in the western Pacific between Japan and the Philippines. *Sagitta (Flaccisagitta) hexaptera* is typically found at depths of 0 to 150 m but occasionally appears as deep as 300 m (Alvariño 1965). It typically preys on copepods, but has also been known to ingest other crustaceans, fish larvae and even other chaetognaths (Alvariño 1985).

The leptocephalus was lodged in the hindgut of the chaetognath in a folded position, with the head and tail pointing anteriorly (Fig. 1). Even in a folded position, the leptocephalus could be identified as *Nemichthys scolopaceus* of the family Nemichthyidae because of its distinctive pigment characteristics. Small *N. scolopaceus* leptocephali have at least 3 large lateral pigment spots and small pigment spots on the notochord (Smith 1989). This combination of characters excludes all other species of leptocephali. The head and eye shape could also be seen clearly to be that of *Nemichthys* (Fig. 1). The adults of this cosmopolitan species live in the midwater environment primarily in the mesopelagic zone

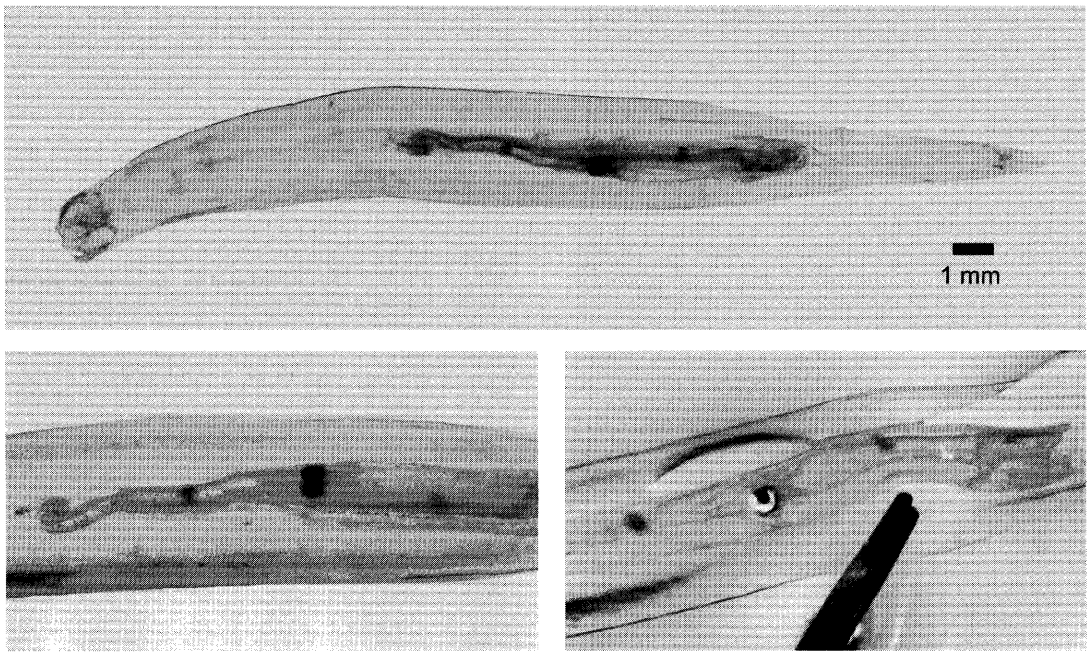

Fig. 1. Photographs of a 25 mm chaetognath (*Sagitta hexaptera*) that had ingested an approximately 17 mm leptocephalus (*Nemichthys scolopaceus*). The body of the leptocephalus is folded, and both its head and tail point toward the anterior end of the chaetognath.

(Nielsen and Smith 1978). Their leptocephali have been collected in many regions of the world and in some areas they can be very abundant after spawning has occurred (Miller and McCleave 1994). All leptocephali are distributed in the surface layer, and pre-metamorphic *N. scolopaceus* leptocephali have been found to be most abundant in the upper 100 m, with almost none being captured deeper than 250 m (Castonguay and McCleave 1997). Thus, the depth distribution of *N. scolopaceus* overlaps directly with that of *S. hexaptera*.

Common methodology in chaetognath gut content analysis considers only prey items in the upper third or quarter of the gut to be the result of cod end feeding (Feigenbaum and Maris 1984, Øresland 1987, Duró and Saiz 2000, Kehayias 2003). The location of the leptocephalus deep within the hindgut suggests it could have been ingested prior to capture of the chaetognath. Furthermore, digestion time would have been long enough to make ingestion prior to capture feasible. Digestion time estimated using Baier and Purcell's (1997a) regression equation for a similar *Flaccisagitta* species, *Sagitta* (*Flaccisagitta*) *enflata*, was ~1.6 hrs for water temperatures in the upper 100 m where leptocephali congregate and rose to ~4.7 hrs for water temperatures experienced throughout the duration of tow. Laboratory observation of *S. enflata* in live tanks reported movement of ingested prey to the hindgut in 2 min or less (Szyper 1978). Yet, it is questionable if the same holds true for all prey types and if the rates of movement are applicable to the more stressful, turbulent conditions of long horizontal tows or to extended periods of time in the cod-end. During short (<2 min), vertical hauls of ~13 m, Szyper (1978) observed *S. enflata* to have less than 3% of all food items forward of the most posterior portion of the gut and proposed that ingested prey must be moved rapidly to the hindgut. However, Baier and Purcell (1997b) found much higher percentages of prey in the foregut of *S. enflata* in surface tows of 2 and 5 min duration with fixed periods of holding time in a simulated cod-end. Their study recorded peaks of 32% (5 min tow) and 34% (5 min tow plus 5 min hold in cod-end), depending on the mesh size of the net. Although the percentage eventually decreased with time, at an overall duration of 40 min in the cod-end there was still ~15% prey in the foregut. Apparently, movement of prey to the hindgut can be slowed or stopped in longer tows where chaetognaths are subjected to more stress in the net. In that case, cod-end feeding may be more readily recognized by prey in the foregut. Furthermore, Baier and Purcell's (1997b) study found that prey loss, not cod-end feeding, was the most notable effect of net collection on chaetognaths.

In tows longer than a couple of minutes it is essentially impossible to be absolutely certain whether any prey item was ingested before or during sampling. What is possible is distinguishing between appropriate prey and inappropriate prey on the basis of what can be ingested and utilized. Obviously, large medusae or salps, which are often found in the grasp of chaetognath hooks (Feigenbaum and Maris 1984), can never be ingested nor considered appropriate prey. However, the leptocephalus presented here, which has been fully ingested and moved to the hindgut for digestion, can be considered an appropriate prey item despite the possibility that it

was ingested in the cod-end. There is nothing to suggest that ingestion of leptocephali by chaetognaths couldn't occur in other circumstances if successfully captured.

Capture of leptocephali could be difficult and infrequent however, because they can actively swim in both forward and backward directions (Miller and Tsukamoto 2004). Yet, if successfully struck, the tetrodotoxin venom (Thuesen 1988) of chaetognaths may aid with incapacitation of these gelatinous larvae. The body structure and physiology of leptocephali is quite different than that of other fish larvae because their laterally compressed body is filled with a transparent gelatinous material that is only overlain by a thin layer of muscle tissue (Pfeiler 1999). This type of body would have a much softer texture than typical fish larvae and may be more easily pierced by the hooks and teeth of chaetognaths. Additionally, the soft flexible body of leptocephali would probably make them relatively easy to be ingested in a folded position, as was suggested by the shape of this specimen in the gut. In cases of cannibalism, soft body chaetognaths are also sometimes ingested in a folded manner (Pers. observ.). Folding is most likely a result of where the hooks and teeth land upon initial strike as that can dictate where the chaetognath will begin ingesting the prey; unfolded chaetognaths also appear in gut content analyses along with unfolded fish larvae (Thuesen and Bieri 1987).

The leptocephalus ingested was relatively large in relation to the overall length of the chaetognath. This is in accordance with the cost-benefit ratio that heavily favors selection of chaetognath-sized particles over copepod-sized particles as food items (Pearre 1982). Previous studies have examined the possibility of chaetognath predation upon fish larvae (Baier and Purcell 1997a, Brodeur and Terazaki 1999), but the fact that leptocephali have never been reported in the guts of chaetognaths suggests that even if they can be easily ingested if captured, they are probably not typically captured and eaten by chaetognaths—perhaps due to the mobility of leptocephali.

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