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Observation of Abundant Larval Arctic Shanny (*Stichaeus punctatus*) in the Western North Atlantic, Found in the Waters of the Isles of Shoals, Maine, USA

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Information about the life history of larval fishes can be sparse, especially at the edges of typical geographic ranges and among fishes for which there is no commercial fishery. We report a new observation of larval Arctic Shanny (*Stichaeus punctatus*) far south of their typical geographic range in the western North Atlantic. Only two previous records of adult of *S. punctatus* have been documented in this region, and there has only been one previous report of larvae in US Atlantic waters. From May through July 2018, we observed large numbers of larval *S. punctatus* by night-lighting off a dock at Shoals Marine Laboratory on Appledore Island, Maine, in the Gulf of Maine. We include approximations of catch per unit effort (number of larvae per ten-minute sampling interval) throughout the sampling period and information regarding identifying features. The high number of larvae seen could indicate that the Isles of Shoals is a spawning locality for this species and could indicate a future increase in their abundance in the southern Gulf of Maine.

ARCTIC Shanny (*Stichaeus punctatus*) is a member of the family Stichaeidae (Infraorder Zoarcales, *sensu* Betancur et al., 2017; Suborder Zoarcoidei, *sensu* Imamura and Yabe, 2002) broadly distributed in arctic and subarctic waters. In the western North Atlantic, the range of adult *S. punctatus* extends from Hudson Bay, Baffin Island, Davis Strait, Labrador, Newfoundland, Gulf of St. Lawrence, and Nova Scotia to a single adult in Massachusetts Bay and another singular occurrence off Desert Island, Maine (Collette and MacPhee, 1969; Farwell et al., 1976; Fahay, 2007). Larvae of *S. punctatus* have only once been previously reported south of Nova Scotia in Penobscot Bay, Maine (Lazzari, 2001). Unlike most other arctic zoarcoid fishes, which tend to have demersal direct development (Dunbrack and Green, 2016), *S. punctatus* have a long pelagic larval stage, and it is possible that larvae are dispersed over long distances by wind-driven ocean currents and strong tidal flow (Farwell et al., 1976; Lazzari, 2001; Dunbrack and Green, 2016). Larvae in the northeast Pacific Ocean and the Bering Sea have been collected in April through August, with highest abundances in May, at lengths of 6.4–27.0 mm (Matarese et al., 2013). In the waters of Newfoundland and northern Maine, larvae have been collected in April through September (Farwell et al., 1976; Lazzari, 2001).

We document the southernmost observation to date of larvae of *S. punctatus* in the Atlantic Ocean and provide a summary of key traits for identification of larvae of this species. We found these larvae in relatively high abundance throughout summer 2018 in the waters surrounding Appledore Island, Maine, USA. This island is part of the Isles of Shoals, a small archipelago that spans the border of Maine and New Hampshire in the southern Gulf of Maine. Presently, there is no information about this species in the United States waters of the Gulf of Maine beyond two records of singular adults (Collette and MacPhee, 1969) and one record of larvae much further north in Maine (Lazzari, 2001). While *S. punctatus* is not of commercial importance, it may play an important role in the ecology of the Gulf of Maine, particularly if the larvae comprise an underreported portion of the zooplankton community. Larval fishes are a major part of the ocean ecosystem, making up to 42.5% of zooplankton by species, depending on the season and location (Highfield et al., 2010). Documentation of larval fish communities within a particular region, such as the Gulf of Maine, can provide critical information related to the health and maintenance of the region's marine fauna. The following information on *S. punctatus* will add to the current natural history records of larval fish assemblages in the Gulf of Maine.

MATERIALS AND METHODS

We collected larvae of *Stichaeus punctatus* in the waters immediately surrounding Appledore Island while conducting research at Shoals Marine Laboratory (SML) from 23 May–18 July 2018. Once per week, we submerged a waterproof LED fishing light off of a dock to attract phototactic zooplankton shortly after sunset ("night-lighting") and used a fine mesh dip net to catch the larvae. On all sampling days (except 18 June, which was cut short due to rain), we sampled for 40–90 minutes. In addition to collecting individuals, we estimated the total number of individuals that we could see. Starting in June, the larvae appeared in large numbers as a swarm, and therefore we estimated their counts by sampling a small area with the dip net, counting individuals in that area, and then extrapolating. We were conservative with our estimates and assume that the actual numbers were higher. Using these estimates, we calculated Catch Per Unit Effort (CPUE) by dividing number of larvae observed per ten-minute interval of sampling. In addition to night-lighting, we conducted occasional plankton tows around Appledore Island during the day. We photographed the larvae *in vivo* using a dissection microscope (Olympus SZX61) with a camera attachment. We then euthanized them in MS-222 and fixed them in 10% formalin solution. The larvae were then progressively transferred into 70% ethanol for long-term storage at the Smithsonian National Museum of Natural History (USNM 451314 and USNM 451315). We used a

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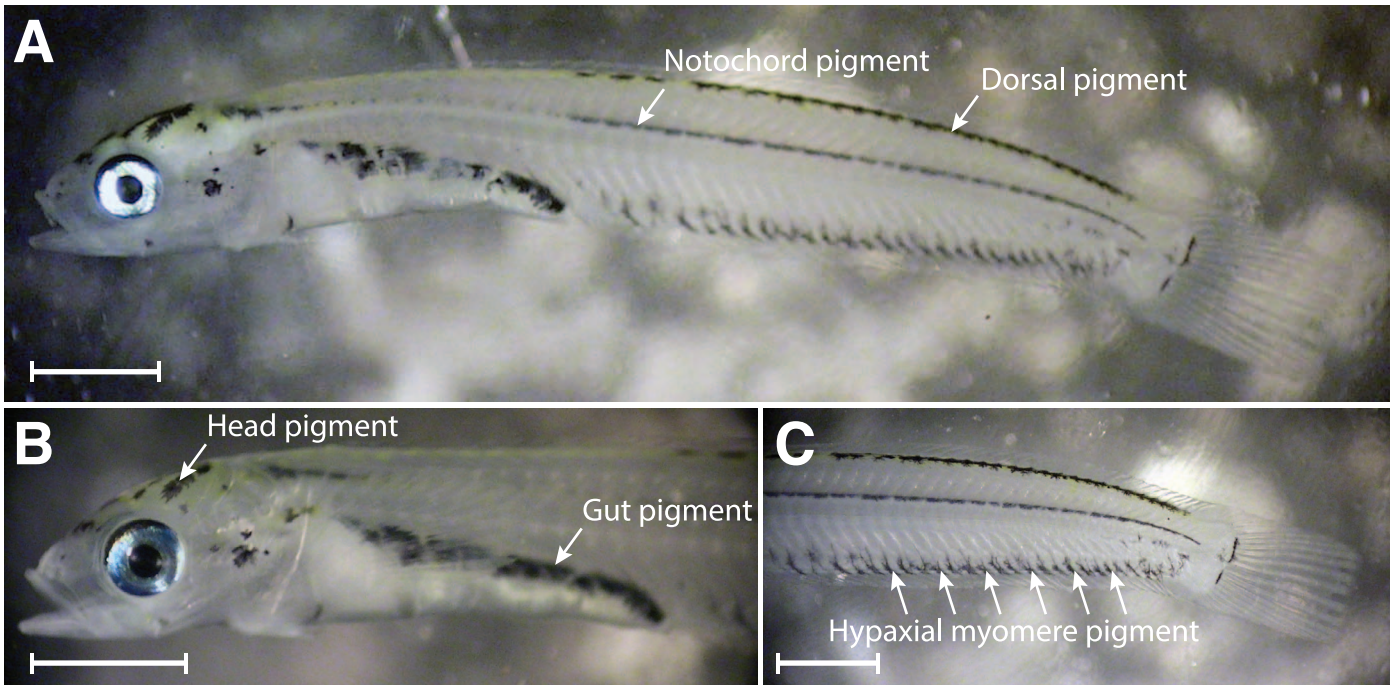

Fig. 1. Microscopy photographs of larvae of *Stichaeus punctatus*. These photographs of live fishes demonstrate pigment patterns and vent position. The image of the whole body (A) shows the overall pigment pattern. The image of the anterior region of the fish (B) shows the melanophores on the head and along the dorsal surface of the gut to the vent. The image of the caudal region (C) shows the ventral hypaxial myomere pigment. Scale bars represent 1 mm.

Camera Lucida to produce an illustration to accompany our photographs. This work was conducted with IACUC approval from the University of New Hampshire (Protocol #180501).

RESULTS

Considering the rarity of *Stichaeus punctatus* at this locality, we were careful to verify our identification. We primarily referenced Fahay (2007), who defined *S. punctatus* as having 33–37 postanal myomeres and a distinctive pattern of melanophores (Figs. 1, 2). Larvae of *S. punctatus* have a much larger amount of pigment than that of other sympatric stichaeid species (Matarese et al., 2013; Suzuki, 2013). Pigment of the larval *S. punctatus* is present internally on the dorsal surface of the gut as a streak of melanophores that extends all the way to the vent (Fig. 2B). Pigment is also present on the head and the dorsum of the posterior half of the body. While notochordal pigment is present in small sizes, midline pigment develops in larger larvae. There are also streaks of pigment on the hypaxial limbs of the postanal myosepta (Fig. 2C), which became important when distinguishing them from other similar-looking zoarcoid species such as *Ulvaria subbifurcata* and *Pholis gunnellus* (Fahay, 2007; Matarese et al., 2013). We also used the vent position, which helped to distinguish from other similar-looking larvae such as that of Ammodytidae, which have a vent position more posterior (greater than 50% of the length of the body) to that of the Stichaeidae and Pholidae (Fritzsche, 1978; Matarese et al., 2013).

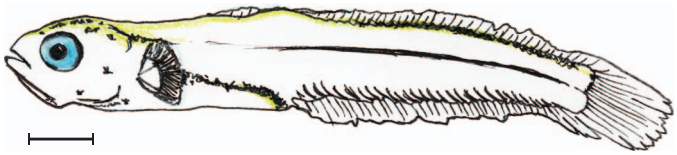

Fig. 2. Color illustration of larvae of *Stichaeus punctatus*. This illustration shows melanophores and color patterns. Scale bar represents 1 mm.

In late May, we caught fewer than 30 individuals each week, catching under five individuals per ten minutes of sampling (Fig. 3). In the following five weeks, according to our estimates, the number of *S. punctatus* increased dramatically, with at least 100 individuals observed each night and a CPUE of 20–50 individuals per ten-minute interval (Fig. 3). Numbers of individuals likely far exceeded 100 on most nights in June, except on a particularly stormy night (18 June) when individuals were sparse and sampling was limited

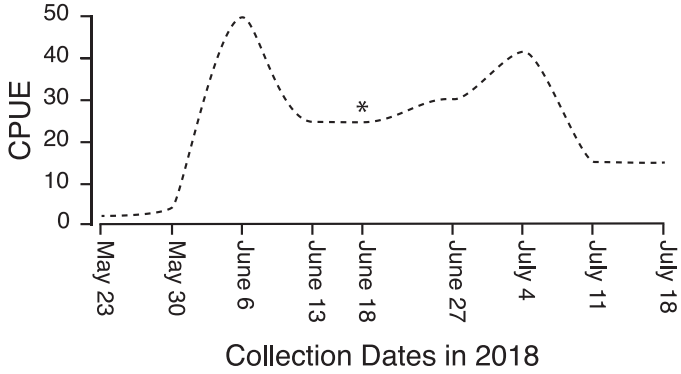

Fig. 3. Approximate Catch Per Unit Effort (CPUE) of larval *Stichaeus punctatus* during the sampling period. We sampled larvae weekly by night-lighting from 23 May to 18 July 2018. We defined CPUE as number of larvae per ten-minute interval. Sampling periods ranged from 40–90 minutes, except on 18 June when sampling was shortened to 20 minutes due to rain and wind (denoted with an asterisk).

to 20 minutes due to rain, wind, and large swells. In the final two sampling weeks, the number decreased to around 75 larvae, or 15 larvae per ten-minute interval (Fig. 3). We also caught a sparse number of individuals (7 total) on occasional daytime plankton tows. Throughout the nine weeks, larval size remained relatively consistent, with individuals ranging from 6–18 mm.

DISCUSSION

There have been only two previous records of adult Arctic Shanny sighted farther south than Nova Scotia (Collette and MacPhee, 1969). There has been only one record of larval Arctic Shanny in US waters of the Atlantic (Lazzari, 2001), far north of the Isles of Shoals. However, throughout the course of our summer sampling, we found hundreds of larval *Stichaeus punctatus* around the Isles of Shoals in the Gulf of Maine (Fig. 3). We identified these larvae using descriptions and illustrations from many sources (Fritzsche, 1978; Fahay, 2007; Matarese, 2013; Suzuki, 2013). We used these descriptions to aid in the creation an illustration (Fig. 2) to accompany our photographs that will assist with future identification. These larvae are easily distinguished from other species due to the anterior position of their gut and their distinctive melanophore pattern (Fig. 1).

Presence of these larvae in high numbers in this region has several implications. First, it is possible that there is a population of spawning adult *S. punctatus* around the Isles of Shoals. It is also possible that these adults are further north or offshore, because pelagic larvae tend to drift and may be brought south by the Labrador Current (Lazzari, 2001). Larval drift may explain the sparse reports of adults in the region. Second, it is possible that these high number of larvae indicate an increase in this prevalence of this species in the Gulf of Maine. We might expect that adults and larvae will be found in larger numbers in the future and may constitute an increasingly important component of the changing Gulf of Maine ichthyofauna.

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