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BRIEF COMMUNICATION

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Nesting behavior of greater eelpout (*Lycodes esmarkii*), identified through a predation event by spotted wolffish (*Anarhichas minor*)

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Abstract

The stomach of a spotted wolffish (*Anarhichas minor*) caught in Icelandic waters was found to contain ~727 greater eelpout larvae (*Lycodes esmarkii*). All the larvae were of similar size and at a similar state of digestion, indicating they were all consumed together. The likely explanation for this observation is that greater eelpout lay their eggs in a nest, with the larvae remaining in the nest for a short period after hatching. The larvae were then predated upon by the spotted wolffish while still in the nest. This study sheds new light on greater eelpout in Icelandic waters, with recently hatched larvae being present in March, breeding at a depth of ~200–250 m, and likely exhibiting nesting behavior, which has not previously been documented.

KEYWORDS
eelpout larvae, Iceland, juvenile predation, spotted wolffish predation, stomach contents

The greater eelpout is a poorly understood, cold-water demersal species, which inhabits the north Atlantic Ocean. Its depth distribution is described, for the entire eastern Atlantic, as 275–550 m (Andriashev, 1986) but has been caught at depths 310–1090 m in western Greenland and 80–1200 m in Iceland (Møller & Jørgensen, 2000; MFRI, unpublished data). Around Iceland, individuals up to 102 cm have been caught, but specimens >70 cm are rare (MFRI, unpublished data). The greater eelpout is known to lay demersal eggs that are ~5.5–6.0 mm in diameter (Andriashev, 1986; Dolgov, 1995). Information on fecundity is sparse; a 36-cm female was reported to have had 216 eggs (presumably referring to the number of oocytes), whereas large females have a fecundity of ~1200–1900 eggs (Andriashev, 1986; Dolgov, 1995; Møller & Jørgensen, 2000).

The spotted wolffish *Anarhichas minor* Olafsen 1772 is another demersal cold-water species but is somewhat larger than the greater eelpout, growing up to ~150 cm (MFRI, unpublished data). In Iceland, spotted wolffish inhabit depths of ~100–500 m with overlap in its distribution with that of the greater eelpout (Figure 1a). Spotted wolffish are equipped with large, protruding teeth, and jaws that they use to feed on echinoderms, crustaceans, mollusks, and other fish species. It is also known to be cannibalistic (Albikovskaya, 1983; González et al., 2006; Jaworski & Ragnarsson, 2006; Kristinsson, 1997; Simpson et al., 2013; Templeman, 1986). Given that a significant portion of their diet consists of sessile organisms, it is likely that they actively forage for prey as opposed to a sit-and-wait strategy.

On March 5, 2023, during the Icelandic groundfish survey, a female spotted wolffish (43 cm and 0.72 kg) was captured at ~236 m depth (depth at casting of trawl = 238 m, depth at hauling of trawl = 234 m, bottom temperature = 2.2°C) (Figure 1a) and dissected to gather information on sex, maturity and age as part of standard data collection. The stomach contents for spotted wolffish are not routinely examined during the survey, but in this instance they were examined out of curiosity by the first author. The stomach of this specimen contained a large number of fish larvae (we use the more common term larvae for newly hatched fish rather than "fry"), of all the same species, which appeared to have been recently consumed given the undigested state (Figure 1c,d). Based on total weight of all larvae (148.4 g) and weight of 20 larvae (4.08 g), it was estimated that there were ~727 larvae. Two larvae were preserved in

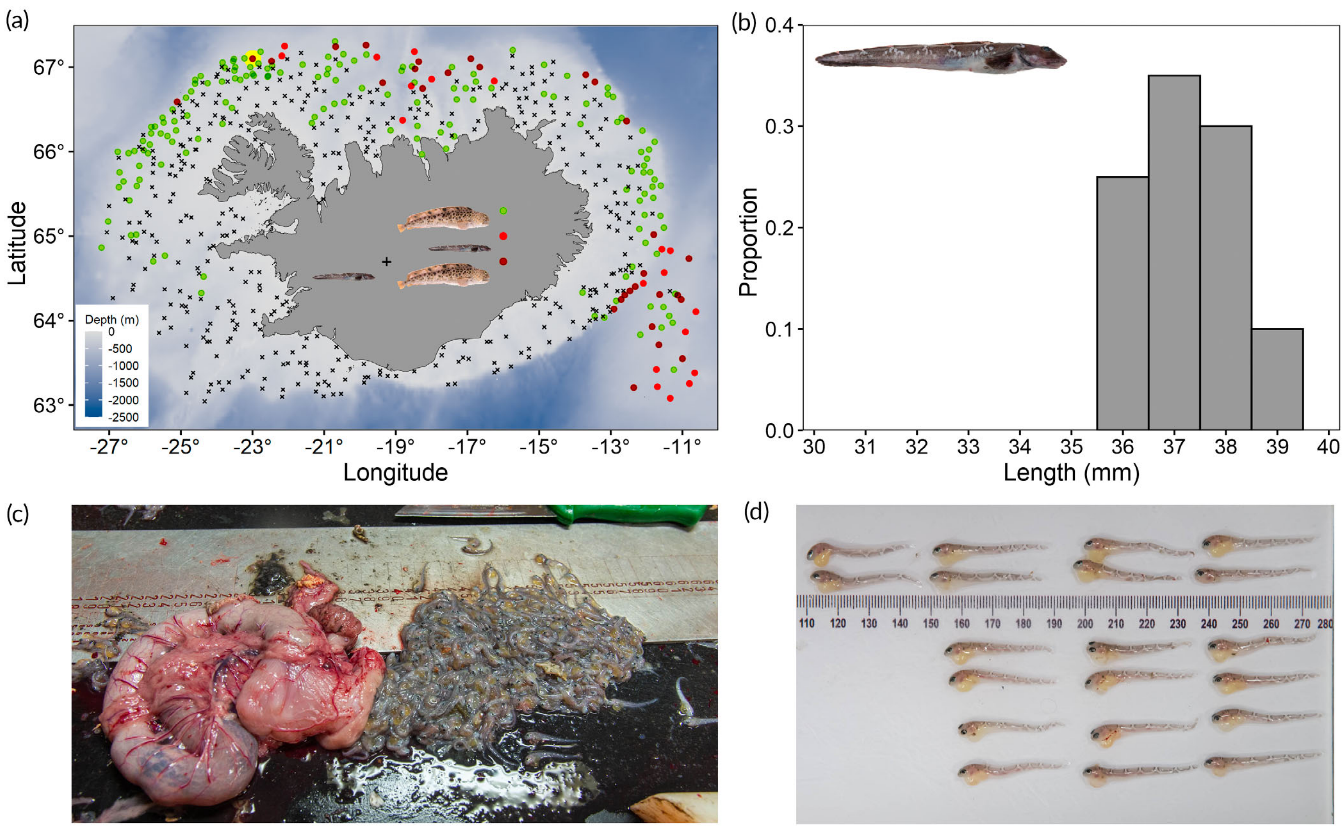

FIGURE 1 (a) Capture locations of spotted wolffish (*Anarhichas minor*) (green dots) and greater eelpout (*Lycodes esmarkii*) (red dots) and where both species were captured together (dark red dots) during the Icelandic groundfish survey in 2023; yellow spot shows the station where the spotted wolffish with the eelpout larvae in its stomach was caught, black crosses show where neither species was caught. (b) Length distribution (mm) of greater eelpout larvae collected from the stomach of *Anarhichas minor*. (c) Stomach content of *A. minor*. (d) Larvae collected from the stomach of *A. minor*.

ethanol for later genetic identification, whereas the rest were frozen. Standard length of 20 larvae was measured before freezing, and their length varied from 36 to 39 mm with an average of 37.3 mm and standard deviation of 0.9 mm (Figure 1b). It was initially believed that the larvae were cannibalized spotted wolffish larvae, but a picture was posted on twitter to show an interesting and unusual finding, and with the hope that the larvae could be identified by any interested parties. The picture was reposted onto a Norwegian science marine biology forum (Spør en havforsker [Ask a marine biologist]) by Bjørnar Eggen, which was then passed on to Rupert Wienerroither by Gro van der Meeren. The larvae were then identified as a zoarcid, the greater eelpout *Lycodes esmarkii* Collett 1875, and the species identification was later confirmed using cytochrome c oxidase subunit I (COI) (Hebert et al., 2003). The previous day on the survey, another spotted wolffish was captured at a similar depth (200–250 m), and its stomach contained a large number of eggs (Arnþór Bragi Kristjánsson, pers. comm.). Unfortunately, no samples were taken, and the eggs were not identified.

Given the large number of larvae that were present in the stomach, which were in a narrow size range and all in a similar state of digestion, it suggests that these larvae were likely concentrated in a small area and not dispersed before being consumed. The likely explanation is that greater eelpout deposit their demersal eggs in close proximity of each other, perhaps in a nest or benthic structure such as a burrow or depression in the seabed. The number of larvae present in the stomach is also consistent with this explanation when considering the fecundity of this species. The use of benthic structures (burrows) has previously been documented for two Pacific zoarcids (Ferry-Graham et al., 2007) but not for greater eelpout. It is difficult to know for sure if greater eelpouts guard their eggs after laying; however, this is known to be common behavior in teleost fishes that exhibit nesting behavior (Blumer, 1982). Given the relatively undigested state of the larvae, it is reasonable to assume that they were consumed within a day or two of the spotted wolffish being caught. This reveals that in Icelandic waters, recently hatched larvae of greater eelpout are present in March and that the species are likely to spawn at ~200–250 m depth. Although the incubation time for this species is unknown, given the low temperature and large egg size, and using information from other species, suggests an incubation time exceeding 1 month, possibly two (Pauly & Pullin, 1988; Teletchea et al., 2009). This lengthy incubation time would place spawning time around December to January. Jónsson and Pálsson (2013) suggested spawning took place late summer/Autumn in Iceland, which in turn would then suggest an incubation time of several months.

As the observations of this study establish that greater eelpout deposits its eggs in a nest, they also provide direct evidence that spotted wolffish predate the nests of other fish species. That we possibly observed this twice within a short period of time suggests that this is not particularly rare. This raises the question whether spotted wolffish specifically visit spawning areas of eelpouts looking for nests or whether predation of these nests is purely opportunistic; that is, they were foraging in the area and came across the nest. However, there is limited overlap between spotted wolffish and greater eelpout with data from the Icelandic spring groundfish survey (depth range: ~50–500 m) showing that greater eelpout (mean depth = 388 m, 0.05 and 0.95 quantiles: 259 and 504 m) tends to occur at greater depths than spotted wolffish (mean depth = 247 m, 0.05 and 0.95 quantiles: 152 and 369 m) (MFRI, unpublished data) (Figure 1a), which will presumably limit the predation pressure on greater eelpout nests from spotted wolffish. Numerous studies have documented the stomach contents of adult spotted wolffish, but only two have found fish eggs and larvae, and this was only in small amounts (González et al., 2006; Simpson et al., 2013) suggesting that opportunistic predation on nests is more likely than actively seeking out nests. However, Jónsson and Sigurðsson (1982) and Jónsson and Pálsson (2013) mention that the eggs of Atlantic wolffish *Anarhichas lupus* Linnaeus 1758 are found in the stomachs of spotted wolffish during the spawning and incubation season of Atlantic wolffish. Unfortunately, it is not known how the eggs in the stomachs of spotted wolffish were identified as Atlantic wolffish eggs, as the source of the information has been lost (Jónbjörn Pálsson, pers. comm.). The egg size of Atlantic wolffish and greater eelpout is similar (>5 mm diameter) (Andriashev, 1986; Falk-Petersen & Hansen, 2003), which means that the eggs may have been misidentified as Atlantic wolffish. Anyway, Atlantic wolffish (mean depth = 137 m, 0.05 and 0.95 quantiles: 61 and 237 m) has a shallower depth distribution than spotted wolffish (MFRI, unpublished data), with limited overlap, which indicates that it is unlikely that spotted wolffish are consuming significant amounts of Atlantic wolffish eggs.

There is still a poor understanding of the feeding behavior of spotted wolffish, and the extent of predation on the nests of other fish species is unknown. There is also an underappreciation of the role played within the marine ecosystem by zoarcids, which are relatively common in northern latitudes, but poorly studied. The nests of zoarcids are clearly a target for spotted wolffish, and likely other fishes, so information on the spatial distribution of their spawning grounds could help understand the distribution and feeding ecology of their predators. The primary visual identification of the larvae highlights the advantage of scientists engaging with the public through social media and through publicly accessible forums that are specifically designed for the public to engage with scientists. The posting of the picture resulted in quick visual identification of the larvae, which was later confirmed using a genetic marker often employed in species determination (COI) (COI analysis performed by Matis, Iceland).

AUTHOR CONTRIBUTIONS

Sampling of the spotted wolffish stomach and measurement of the larvae was performed by James Kennedy. The larvae were visually identified by Rupert Wienerroither. The first draft of the manuscript was written by James Kennedy, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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DATA AVAILABILITY STATEMENT

The cytochrome c oxidase subunit I sequence is available on request to the corresponding author.

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