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Short Note

Unorthodox Sampling of a Fin Whale's (*Balaenoptera physalus*) Diet Yields Several New Mesopelagic Prey Species

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Fin whales (*Balaenoptera physalus*) are large filter feeders that target aggregated small crustaceans and fishes that occur in bulk in the upper 500 m of the water column (Deméré, 2014). Much of the knowledge on fin whale diet stems from stomach content analyses associated with whaling (Nemoto, 1959; Jonsgård, 1966; Kawamura, 1980; Christensen et al., 1992; Vikingsson, 1997). Whales' intestines were not normally sampled but should also hold prey remains since prey have also been identified from faeces (e.g., Notarbartolo di Sciara et al., 2003; Villa et al., 2011). Further, if successive meals vary, the stomach and intestine may contain different prey. Therefore, dietary information may be missed if only stomach contents are examined.

On 19 August 2014, a fin whale carcass was reported afloat in the North Sea off The Netherlands. The carcass was brought ashore and determined to be a 16.8-m-long immature male. Among other studies, we aimed to add to the knowledge of the diet of fin whales based on an examination of this individual's stomach and intestinal contents. During the *postmortem* investigation on the beach, a crane was used to collect the stomach, which was badly damaged in the process, and only a fraction of the stomach contents could be collected. It was not possible to string out the mass of partially decomposed intestine and systematically sample from stomach to anus. Instead, eight segments of 0.5 to 3.0 m length were tied shut at either end and bagged individually. Approximately 20 m (271 kg) of intestines (cross section: 10 to 30 cm) were collected. It was estimated that less than half of the total length of the intestine was collected. The samples were frozen until analysis.

On defrosting, the stomach contents were washed into a series of large (1 × 1 m) sieves, with 1.0- and 0.5-mm mesh size. A large bag made out of plankton netting (0.3-mm mesh) was placed underneath as a final sieve. A gross examination indicated virtually all prey remains were from krill (Euphausiid crustaceans). Some of the more intact krill were picked out and identified to be *Meganyctiphanes norvegica*. The three resulting sieve fractions (weighing 3 kg in total) were machine-washed, following Bravo Rebolledo et al. (2013, online supplement). Machine washing dissolves most krill exoskeletons (pers. obs.) but leaves harder prey remains (e.g., bones, beaks, and otoliths) and foreign objects (e.g., plastic particles) unaffected, making these easy to recognize.

The eight sections of intestines were treated separately. Each section was cut open, and a subsample of the contents was collected (averaging 772 g; SD = 675 g; range: 387 to 1,487 g). The remainders of all intestinal contents were pooled and washed over the same set of sieves and went through the same washing machine treatment as the stomach samples. The eight intestine subsamples were hand-washed individually over two smaller sieves (425- and 200-µm mesh, respectively), and the material retained was collected and subsequently sorted under a binocular microscope. While sorting, we were vigilant to also collect hard parts of other prey (e.g., squid beaks or squid eyes, or polychaete jaws) and nonfood items (e.g., stones, plastics, or pieces of wood), but none were found.

The only non-krill prey remains identified were fish sagittal otoliths. These were photographed with a Zeiss camera stereoscope, identified, and had their length and width measured using Axiovision software (*AxioVs 40*, Version 4.8). Most of the otoliths found in the intestine were pearlsides (*Maurolicus muelleri*) (97.5%, $n = 239$). Härkönen (1986) offers regression equations to estimate pearlsides' length and mass from pristine otolith length (OL, mm):

Fish total length (cm) = (9.82 + (OL*28.75))/10 (1)

Fish mass (g) = $0.3737*OL^{2.503}$ (2)

Fourteen pearlsides otoliths were found in the stomach contents. No otoliths were found in seven of the eight subsamples from the intestine, but in one (a relatively small sample of 382 g), 216 pearlsides otoliths were found, including 74 that were determined to be in near-pristine condition (see Leopold et al., 2015, for the method of assessing wear in otoliths used in diet studies). Rostrum presence and otolith length were apparently unaffected by wear. Based on measurements of these, the pearlsides eaten by the fin whale averaged 4.15 ± 0.17 cm in length and 0.48 ± 0.07 g in mass (Figure 1). As each fish has two sagittal otoliths, the minimum number of pearlsides represented by the 230 otoliths was 115, and these had a combined mass of approximately 55.2 g. No otoliths were found in the pooled sample of intestinal contents, probably indicating that these had been destroyed in the process of sieving the large quantity of digesta.

In addition to the pearlsides otoliths, nine otoliths of other mesopelagic fishes were found, all in the stomach contents. Seven otoliths of spotted lantern fish (*Myctophum punctatum*) were identified, and two otoliths (of two fishes) were determined to be from a myctophid species but could not be further identified due to their highly eroded state. Using unpublished regression equations (Jérôme Spitz, pers. comm.), the fork lengths of the spotted lantern fish ranged from 4.51 to 5.57 cm (total lengths between 5.26 and 6.49 cm, with total length estimated as 1.166*fork length from photographs of intact fishes), and in mass from 0.64 and 1.32 g. The estimated combined mass for the four spotted lantern fish represented was 4.5 g.

Many fin whale diet studies have ignored intestinal contents. This is probably due to the large length and volume of the intestinal tract and the more advanced decomposition of the prey, making direct identifications more challenging. Moreover, as a full stomach provides so many prey to work

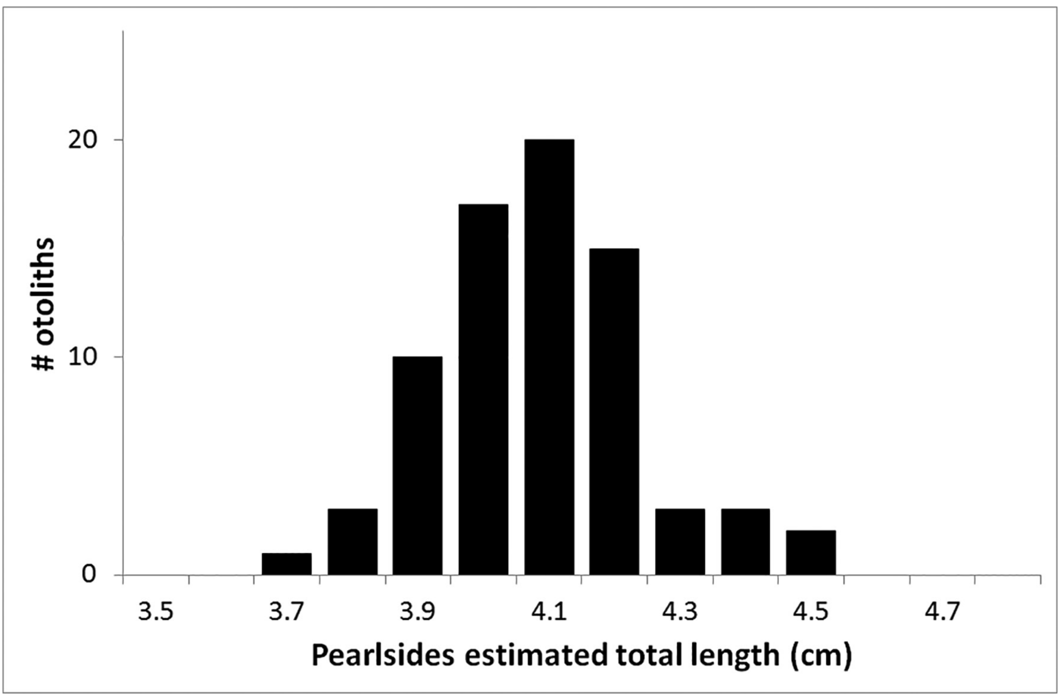

Figure 1. Length-frequency distribution of pearlsides (*Maurolicus muelleri*) estimated from the lengths of near-pristine otoliths found in the intestine of the fin whale

with, intestinal contents might seem to be redundant. However, if meals are processed as successive batches, the stomach would only contain the last meal(s), while earlier meals will have already passed into the intestine. Several authors have suggested that meals pass through the entire digestive system of a whale as batches. Diffusion or mixing between meals may be negligible such that ingested meals can be evident through the digestive tract as *plugs* (Penry & Jumars, 1986, 1987; Kooijman, 2010).

In the fin whale digestive tract we examined, the fact that the vast majority of pearlsides otoliths were found in only one part of the intestine is evidence for a meal plug. This also indicates that one aberrant meal is easily missed. Potentially, the whale had been predominantly feeding on krill (all intestinal contents had the typical brown colour of partly digested krill), but also took pearlsides independently or as a school that was intermingled with krill. The number of pearlsides otoliths in the intestine only represented ~55 g of fish, but many otoliths could have eroded completely. The total amount of fish consumed in this meal cannot be determined. The lantern fish otoliths found in the stomach are less likely indicative of specific targeting of myctophids than they are of "bycatch" of a few fishes incidentally swallowed with a mouthful of krill. A fin whale found on the bow of a ship in the port of Rotterdam in 2013 (IJsseldijk et al., 2014) also had mostly krill in its stomach as well as two myctophid otoliths, probably *M. punctatum*. Hence, myctophid fish may be a more common prey of fin whales than previously thought.

Our study also suggests that dietary information may be missed if only a cursory examination of the stomach contents is made. The few pearlsides otoliths in the stomach were only recognized following machine washing and careful sorting. A less thorough examination of the stomach contents would have suggested that this whale was a monophagous krill eater. Because the pearlsides were predominantly found in one section of the intestine, it would seem important to sample the entire length of the gastrointestinal tract to maximise prey determinations for large whales from the intestine. This may be impractical in large whales, however. For example, Vikingsson (1997) found that forestomachs can contain 5 to 600 kg of krill. Considerably more material could come from the intestine. We suggest that subsamples at regular intervals along the length of the intestine may be appropriate. This is likely more effective and less destructive in the case of small fragile otoliths than taking large sections of intestine and processing the contents (as done in this study) or the entire gastrointestinal tract.

The single whale that was found in 2014 does not reveal the true importance of mesopelagic fish species in the fin whale diet, but finding these prey should not be a surprise. Pearlsides in particular, like northern krill, occur over a vast range of the ocean and are common in the deep scattering layer (Kaartvedt et al., 1996) where fin whales probably do much of their foraging (Deméré, 2014). Pearlsides are rich in energy (Spitz et al., 2010) and would be a highly suitable prey for fin whales (Spitz et al., 2012). It is likely that fin whales would deliberately target pearlsides schools as an alternative food source if these were encountered in sufficient densities. To the best of our knowledge, however, this is the first report of pearlsides and spotted lantern fish found as prey species of fin whales.

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