

Abstract—We describe the food habits of the Sowerby's beaked whale (*Mesoplodon bidens*) from observations of 10 individuals taken as bycatch in the pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*) in the western North Atlantic and 1 stranded individual from Kennebunk, Maine. The stomachs of 8 bycaught whales were intact and contained prey. The diet of these 8 whales was dominated by meso- and benthopelagic fishes that composed 98.5% of the prey items found in their stomachs and cephalopods that accounted for only 1.5% of the number of prey. Otoliths and jaws representing at least 31 fish taxa from 15 families were present in the stomach contents. Fishes, primarily from the families Moridae (37.9% of prey), Myctophidae (22.9%), Macrouridae (11.2%), and Phycidae (7.2%), were present in all 8 stomachs. Most prey were from 5 fish taxa: Shortbeard Codling (*Laeomonema barbatulum*) accounted for 35.3% of otoliths, Cocco's Lanternfish (*Lobianchia gemellarii*) contributed 12.9%, Marlin-spike (*Nezumia bairdii*) composed 10.8%, lanternfishes (*Lampanyctus* spp.) accounted for 8.4%; and Longfin Hake (*Phycis chesteri*) contributed 6.7%. The mean number of otoliths per stomach was 1196 (range: 327–3452). Most of the fish prey found in the stomachs was quite small, ranging in length from 4.0 to 27.7 cm. We conclude that the Sowerby's beaked whales that we examined in this study fed on large numbers of relatively small meso- and benthopelagic fishes that are abundant along the slope and shelf break of the western North Atlantic.

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Food habits of Sowerby's beaked whales (*Mesoplodon bidens*) taken in the pelagic drift gillnet fishery of the western North Atlantic

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The Sowerby's beaked whale (*Mesoplodon bidens*) is 1 of 4 species of the genus *Mesoplodon* (Family Ziphiidae) in the western North Atlantic. The Sowerby's beaked whale is restricted to the North Atlantic and the most boreal species in its genus, with observations recorded as far north as 71°N (Carlstrom et al., 1997; Hooker and Baird, 1999; McAlpine and Rae, 1999; Lucas and Hooker, 2000; Waring et al., 2010). There is also a single record of a stranded Sowerby's beaked whale from the Gulf of Mexico (Bonde and O'Shea, 1989).

Most information on the distribution and abundance of beaked whales off the northeastern coast of the United States has been derived from vessel surveys conducted by NOAA Fisheries. It is difficult to identify *Mesoplodon* beaked whales to species level at sea; therefore estimates of abundance are often reported at the generic level in stock assessments

(e.g., Waring et al., 2010). Waring et al. (2001) reported that off the northeastern coast of the United States, *Mesoplodon* beaked whales were encountered most frequently along the shelf break and north wall of the Gulf Stream. The habitat preferences of these animals overlap with the habitat preferences of the sperm whale (*Physeter macrocephalus*), but Sowerby's beaked whales were concentrated on the colder shelf edge (Griffin, 1999; Waring et al., 2001).

MacLeod et al. (2003) reviewed available information on the diet of beaked whales and concluded that fishes are important prey of 5 of the 10 (Family Ziphiidae) species for which diet information was available. This conclusion stands in contrast to earlier reviews of the diet of beaked whales where the importance of squids was emphasized (e.g., Clarke, 1986). Beaked whales are cryptic, deep-diving odontocetes, and,

as a result, direct observation of foraging is impossible. Most insight into their feeding behavior has come from digital acoustic tags, which record the 3-D movement and acoustic environment of tagged individuals (e.g., Madsen et al., 2005). Application of these tags to individuals of the Blainville's beaked whale (*Mesoplodon densirostris*) indicates that this species forages at depths of more than 1000 m in dives that may last for almost 1 h (Arranz et al., 2011). To date, however, no Sowerby's beaked whales have been studied with digital acoustic tags.

Given the challenges of studying live whales, all published information on the food habits of the Sowerby's beaked whale has been acquired from stranded specimens (Dix et al., 1986; Lien and Barry, 1990; Lien et al. 1990; Ostrom et al., 1993; Pereira et al., 2011; Spitz et al., 2011; Santos et al.^{1,2}). Recent analysis of the stomach contents of 10 stranded Sowerby's beaked whales from the Azores in the eastern North Atlantic (Pereira et al., 2011) provided evidence that small meso- and bathypelagic fishes constitute an important part of the diet of this species in this area.

One largely untapped source of information on the biology of the Sowerby's beaked whale comes from a sample of animals taken as bycatch in a pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*) that operated in the western North Atlantic between 1989 and 1998. The pelagic drift gillnet fishery was monitored by observers from the Northeast Fisheries Observer Program (NEFOP); these observers documented bycatch consisting of more than 1100 individuals of 14 marine mammal species (Waring et al., 2000). This bycatch included 46 beaked whales taken in the "northern or summer stratum" of the fishery that operated along the continental shelf break along the southern side of Georges Bank (Waring et al., 2009). Pelagic drift gillnets were prohibited after 1998 because of the large number of cetaceans taken during fishing operations that used them (Waring et al., 2000; 2002). Here, we describe the stomach contents of Sowerby's beaked whales taken in this pelagic drift net fishery, and we provide the first detailed account of the food habits of Sowerby's beaked whales from the western North Atlantic.

Materials and methods

We examined the stomach contents of 10 Sowerby's beaked whales taken incidentally in the pelagic drift gillnet fishery for Swordfish in the Atlantic between August 1989 and July 1996 and a single dead stranded

individual from Kennebunk, Maine (Table 1 and Fig. 1). We obtained skin tissue from each bycaught specimen and conducted DNA analysis at the NOAA Southeast Fisheries Science Center to confirm that each animal was in fact a Sowerby's beaked whale. DNA was extracted from the tissue through the use of standard proteinase K digestion followed by organic extraction (Rosel and Block, 1996). The quality of the DNA was assessed through agarose gel electrophoresis, and DNA quantity was measured with a fluorometer (Amersham Biosciences³, now GE Healthcare Life Sciences, Little Chalfont, UK).

To confirm field identifications on the basis of morphology, the 5'-end of the mitochondrial DNA control region was amplified and sequenced as described in Sellas et al. (2005). Resultant DNA sequences were identified to species through phylogenetic reconstruction with an alignment that contained the new control region sequences and the sequences obtained from the 5 species of beaked whales present in the western North Atlantic. Mesoplodont whales form strongly supported clades in phylogenetic analyses of control region sequences; therefore, this method is well suited to species identification of unknown samples (Henshaw et al., 1997; Dalebout et al., 2004).

The unusual stomach anatomy of beaked whales has been described in detail by Mead (1989, 1993, 2007). We examined the contents of the esophagus and upper digestive tract, including the fore stomach, main stomach, connecting chambers, and pyloric stomach. We followed a standard protocol for analysis of stomach contents (see Craddock et al., 2009), separating hard parts from the remaining digesta by elutriation and then decanting them through a sieve with a 0.5-mm mesh. We then sorted, dried, and identified all hard parts to the lowest possible taxonomic level. Certain diagnostic bones of fishes (e.g., otoliths, dentaries, premaxillaries, and maxillaries) were stored separately from other hard parts. Squid beaks and all parasites were counted and preserved in 70% ethanol. We archived the contents of each stomach separately.

We identified the hard parts of prey items through the use of published guides (Roper et al., 1984; Clarke, 1986; Harkonen, 1986; Vecchione et al., 1989; Campana, 2004) and the otolith and skeletal bone reference collection prepared by J. E. Craddock at the Woods Hole Oceanographic Institution (WHOI). This collection is now part of the ichthyology collection of the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts (<http://www.mcz.harvard.edu/Departments/Ichthyology/researchcoll.html>, accessed May 2013).

We estimated the number of fish prey using half the number of otoliths when more than 50 otoliths were present. When fewer than 50 otoliths were present, we

¹ Santos, M. B., G. J. Pierce, H. M. Ross, R. J. Reid, and B. Wilson. 1994. Diets of small cetaceans from the Scottish coast. ICES Council Meeting (C.M.) document, 1994/N:11. [Presented as a poster.]

² Santos, M. B., G. J. Pierce, G. Wijnsma, H. M. Ross, and R. J. Reid. 1995. Diets of small cetaceans stranded in Scotland 1993–1995. ICES Council Meeting (C.M.) document, 1995/N:6.

³ Mention of trade names or commercial companies is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1

Origin and description of Sowerby's beaked whales (*Mesoplodon bidens*) obtained in the western North Atlantic between August 1989 and October 2003. Most whales were retained as bycatch in the pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*). One whale was collected stranded in Kennebunk, Maine. Latitudes and longitudes are given in decimal degrees. NA=not available; M=male; F=female.

| Whale identification | Latitude | Longitude | Depth (m) | Year | Month | Day | Source | Sex | Length (cm) | Wt. of stomach contents (g) |
|----------------------|----------|-----------|-----------|------|-------|-----|---------------|-----|-------------|-----------------------------|
| D00253 | 40.23 | 67.90 | 1050 | 1989 | 10 | 10 | Drift gillnet | M | 491 | 1816 |
| D00341 | 40.02 | 68.80 | 1200 | 1995 | 6 | 24 | Drift gillnet | F | 485 | 5830 |
| D01369 | 40.87 | 66.42 | 1600 | 1994 | 6 | 10 | Drift gillnet | M | 462 | 5897 |
| D01380 | 40.97 | 66.32 | 1900 | 1994 | 6 | 3 | Drift gillnet | F | 460 | 4082 |
| D03070 | 40.03 | 68.77 | 1350 | 1996 | 7 | 4 | Drift gillnet | F | 476 | 2700 |
| D03202 | 40.35 | 67.35 | 1350 | 1996 | 7 | 6 | Drift gillnet | M | 470 | 2650 |
| D03458 | 40.03 | 68.63 | 1600 | 1996 | 7 | 4 | Drift gillnet | F | 471 | NA |
| D03486 | 40.97 | 66.40 | 750 | 1994 | 7 | 10 | Drift gillnet | F | 495 | 4082 |
| D06061 | 40.78 | 66.57 | 1250 | 1990 | 8 | 9 | Drift gillnet | F | 274 | Empty |
| F00120 | 40.87 | 66.48 | 1150 | 1989 | 8 | 26 | Drift gillnet | M | 473 | Partial |
| MH03-604 | 43.33 | 70.52 | NA | 2003 | 10 | 2 | Stranding | M | 442 | Empty |

counted the maximum number of either right or left otoliths for each fish species. We assessed relative prey importance by frequency of occurrence (FO) and proportion of numerical abundance (%N). FO is the proportion of stomachs that contained a particular type of prey, %N is the proportion that each prey type represented of the total number of prey items recovered, and the minimum number of fish, is determined by the number of paired otoliths found in each stomach, with any odd numbered otolith raising the minimum number of fish by one (Table 2). We measured whole undigested otoliths from abundant fish prey with a stage micrometer or vernier calipers and estimated prey sizes with linear regressions derived from the WHOI reference collection (Table 3). We estimated the number of individual cephalopod prey from the maximum number of either upper or lower beaks (Table 4).

Results

One of the 10 stomachs which we examined was from a calf and contained only mucous or milk, and the stomach of the stranded individual was completely empty. In addition to the 10 stomachs examined for this study, another stomach was dissected and examined at sea by a NEFOP observer who retained only 14 otoliths: 9 Marlin-spike (*Nezumia bairdii*) and 5 Cocco's Lanternfish (*Lobianchia gemellarii*). Because of the incomplete examination of the stomach contents of this individual, we did not include it in the quantitative analysis of food habits. The remaining 8 stomachs were intact and contained prey; therefore we used the contents of these stomachs in our quantitative analysis of the frequency,

numerical abundance, and size of prey. Genetic analysis confirmed that these stomachs were all from Sowerby's beaked whales.

Fishes dominated the diet of these whales; in total, we recovered 9451 otoliths of fishes and jaws of 18 Sloan's Viperfish (*Chauliodus sloani*). The only prey represented by more jawbones than otoliths was Sloan's Viperfish. The mean number of otoliths per stomach was 1196 (range: 327–3452). The recovered otoliths represented at least 31 species from 15 families of deepwater fishes (Table 2). Fishes from the families Moridae (%N=37.9% of prey), Myctophidae (22.9%), Macrouridae (11.2%), and Phycidae (7.2%) were present in all 8 stomachs. Most (74.1%) prey were from the following 5 taxa, ordered by proportion of numerical abundance: 1) Shortbeard Codling (*Laemonema barbatulum*), Moridae, 35.3%; 2) Cocco's Lanternfish, Myctophidae, 12.9%; 3) Marlin-spike, Macrouridae, 10.8%; 4) lanternfishes (*Lampanyctus* spp.), Myctophidae, 8.4%; and 5) Longfin Hake (*Phycis chesteri*), Phycidae, 6.7%. In each stomach, 12–19 different fish taxa were present, with a mean of 15. The estimated standard lengths of fish prey ranged from 4.0 cm to 27.7 cm (Table 3). In its esophagus, whale D01380 had 13 whole Cocco's Lanternfish, ranging in length from 8.0 to 10.0 cm (mean: 9.2 cm), similar to lengths of fish estimated from otoliths of this species found in the other 7 stomachs examined (Table 3).

Squid remains were found in 7 of the 8 analyzed stomachs, but they were represented by only 123 beaks (minimum 73 individuals) of 3 identified taxa (Table 4); cephalopods accounted for only 1.5% of total prey. The mean number of squid beaks per stomach was 15.4 (range: 0.0–35.0).

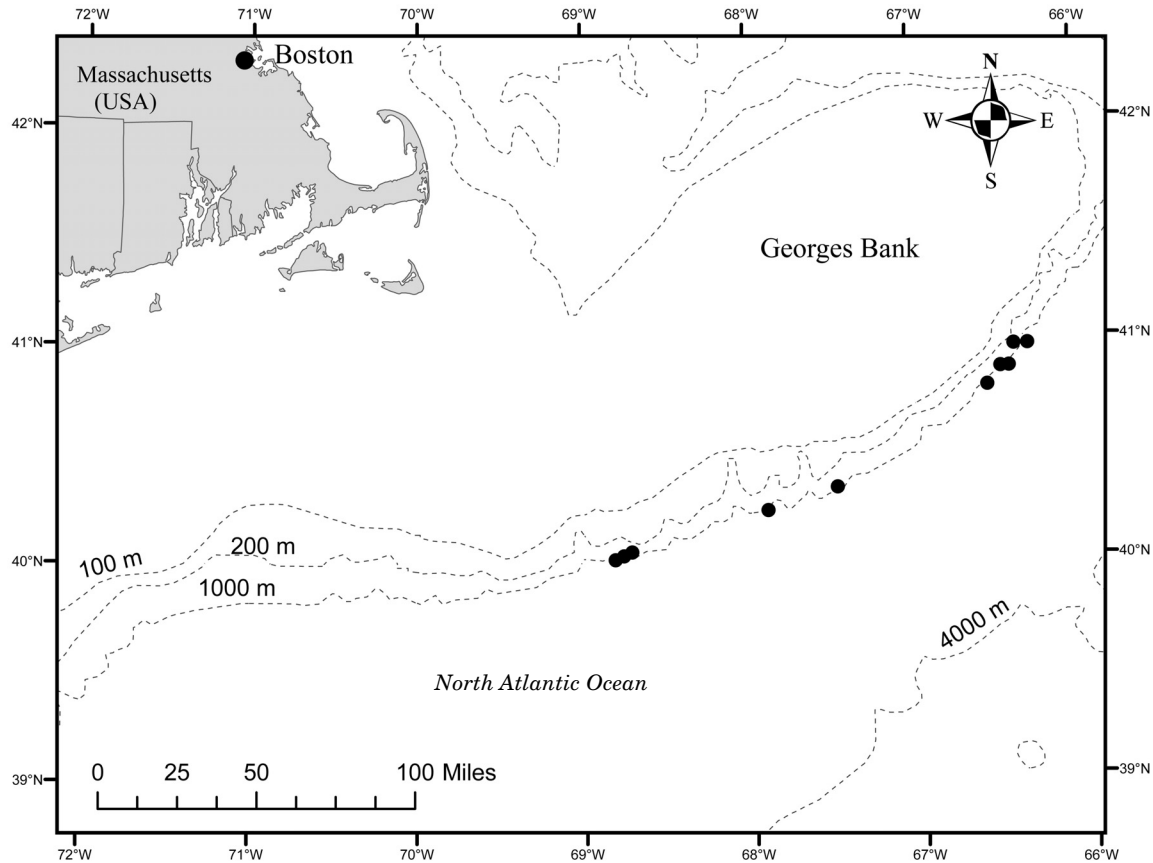


Figure 1

Map of locations where 10 specimens of the Sowerby's beaked whale (*Mesoplodon bidens*) were taken in the pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*) in the western North Atlantic between August 1989 and July 1996. The stomach contents of 8 of these whales were examined to determine the food habits of this species.

Discussion

The Sowerby's beaked whales that we examined had been feeding primarily on large numbers of relatively small meso- and benthopelagic fishes before their death; cephalopod prey constituted a very minor part of the diet of these animals. Our findings are similar to those of Pereira et al. (2011), who examined the stomach contents of 10 stranded Sowerby's beaked whales from the Azores and found a predominance of small fish prey. It is important to note that all but one of the whales that we examined were killed at sea, and, with the exception of the single stranded animal, they were apparently healthy at the time of their death. The presence of intact prey in the esophagus of one specimen and the large numbers of prey items in the stomachs that we examined indicate that these animals had been foraging before death. The average minimum number of prey in the stomachs that we examined was more than 600 (4789 fishes, plus 73 squids, in all 8 stomachs combined), compared with 85

prey in the stranded specimens examined by Pereira et al. (2011).

We believe the stomach contents of the whales that we examined are representative of the summer diet of Sowerby's beaked whales along the continental shelf break off the northeastern coast of the United States. Nevertheless, biases from several sources could affect our conclusions. For example, our analysis of the stomach contents of these bycaught cetaceans could have been biased if these whales had been feeding in or around a fishing gear. Such behavior has not been reported for beaked whales, however, and the Sowerby's beaked whales that we examined were taken in pelagic drift gillnets that targeted large Swordfish and tunas in the top 10 m of the water column. These large-mesh gillnets could not have captured the prey we identified in stomachs of Sowerby's beaked whales; the only whole fish we recovered were 13 small (<10.0 cm) Cocco's Lanternfish found in one esophagus. Therefore, the Sowerby's beaked whales that we examined were not actively feeding in nets when captured.

Table 2

Analysis of fish prey identified in stomachs of Sowerby's beaked whales (*Mesoplodon bidens*) taken in the pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*) in the western North Atlantic between August 1989 and July 1996. %FO=percentage of frequency of occurrence; %N=percentage of number of otoliths. *Unidentified* means that the structure of the otoliths was distinct for identification but the otoliths were not identified. *Unidentifiable* otoliths were worn or digested and not identifiable.

| Family | Species | Common name | Occurrence (no. of stomachs) | %FO | Number of otoliths | %N | Minimum number of fish |
|-----------------|------------------------------------|-------------------------|------------------------------------|-----|--------------------------|------|------------------------------|
| Alepocephalidae | <i>Alepocephalus cf. agassizii</i> | Agassiz's Smoothhead | 4 | 50 | 10 | 0.1 | 6 |
| Diretmidae | <i>Diretmus argenteus</i> | Spinyfin | 1 | 13 | 2 | 0.0 | 1 |
| Gonostomatidae | <i>Gonostoma elongatum</i> | Longtooth Anglemouth | 2 | 25 | 6 | 0.1 | 4 |
| Macrouridae | <i>Coelorinchus</i> sp. | Grenadier | 1 | 13 | 4 | 0.0 | 2 |
| Macrouridae | <i>Coryphaenoides</i> sp. | Grenadier | 3 | 38 | 39 | 0.4 | 21 |
| Macrouridae | <i>Nezumia bairdii</i> | Marlin-spike | 8 | 100 | 1019 | 10.8 | 515 |
| Melamphaidae | <i>Poromitra capito</i> | Ridgehead | 1 | 13 | 3 | 0.0 | 2 |
| Melamphaidae | <i>Scopelogadus beanii</i> | Bean's Bigscale | 7 | 88 | 344 | 3.6 | 178 |
| Merlucciidae | <i>Merluccius albidus</i> | Offshore Hake | 1 | 13 | 1 | 0.0 | 1 |
| Merlucciidae | <i>Merluccius bilinearis</i> | Silver Hake | 2 | 25 | 311 | 3.3 | 156 |
| Moridae | <i>Gadella imberbis</i> | Beardless Codling | 3 | 38 | 65 | 0.7 | 33 |
| Moridae | <i>Laemonema barbatulum</i> | Shortbeard Codling | 8 | 100 | 3332 | 35.3 | 1672 |
| Moridae | Unidentified morid | Codling | 1 | 13 | 178 | 1.9 | 89 |
| Myctophidae | <i>Benthoosema glaciale</i> | Glacier Lanternfish | 3 | 38 | 5 | 0.1 | 3 |
| Myctophidae | <i>Bolinichthys supralateralis</i> | Stubby Lanternfish | 1 | 13 | 2 | 0.0 | 1 |
| Myctophidae | <i>Ceratoscopelus maderensis</i> | Horned Lanternfish | 7 | 88 | 75 | 0.8 | 40 |
| Myctophidae | <i>Hygophum hygomii</i> | Bermuda Lanternfish | 4 | 50 | 6 | 0.1 | 4 |
| Myctophidae | <i>Lampadena speculigera</i> | Mirror Lanternfish | 7 | 88 | 36 | 0.4 | 19 |
| Myctophidae | <i>Lampanyctus</i> spp. | Lanternfishes | 8 | 100 | 797 | 8.4 | 403 |
| Myctophidae | <i>Lobianchia gemellarii</i> | Cocco's Lanternfish | 8 | 100 | 1222 | 12.9 | 613 |
| Myctophidae | <i>Nannobranchium cf. atrum</i> | Dusky Lanternfish | 5 | 63 | 15 | 0.2 | 8 |
| Paralepididae | <i>Arctozenus risso</i> | White Barracudina | 8 | 100 | 90 | 1.0 | 49 |
| Paralepididae | Unidentified paralepidid | | 2 | 25 | 4 | 0.0 | 2 |
| Paralichthyidae | <i>Paralichthys oblongus</i> | Fourspot Flounder | 1 | 13 | 1 | 0.0 | 1 |
| Phycidae | <i>Phycis chesteri</i> | Longfin Hake | 7 | 88 | 634 | 6.7 | 321 |
| Phycidae | <i>Urophycis chuss</i> | Red Hake | 2 | 25 | 30 | 0.3 | 15 |
| Phycidae | <i>Urophycis tenuis</i> | White Hake | 2 | 25 | 8 | 0.1 | 4 |
| Scorpaenidae | <i>Helicolenus dactylopterus</i> | Blackbelly Rosefish | 7 | 88 | 350 | 3.7 | 179 |
| Serrivomeridae | <i>Serrivomer beanii</i> | Stout Sawpalate | 1 | 13 | 3 | 0.0 | 2 |
| Sternoptychidae | <i>Polyipnus clarus</i> | Slope Hatchetfish | 1 | 13 | 2 | 0.0 | 1 |
| Stomiidae | <i>Chauliodus cf. sloani</i> | Sloan's Viperfish | 4 | 50 | 15 | 0.2 | 9 |
| | | Unidentified otoliths | 8 | 100 | 215 | 2.3 | 114 |
| | | Unidentifiable otoliths | 8 | 100 | 627 | 6.6 | 318 |
| Total otoliths | | | | | 9451 | | |
| Stomiidae | <i>Chauliodus</i> spp. | Viperfish jaws | 2 | 25 | 18 | | 3 |
| Total fishes | | | | | | | 4789 |

A second potential bias arises because hard parts of different prey may pass through the gastrointestinal tract at different rates. For example, squid beaks are resistant to digestion and often accumulate in stomachs of marine mammals, but the soft tissue and bones of fishes are more readily digested (Bigg and Fawcett, 1985). The complex structure of beaked whale stomachs (Mead 1989, 1993, 2007) makes it likely that relatively indigestible squid beaks are retained for prolonged periods. Therefore, the results reported here may overestimate the already low im-

portance of cephalopods in the diet of the Sowerby's beaked whale.

A third possible bias arises from the secondary ingestion of prey, in which recovered hard parts enter whales in the stomachs of prey and are not consumed directly by whales themselves. It is difficult to evaluate this potential source of bias. It is possible, for example, that the Horned Lanternfish (*Ceratoscopelus maderensis*) we recovered could have been secondarily introduced into the stomachs of the Sowerby's beaked whales that we examined, given the small size of the

Table 3

Habitat and size of the most abundant prey species found in stomachs of Sowerby's beaked whales (*Mesoplodon bidens*) taken in the pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*) in the western North Atlantic between August 1989 and July 1996. Habitat/depths are taken from Fishbase (<http://www.fishbase.org/search.php>, accessed June 2013). Standard length was used to measure fish lengths. R^2 =coefficient of multiple determination; NA=not available

| Prey species | Habitat | Diurnal migrant | Depth range (m) | Number measured | Mean otolith length (cm) | Otolith length range (cm) | Otolith length (OL) – fish length regression | Mean length of prey (cm) with range |
|----------------------------------|-----------------------|-----------------|-----------------|-----------------|--------------------------|---------------------------|--|-------------------------------------|
| <i>Laemonema barbatulum</i> | Benthopelagic | No | 50–1620 | 136 | 0.4 | 0.2–0.6 | NA | NA |
| <i>Lobianchia gemellarii</i> | Mesopelagic | Yes | 200–800 | 140 | 0.7 | 0.6–0.8 | Fish length = 0.0643OL + 1.0482 $R^2=0.9799$ | 9.7 (8–11) |
| <i>Nezumia bairdii</i> | Benthopelagic | No | 90–700 | 198 | 0.8 | 0.5–1.0 | Fish length = 0.035OL – 0.0961 $R^2=0.9348$ | 22 (13–28) |
| <i>Lampanyctus</i> spp. | Mesopelagic | Yes | 40–1000 | 127 | 0.3 | 0.2–0.4 | NA | NA |
| <i>Phycis chesteri</i> | Benthopelagic | No | 90–1400 | 74 | 1 | 0.6–1.3 | NA | NA |
| <i>Helicolenus dactylopterus</i> | Bathydemersal | No | 50–1100 | 40 | 0.3 | 0.2–0.6 | NA | NA |
| <i>Scopelogadus beanii</i> | Meso- to bathypelagic | Yes | 400–1000 | 38 | 0.3 | 0.2–0.4 | Fish length = 0.0169OL + 1.6267 $R^2=0.5816$ | 8.1 (5–11) |
| <i>Arctozenus risso</i> | Mesopelagic | No | 200–1000 | 43 | 0.4 | 0.3–0.4 | Fish length = 0.0086OL + 1.6552 $R^2=0.8359$ | 21.5 (10–27) |
| <i>Ceratoscopelus maderensis</i> | Mesopelagic | Yes | 330–600 | 24 | 0.3 | 0.2–0.3 | Fish length = 0.0511OL – 0.1393 $R^2=0.9454$ | 5.4 (4–6) |

fish we recovered (4.0–6.3 cm) and their low numbers. This fish species is generally abundant and found in schools in the deep scattering layer (DSL) along the shelf break on the southern side of Georges Bank (Backus et al., 1968) where the Sowerby's beaked whales that we examined were taken.

The mechanisms by which the Sowerby's beaked whale locates and captures prey are largely unknown. All whales in the genus *Mesoplodon* have relatively small mouths and few teeth, and they are believed to employ suction while feeding (Mead et al. 1982; Heyning and Mead, 1996). The Sowerby's beaked whale has 2 teeth that erupt only in sexually mature males (Mead, 1989; Heyning and Mead, 1996). The relatively small mouth and 2 teeth of this species may explain why Sowerby's beaked whales typically are found to have only small prey items in their stomachs.

Studies that employed digital acoustic tags on other beaked whales in this genus have provided brief but

exceptionally rich glimpses into the foraging behavior of these animals. For example, tagged Blainville's beaked whales in the Canary Islands have been reported to feed on prey in the lower part of the DSL and within the benthopelagic zone (Arranz et al., 2011). Almost half of the attempts at prey capture made by these whales in the Canary Islands occurred in the benthic boundary layer, reinforcing the importance of benthopelagic prey for them. In addition, these Blainville's beaked whales appeared to focus on the oxygen minimum layer just below the DSL in areas of steep topography. Johnson et al. (2008) described the behavior of a tagged Blainville's beaked whale in the Bahamas that appeared to provoke a schooling reaction in mesopelagic prey that resulted in a school of prey up to 4 m in diameter and created an opportunity for the whale to more easily capture those prey. Until a tag is deployed for the deep-diving Sowerby's beaked whale, we can only speculate about the foraging behavior of

Table 4

Cephalopod prey from the stomachs of Sowerby's beaked whales (*Mesoplodon bidens*) taken in the pelagic drift gillnet fishery for Swordfish (*Xiphias gladius*) in the western North Atlantic between August 1989 and July 1996. %N=percentage of number of total beaks. %FO=percentage of frequency of occurrence, on the basis of the number of stomachs studied.

| Prey item | D00253 | D00341 | D01369 | D01380 | D03070 | D03202 | D03458 | D03486 | Total | %N | %FO |
|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|------|
| Unidentified upper beaks | | 0 | 2 | 2 | 4 | 10 | 19 | 12 | 49 | 39.8 | 87.5 |
| Unidentified lower beaks | | 0 | | | 5 | 8 | 16 | | 29 | 23.6 | 50.0 |
| <i>Histioteuthis</i> spp. | 4 | | 13 | 7 | | | | 9 | 33 | 26.8 | 50.0 |
| <i>Taonius pavo</i> | 9 | | | | | | | 2 | 11 | 8.9 | 25.0 |
| <i>Chiroteuthis veranyi</i> | 1 | | | | | | | | 1 | 0.8 | 12.5 |
| Total beaks | 14 | 0 | 15 | 9 | 9 | 18 | 35 | 23 | 123 | 100.0 | |
| Total cephalopods | | | | | | | | | 73 | | |

this species, but the results presented here indicate that their hunting strategies may be similar to those of their better-studied congener.

Therefore, on the basis of knowledge of the habitat preferences of prey recovered from the stomachs of Sowerby's beaked whales, we conclude that these animals feed in the meso- and benthopelagic environments along the shelf break, foraging in the water column and near the seafloor. Mesopelagic fishes in this region are important prey for several other cetacean species. Horned Lanternfish, in particular, is consumed by the Atlantic white-sided dolphin (*Lagenorhynchus acutus*) (Craddock et al., 2009) and by the common dolphin (*Delphinus delphis*), both of which are also caught incidentally in the pelagic drift gillnet fishery for Swordfish in the Atlantic (Craddock and Polloni⁴). The stomach of a harbor porpoise (*Phocoena phocoena*), captured in a pelagic drift net fishery off North Carolina was found to contain more than 1900 otoliths of Horned Lanternfish (Read et al., 1996).

Many marine organisms are concentrated in oceanographic frontal zones, as a result of increased production and advection (Jahn and Backus, 1976; Backus et al., 1977; Olson and Backus, 1985). As a consequence of these aggregations, predators (including swordfish) and fishermen exploit fronts. The mosaic of oceanic fronts associated with the Gulf Stream and its warm- and cold-core rings have long been targeted by fishermen of Swordfish, particularly along the shelf break (Smith et al., 1996). Swordfish have been reported to feed on some of the same prey items that we recovered from

Sowerby's beaked whales (Scott and Tibbo, 1968; Stillwell and Kohler, 1985).

For example, barracudinas (Paralepididae) are important food items for Swordfish in the northwestern Atlantic (Scott and Tibbo, 1968) and were common prey of the Sowerby's beaked whales that we examined; White Barracudina (*Arctozenus risso*) is the most common barracudina in this region (Moore et al., 2003). Lanternfishes (Myctophidae) also are consumed by Swordfish in large numbers, but, because of their relatively small size, they do not contribute significantly to the mass ingested by these predators (Scott and Tibbo, 1968). The pelagic drift gillnet fishery in the Atlantic targeted Swordfish and tunas, and the fishing effort focused on thermal fronts along the shelf break, as described by Podesta et al. (1993). Therefore, the common prey fields and habitats of Swordfish and Sowerby's beaked whales may help to explain the relatively high bycatch rates of Sowerby's beaked whales in this fishery.

Conclusions

The diet of Sowerby's beaked whales in the western North Atlantic is dominated by meso- and benthopelagic fishes (98.5%), and cephalopods accounted for only 1.5% of their prey. Future research with digital acoustic tags would be helpful to examine the diving and echolocation behavior of Sowerby's beaked whales in relation to the vertical and horizontal distribution of prey. A study that combines both the tagging methods used by Arranz et al. (2011) and survey data of the prey field documented with the use of scientific echosounders and by direct capture of voucher specimens would be particularly profitable. The regular occurrence of Sowerby's beaked whales in and near the canyons on the southern margin of Georges Bank, where the whale specimens we studied were captured, offers a promising field opportunity for such research.

⁴ Craddock J. E., and P. T. Polloni. 2005. Food habits of small marine mammals from the Gulf of Maine and from slope water off the northeast US coast. Year 3, Final Report, revised, 31 p. Request no. EA 133F-02-RQ-0081. Requisition no. NFFM7320-2-15375. [Available from Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 166 Water St., Woods Hole, MA 02543 <http://www.nefsc.noaa.gov/publications/reports/EA133F02RQ0081.pdf>]

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