Journal of the Marine Biological Association of the United Kingdom, 2014, 94(6), 1087–1091.
doi:10.1017/S0025315413000428

Stomach contents of a sperm whale (*Physeter macrocephalus*) stranded in Italy (Ligurian Sea, north-western Mediterranean)

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The stomach contents of a male sperm whale, Physeter macrocephalus, *stranded on Forte dei Marmi beach (Italy, Ligurian Sea) were examined. Food items consisted exclusively of cephalopod hard parts: 233 upper and 291 lower beaks and one fish eye lens. The majority of the identified cephalopod beaks belonged to* Histioteuthis bonnellii, *but a few beaks of* Galiteuthis armata *and* Octopoteuthis *sp. were also found. A new beak size–cephalopod size regression was created for* H. bonnellii *with specimens caught in the study area. Reconstructed prey weight for the species was much higher when applying this new regression instead of Clarke's, highlighting the need for area- and species-specific regressions for dietary studies. Our analysis represents the second report on the stomach contents of sperm whales from the Mediterranean and the first available information for the Western basin.*

Keywords: *Physeter macrocephalus*, *Histioteuthis bonnellii*, diet, Ligurian Sea, Mediterranean Sea

Submitted 11 May 2012; accepted 12 March 2013; first published online 17 April 2013

INTRODUCTION

The sperm whale (*Physeter macrocephalus* Linnaeus, 1758) has a cosmopolitan distribution, inhabiting all oceans and also reaching high latitudes (Whitehead, 2003). In the Mediterranean Sea, sperm whales are widely distributed (Notarbartolo *et al.*, 2006), in both the Eastern (Frantzis *et al.*, 2003) and Western basins (Gannier *et al.*, 2002). Sperm whale strandings along Italian coasts have been recorded in the past (Bolognari, 1950) and were quite commonly reported in the last 20 years of strandings monitoring (Banca Dati Spiaggiamenti, 2011; Bearzi *et al.*, 2011; Mazzariol *et al.*, 2011). Few data are available concerning population structure and abundance in these areas (Gannier *et al.*, 2002; Lewis *et al.*, 2007), as well as the habitat use for this species (Azzellino *et al.*, 2008; Praca *et al.*, 2009). The feeding habits of sperm whale have been widely investigated throughout the oceans, establishing that cephalopods are its preferred prey, although some cases of predation upon other animal species and debris are reported (Clarke, 1980; Kawakami, 1980; Santos *et al.*, 1999, 2002; Whitehead, 2003; Jacobsen *et al.*, 2010; Mazzariol *et al.*, 2011). Moreover, little is known about the ecology and feeding habits in the Mediterranean Sea (Drouot *et al.*, 2004; Praca & Gannier, 2008); so far stomach content analysis was performed on one single specimen stranded in Crete (Roberts, 2003), resulting in cephalopod beaks only, belonging to seven different species, of which *Histioteuthis bonnellii* (Férussac, 1834) represented the great majority.

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Recent advances in the investigation of the diving and foraging behaviour of sperm whale were obtained using tagging technologies (Madsen *et al.*, 2002; Miller *et al.*, 2004; Zimmer *et al.*, 2003), resulting in the description of the predator–prey interactions and the use of creak sounds to locate prey.

The aim of this note is to provide a contribution to knowledge about the food habits of sperm whales in the Mediterranean Sea, considering that this is the first record available to date in the Western part, and to relate prey sizes and food requirements to recent results from observations on the diving behaviour of the species.

MATERIALS AND METHODS

On 16 May 1988, a sperm whale was sighted while swimming slowly near the coast of Forte dei Marmi, Tuscany (Figure 1); the day after, it was found stranded on the beach, already dead. The carcass was picked up and transported to the Natural History Museum of Milan for dissection. It was a male, which measured 11.75 m and weighed 18 t. Stomach contents were carefully removed and preserved in 70% ethanol for the analysis. The whole skeleton is now mounted in the Natural History Museum of Milan exhibition.

Cephalopod lower beaks were identified by species using the reference collection of the laboratory, following the indication of Clarke (1986). Lower rostral length (LRL) was measured to the nearest 0.01 mm with a digital Vernier caliper. Dorsal mantle length (DML) and wet weight (WW) for each ingested prey were estimated from the regressions of Clarke (1986) for *Galiteuthis armata* Joubin, 1898 and

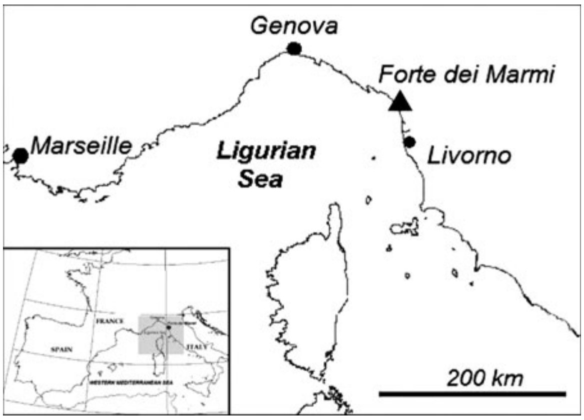

Fig. 1. Stranding site ▲.

Octopoteuthis sp., and from a new original regression for *Histioteuthis bonnellii* obtained on the basis of Ligurian Sea material. In fact, the relationships between LRL and both DML and WW published in the past were referred to other histioteuthid species and to the family as a whole (Clarke, 1986) or calculated by means of small specimens (Wurtz *et al.*, 1992), and were not representative of the entire size range of this species. Details about specimens used for this purpose are reported in Table 1. Larger individuals were collected during bottom trawl surveys (i.e. MEDITS surveys) or by monitoring professional trawl and longline fisheries, while smaller ones were caught by the 16 ft Isaacs-Kidd Midwater Trawl (IKMT) during oceanographic campaigns carried out with the aim to study the biodiversity of the mesopelagic fauna of the Ligurian Sea. The total ingested biomass was calculated as the sum of the weights of each single cephalopod. The total biomass of cephalopods with highly digested beaks was estimated by multiplying the average weight of cephalopods of that species found in the stomach by their number.

Table 1. Details of *Histioteuthis bonnellii* specimens used to develop the new relationships between beak lower rostral length (LRL) and dorsal mantle length (DML) or weight. IKMT indicates specimens caught by Isaacs-Kidd Midwater Trawl during oceanographic campaigns.

Date of capture	Ligurian Sea area	Gear	DML (cm)	Weight (g)	LRL (mm)
20 August 1991	Western	IKMT	1.9	5.6	1.2
01 August 1990	Western	IKMT	3.2	2.4	2.2
13 May 2010	Eastern	Trawl net	5.5	154.4	4.2
01 August 1991	Western	IKMT	5.6	135.0	3.4
01 December 2005	Western	Trawl net	5.8	120.0	3.4
30 January 1991	Eastern	IKMT	5.9	125.0	4.0
05 June 2006	Eastern	Trawl net	8.0	280.0	4.8
13 May 2010	Eastern	Trawl net	8.1	510.0	5.4
12 May 2010	Eastern	Trawl net	8.4	402.2	5.8
27 March 2009	Western	Trawl net	10.1	650.0	6.4
–	Eastern	Trawl net	10.3	530.0	5.3
14 October 2008	Western	Longline	10.4	1330.0	8.3
03 April 2009	Western	Trawl net	10.5	810.0	7.6
25 March 2009	Western	Trawl net	10.6	720.0	6.3
23 February 1996	Western	Trawl net	11.0	630.0	7.7
10 May 2010	Western	Trawl net	11.1	565.8	7.3
30 June 2009	Western	Trawl net	11.8	1020.0	8.5
11 May 2010	Eastern	Trawl net	11.9	817.7	7.4
26 March 2009	Western	Trawl net	12.1	1280.0	8.1
27 March 2009	Western	Trawl net	12.2	1120.0	7.4
–	Eastern	Trawl net	13.0	1180.0	7.7
29 July 2009	Western	Trawl net	13.5	1110.0	8.7
29 June 2009	Western	Trawl net	13.6	980.0	8.2
05 June 2006	Eastern	Trawl net	14.4	1520.0	9.8
10 May 2010	Western	Trawl net	14.4	1528.2	8.1
12 January 2007	Western	Longline	14.9	1890.0	9.2
27 June 2010	Western	Longline	16.7	2060.0	9.7
10 June 2002	Western	Longline	18.2	1450.0	9.0
17 November 1997	Western	Longline	18.8	3000.0	9.9
02 July 2010	Western	Longline	19.1	3800.0	10.8
20 July 1997	Eastern	Trawl net	19.5	2900.0	9.4
29 April 2005	Western	Trawl net	19.5	3050.0	9.5
17 August 1989	Eastern	Trawl net	22.0	3300.0	9.9
–	Eastern	Trawl net	26.0	6000.0	11.9

RESULTS

Food items were made up of cephalopod beaks, 233 upper and 291 lower beaks, and one cephalopod eye lens: no flesh remains were found.

Of the 291 lower beaks examined, 288 belonged to *Histioteuthis bonnellii*, two to *Galiteuthis armata* and one to *Octopoteuthis* sp. (Table 2). All beaks were found at about the same digestion rate, except for 41 highly digested beaks: they were identified as all belonging to *H. bonnellii*.

On the basis of the Ligurian Sea material, the two new relationships for *H. bonnellii* can be expressed as follows:

$$DML = 2.0012LRL - 2.1788\ (N = 34;\ r^2 = 0.87)$$

$$WW = 1.442LRL^{3.2462}(N = 34;\ r^2 = 0.91)$$

They are represented in Figure 2, compared to the older Clarke equations. The relationships between LRL and DML

Table 2. Identified species, beak dimensions and estimated size and weight of cephalopods found in the stomach contents of sperm whale stranded in Italy.

Species	*N*	LRL range (mm)	LRL mean size (mm)	DML range (mm)	Mean DML (mm)	Wet weight range (g)	Mean weight (g)	Total est. biomass (g)
Histioteuthis bonnellii	288	4.67–12.57	9.17	71.7–229.8	161.8	214.6–5341.1	2108.6	607,273.4
Galiteuthis armata	2	4.94–6.5	5.72	38.8–50.4	44.6	86.9–165.3	126.17	252.3
Octopoteuthis sp.	1	13.65	13.65	236.9	236.9	494.6	494.6	494.6
Totals	291	–	–	–	–	–	–	608,020.3

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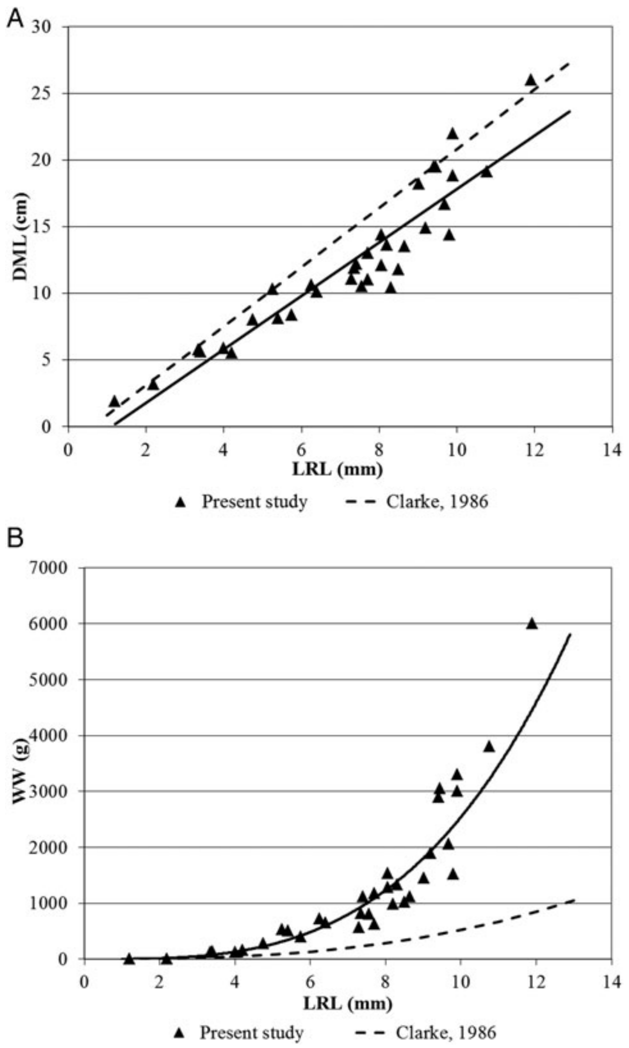

Fig. 2. (A) Relationship of lower rostral length to dorsal mantle length in *Histioteuthis bonnellii*; (B) relationship of lower rostral length to wet weight in *H. bonnellii.*

are similar (Figure 2A), while a great difference is evident for the relationships between LRL and WW (Figure 2B), resulting in a great underestimation of the reconstructed biomass if the old Clarke equation was applied.

The total estimated ingested biomass was 608.02 kg, which represents 3.38% of the total sperm whale body mass. The mean estimated WW of the ingested preys was 2089.42 g. In Figure 3, the LRL frequency distribution of *H. bonnellii* beaks is reported. By applying the newly calculated relationships, *H. bonnellii* ranged from 71.7 mm to 229.8 mm DML and from 214.6 g to 5341.1 g WW, with a mean size of 161.8 mm and a mean weight of 2108.6 g, representing about 1.38% in length and 0.012% in weight of the whale, respectively.

DISCUSSION

Caution is needed in analysing stomach contents of stranded animals (Santos *et al.*, 1998), as they may not be in a healthy condition, meaning that they are unable to feed for several days beforehand, or not able to feed properly. In our case, considering that no flesh remains were found and all beaks were in approximately the same digestion stage (except for the 41 highly digested beaks), we can assume that the whale could probably not feed properly during the last days and the stomach contents represent the last foraging day. As stated by MacLeod *et al.* (2006), cetaceans with reduced dentition (such as the sperm whale) specialize in using suction to capture prey, consuming a narrow range of relatively small organisms. In our case, the predator–prey size ratio (PPSR) was 1.37% of the sperm whale's body length, which is consistent with this hypothesis.

The sperm whale shows a great variety of prey throughout all seas and oceans. This may be due to geographical, seasonal or sex- and age-related factors. In some areas it prefers ammoniacal, slow swimming squids (Whitehead, 2003), which are also dominant or abundant in the stomach contents of

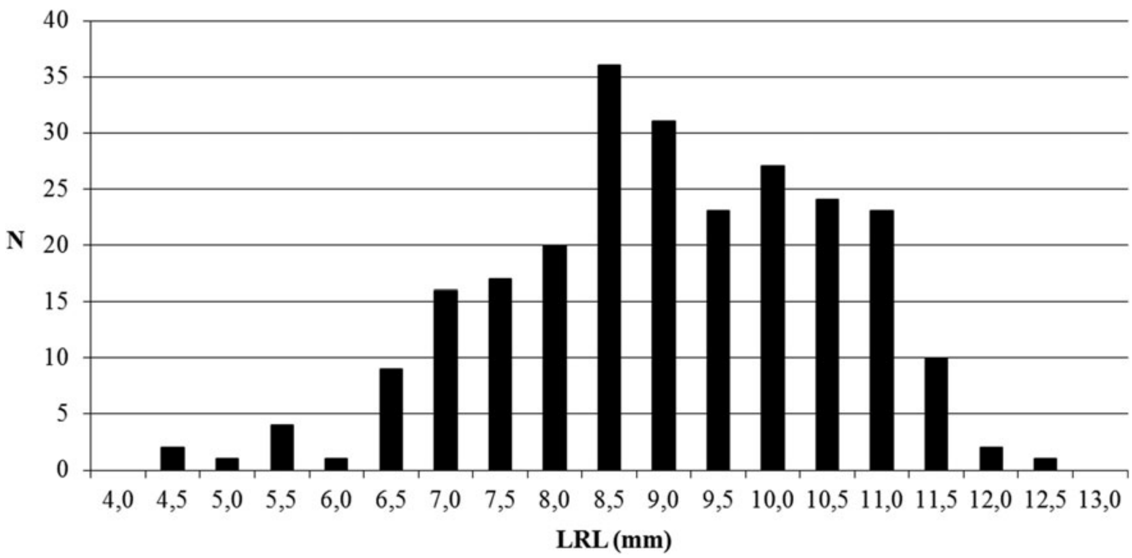

Fig. 3. Lower rostral length frequency distribution of *Histioteuthis bonnellii* beaks found in the sperm whale stomach contents.

https://doi.org/10.1017/S0025315413000428 Published online by Cambridge University Press

sperm whales that have not been stranded, but directly killed by whaling (Clarke, 1980; Clarke *et al.*, 1993). In other cases, it can largely feed on muscular squids (Clarke & Paliza, 2001) or fish (Martin & Clarke, 1986).

In the Mediterranean Sea, as far as we know, there are no squid as big as some species found in other oceans, which probably have a higher calorific value, except for ommastrephid squids (i.e. *Todarodes sagittatus* (Lamarck, 1798) and *Ommastrephes bartramii* (Lesueur, 1821)) or *Thysanoteuthis rhombus* Troschel, 1857, and only a few records of very large squid (Bello, 2003). All other pelagic cephalopods in the Mediterranean are represented by small-sized species, except *Histioteuthis bonnellii*, which can grow up to more than 6 kg in weight.

The results derived from some studies carried out in recent years using D-Tag allow us to understand much more about the diving behaviour of sperm whales in the Ligurian Sea; it seems that the sperm whale starts clicking at 96.7 m depth during its descent, and the foraging phase starts at a depth of 635.6 m (Watwood *et al.*, 2006). Considering that the most important prey is *H. bonnellii*, both in the Mediterranean (Roberts, 2003; Mazzariol *et al.*, 2011; Praca *et al.*, 2011; present study) and in some areas of the Atlantic (Clarke *et al.*, 1993; Spitz *et al.*, 2011), it is possible that sperm whales go to the correct depth to catch this species that undergoes significant vertical migrations, even if the largest specimens are preferably found in deeper water. In fact, Voss *et al.* (1992) found larger juveniles and sub-adults at night in the Eastern Atlantic between 200 m and 800 m, and all but one mature animal at a depth below 600 m, with the great majority below 1000 m.

Histioteuthids are an important food source for several top predator species, such as fish, sharks and cetaceans (Orsi Relini & Garibaldi, 2005). In particular, comparing our results with those obtained by Roberts (2003) in waters around Crete and in the Ionian Sea (Mazzariol *et al.*, 2011), *H. bonnellii* represents the main prey species for the sperm whale and it is thought that its importance in the cetacean diet of the Mediterranean has been generally underestimated in the past.

ACKNOWLEDGEMENTS

The authors thank all of the people from the Natural History Museum of Milan who participated in the dissection of the stranded sperm whale and also made possible the collection of the stomach contents. The MEDITS specimens were collected by Dr A. Mannini and L. Lanteri. Thanks to Graziella Perini for the map drawing. Many thanks to the anonymous referees who contributed with valuable suggestions and comments.

FINANCIAL SUPPORT

The relationships between LRL and DML or WW for *Histioteuthis bonnellii* were calculated from old material collected by Professor L. Orsi Relini and in the framework of a project funded by the Italian Ministry for the Environment and the Protection of the Land and the Sea on biodiversity of cephalopods in the Pelagos Cetacean Sanctuary.

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https://doi.org/10.1017/S0025315413000428 Published online by Cambridge University Press