Journal of Mammalogy Advance Access published March 24, 2016

Journal of Mammalogy, xx(x):1–6, 2016
DOI:10.1093/jmammal/gyw022

First record of a hagfish anchored to a living bottlenose dolphin in the Mediterranean Sea

Daniela Silvia Pace,* Barbara Mussi, Angelo Miragliuolo, Carlotta Vivaldi, and Giandomenico Ardizzone

Oceanomare Delphis Onlus, Via Gino Marinuzzi, 74, 00124 Rome, Italy (DSP, BM, AM, CV)
Department of Environmental Biology, Sapienza University of Rome, Viale dell'Università 32, 00185 Rome, Italy (DSP, GA)

* *Correspondent: danielasilvia.pace@gmail.com*

An unusual observation of a hagfish (*Myxine glutinosa*) anchored to a living bottlenose dolphin (*Tursiops truncatus*) was documented in an encounter with a group of about 80 dolphins during an ongoing long-term research program on cetaceans in the central Mediterranean Sea, Italy. The body of the hagfish was observed extruding from the blowhole of the bottlenose dolphin showing a stereotypical surfacing–breathing pattern. The observation lasted 2 h; photo-identification, acoustic, and behavioral data were collected. Succorant behaviors (i.e., "standing by") from conspecifics and overlapping vocalizations during social phases were recorded. The dolphin was encountered again after 1 month in the same area without the hagfish, apparently in healthy conditions.

Key words: bottlenose dolphin, hagfish, Mediterranean Sea, *Myxine glutinosa*, *Tursiops truncatus*

Skin lesions or marks from members of jawless fishes, such as the sea lamprey *Petromyzon marinus*, have been described on several cetacean species, and only recently, photographs of this organism attached to the North Atlantic right whale *Eubalaena glacialis* (Nichols and Hamilton 2004) and minke whale *Balaenoptera acutorostrata* (Nichols and Tscherter 2011) in the western North Atlantic, the killer whale *Orcinus orca* (Samarra et al. 2012) and minke whale (Ólafsdóttir and Shinn 2013) in Icelandic waters conclusively showed that lampreys do associate with those species. Similar data for other cetaceans are still lacking and to our knowledge no evidence of anchorages on living cetaceans by another family of jawless fishes, such as the hagfish *Myxine glutinosa*, have been reported to date.

Myxine glutinosa is an eel-like fish pinkish in color and 20–90 cm in length. It is distributed along North Atlantic Sea coasts, with spotty presence in the Mediterranean Sea (FAO 2015). Here, we describe an unusual observation of a hagfish anchored inside the blowhole of an adult bottlenose dolphin (*Tursiops truncatus*) in the central Mediterranean Sea.

Materials and Methods

The observation was collected during an ongoing long-term research program on cetaceans in the southeastern Tyrrhenian Sea (Italy). The program follows the research guidelines of the American Society of Mammalogists on live animals (Sikes et al. 2011). The study area extends some 8,800 km^2 (Fig. 1) and is characterized by the presence of several canyon systems, erosion channels, and a large submarine valley between the islands of Ischia and Ventotene; the whole region is described as "Cuma's Canyon" (Pennetta et al. 1998; de Alteriis and Toscano 2003). The area is well known for its high biodiversity and for the presence of large pelagic predators, including 7 cetacean species (Pace et al. 2012).

Observations of cetaceans were made from a 17.7 m sailing vessel powered by 145-hp diesel engine. Dedicated daily visual and acoustic surveys were carried out by at least 3 experienced observers in Beaufort Sea states of ≤ 3 during good light conditions. Searches for cetaceans were conducted by scanning continuously with the naked eye and using 8× binoculars. Whitehead's focal group protocol (Whitehead 2004) was used to collect behavioral data at surface. During all surveys, the IFAW data logging software "Logger 2000" and whistle detector software were run continuously on a laptop connected to a GPS. Real-time records of date, time, latitude/longitude, cloud cover, Beaufort Sea state, and visibility, as well as number of animals, vocalization, and behaviors, were collected during all visual/acoustic detections of cetaceans. A high-performance digital camera equipped with an image stabilized telephoto zoom lens (100–400 mm F4.5–5.6) was used to take photo-identification images. Patches, nicks, notches, scars, and other irregularities were then analyzed to identify individuals (Würsig and Jefferson 1990).

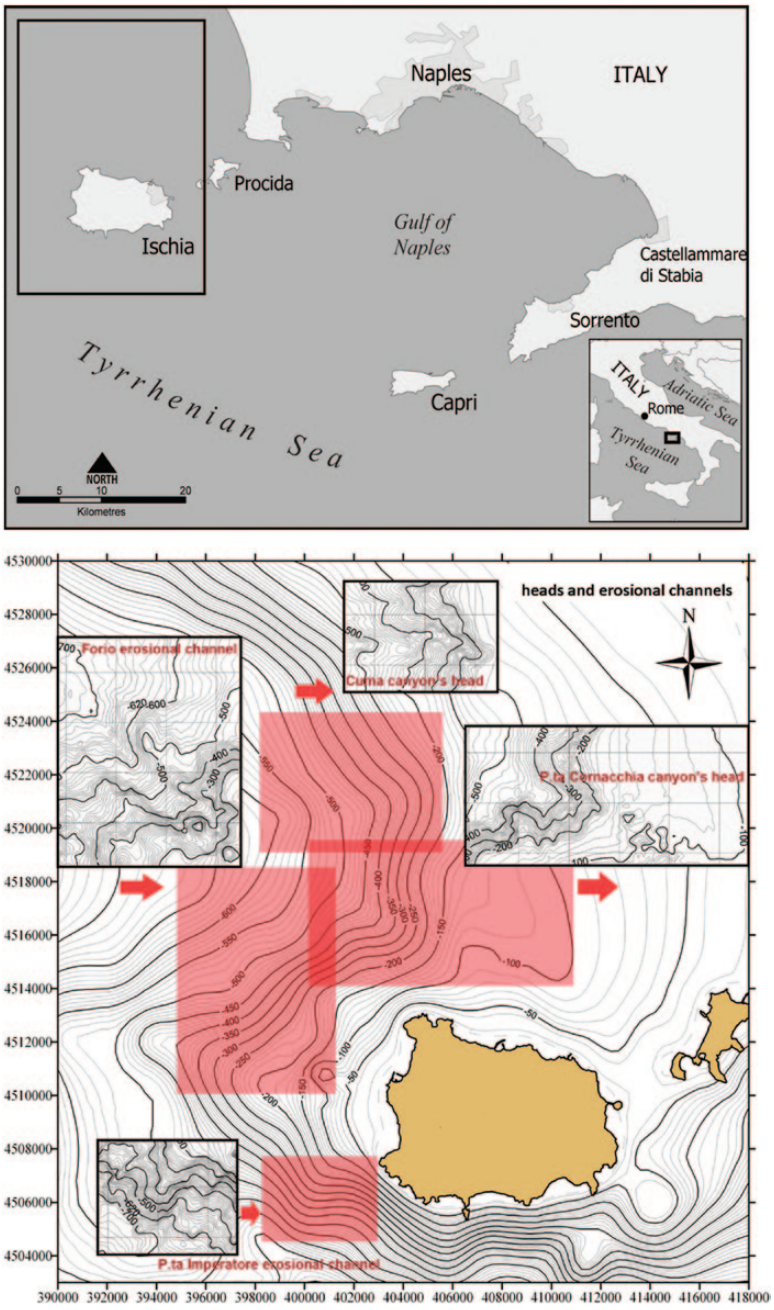

Fig. 1.—The study area and the submarine canyon system (QGIS, Version 2.8.2).

Results

A unique interaction between a hagfish and a bottlenose dolphin was recorded on 24 July 2013, North Ischia Island (40°45′54.252″N, 13°53′39.696″E), during an encounter with a group of approximately 80 dolphins. An often isolated, adult individual showed a mostly stereotypical surfacing–breathing pattern, with an awkward head-up respiratory arrangement similar to that typically observed in a neonate's immature swimming (Fig. 2). The breathing rate was high, ranging from 8 up to 13 ventilations per minute, with strong exhalations. When approached, the body of a pinkish eel-like organism was observed coming out from the blowhole of the dolphin, so the dolphin might be experiencing difficulties to breathe properly due to its respiratory ways being partially, if not totally, obstructed by the hagfish. The specimen was a posteriori identified by one of the authors (GA) as a hagfish (Fig. 3) and not a lamprey principally by 1) the color and 2) the morphology of the fins, as hagfish have only 1 thin continuous median fin fold on the back and around the tail, whereas lampreys have one or more dorsal fins separate from the caudal fin. A total number of 519 images were taken during the sighting and a selection of 23 was used to identify the hagfish. The estimated length of the hagfish was 50 cm. It was not possible to assess if the hagfish was alive, moribund, or dead.

Fig. 2.—The surfacing–breathing pattern of the bottlenose dolphin (*Tursiops truncatus*) with the hagfish (*Myxine glutinosa*) anchored in the blowhole.

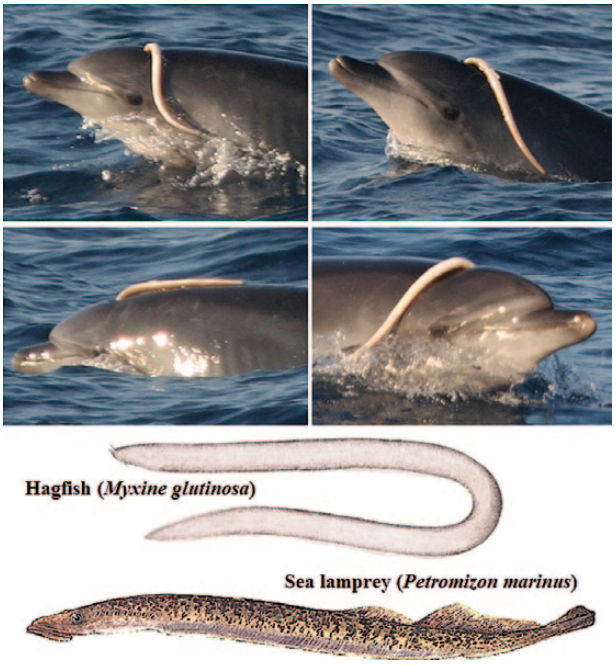

Fig. 3.—Closer images of the hagfish (*Myxine glutinosa*) protruding from the blowhole. A comparison between the morphology/color of a hagfish and a sea lamprey (*Petromyzon marinus*) is also shown (both drawings are of public domain: hagfish by H. T. Todd, figb0523, Historic NMFS Collection, NOAA; sea lamprey by E. Edmonson and H. Chrisp, http://pond.dnr.cornell.edu/nyfish/fish.html).

The bottlenose dolphin was photo-identified and visually/acoustically monitored for 2 h, until sunset; it was never seen to dive, remaining isolated at surface most of the time while the rest of the group of dolphins was actively hunting and feeding. In 3 occasions, other dolphins approached the one with the hagfish, standing by and swimming very close to it in a tight formation. We were not able to record any pushing, rubbing, or other kind of physical contacts. During these social phases, series of overlapped clicks, whistles, and whistle/buzzes bouts (Fig. 4) were recorded. No vigorous maneuvers to try to pull out the hagfish were documented during the observation period.

Part of the group encountered on 24 July was resighted on 23 and 28 August 2013. On both occasions, the dolphin with the hagfish in July was photo-identified without it (Fig. 5). The animal showed no physical evidence of malnutrition/starvation (i.e., visibly reduced blubber thickness) and no anomalies were observed in the breathing pattern.

Discussion

To our knowledge, this is the 1st report of a hagfish anchored to a living cetacean species.

Hagfishes occur in muddy benthic habitats at 15–5,000 m in depth (Clark and Summers 2012) and are commonly considered opportunistic scavengers on various invertebrates and vertebrates, including cetaceans (Martini 1998; Zintzen et al. 2011). However, hagfishes may also be active and successful hunters of live animals on the substratum, i.e., fishes in the deep sea, suggesting a broader trophic niche and a different ecological role for the entire family (Zintzen et al. 2011). When feeding as scavengers or active predators, these species grasp food with dental plates that are repeatedly protracted from the mouth, then forcefully retracted; occasionally, they can tie their bodies into knots to vigorously remove chunks of flesh from large carcasses (Martini 1998) or to extract the prey from its burrow (Zintzen et al. 2011). A single posteriorly curved tooth situated in the palate augments knot-tying behaviors by allowing a hagfish to anchor itself to the prey (Clark and Summers 2012).

Bottlenose dolphins can use a benthic-feeding method (i.e., "crater feeding," observed in the Bahamas) when fish cues are detected acoustically in the soft bottom, diving vertically into the sediment, moving flukes vigorously, and digging, occasionally burying themselves nearly to the pectoral fins (Rossbach and Herzing 1997). Although this feeding technique has never been reported in the Mediterranean Sea, it cannot be ruled out that bottlenose dolphins may have used this method as a

Fig. 4.—Photo-identification of the bottlenose dolphin (*Tursiops truncatus*) with the hagfish (*Myxine glutinosa*) on 24 July 2013 (A = right side, C = left side) and 1 month later (23 August 2013; B = right side, D = left side, E = blowhole without the hagfish). Main marks are indicated and mark changes are visible comparing A and B.

foraging option in the study area. This region is characterized by the presence of a canyon system, with a sandy and muddy bottom at between 50 and 200 m in depth (de Alteriis and Toscano 2003), a depth range that represents the typical habitat of the bottlenose dolphin. The dolphin may have encountered the hagfish during benthic-feeding toward the hagfish itself or another target species. No data on the presence of hagfishes in stomach contents of stranded bottlenose dolphins are available in the study region. However, direct observations of dead/injured prey in the wake of bottlenose dolphin groups feeding in Doubtful Sound fjords (New Zealand) and stomach content analysis on adult harbor porpoises (*Phocoena phocoena*) in the Kattegat and Skagerrak (Northern Sea) showed that hagfishes might be target prey for some odontocetes (Boerjesson et al. 2003; Lusseau and Wing 2006), representing a relevant component of their diet in specific populations.

Hagfishes are able to produce substantial amounts of slime when provoked or stressed (Ferry 1941; Koch et al. 1991), with multiple functions (Zintzen et al. 2011). One function is as a predation tool that incapacitates prey by suffocating them (Subramanian et al. 2008). Slime-use against predation by dolphins or as a tool to attack living dolphins has never been reported. In this case, we first speculated that the hagfish, anchored inside the blowhole with its dental plates, would produce slime, resulting in the asphyxiation of the dolphin. However, this conjecture was rejected since 1) the hagfish head has few slime glands compared to the trunk and tail, and any significant amount of slime produced would probably stream off nowhere near the blowhole and 2) the dolphin was encountered alive 1 month later without the hagfish into the blowhole.

The blowhole is vital for dolphins, both for breathing and sound production. The dolphin showed a stereotypical surfacing–breathing pattern similar to that of baiji (*Lipotes vexillifer*—Renjun et al. 1986) and of humpback dolphins (*Sousa chinensis*—Karczmarski et al. 1997), probably in an attempt to gain a longer time of blowhole exposure. It has been suggested (Hui 1989) that dolphins may control blowhole exposure by changing their emergence angle with little modification of swimming speed. Consequently, the surfacing pattern of this injured animal may possibly benefit the efficiency of ventilation before the next respiratory act (Dral and Verwey 1977), along with producing a significantly higher breathing rate than the rest of the group. Although no behaviors were identified as attempts to tear off the hagfish, the close proximity of other dolphins as well as the presence of overlapping vocal events may suggest a degree of social bonds between these individuals. From a behavioral perspective, a possible role of conspecifics in helping the disabled dolphin may be postulated. Epimeletic (caregiving) behavior is described as the providing of care/attention to another individual and is termed succorant when directed toward individuals in distress (Caldwell and Caldwell 1966). Succorant behavior has been reported in at least 8 genera of odontocetes (for review, see Felix 1994; Fertl and Schiro 1994), including members of at least 10 different species (Brown and Norris 1956; Norris and Prescott 1961; Essapian 1962; Caldwell et al. 1963; Caldwell and Caldwell 1966; de Moura et al. 2009; Park et al. 2013; Alves et al. 2015). Among 7 of these genera, including *Tursiops*, the succorant behavior involved supporting a distressed or a dead conspecific at the water's surface (Norris and Prescott 1961; Pilleri and Knuckey 1969; Pilleri 1971; Kasuya and Miyazaki 1976; Cockcroft and Sauer 1990; Lodi 1992; de Moura et al. 2009; Kuczaj et al. 2015). Succorant behavior was broken down into 1) "standing by" which is to remain in or approach the area of a distressed species member but without rendering assistance, 2) "excitement" includes approaching an injured comrade and showing hyperexcitability or distress, and 3) "supporting behavior" is when one or more animals support an injured individual in body contact at the surface. Distress may be vocalized or silent

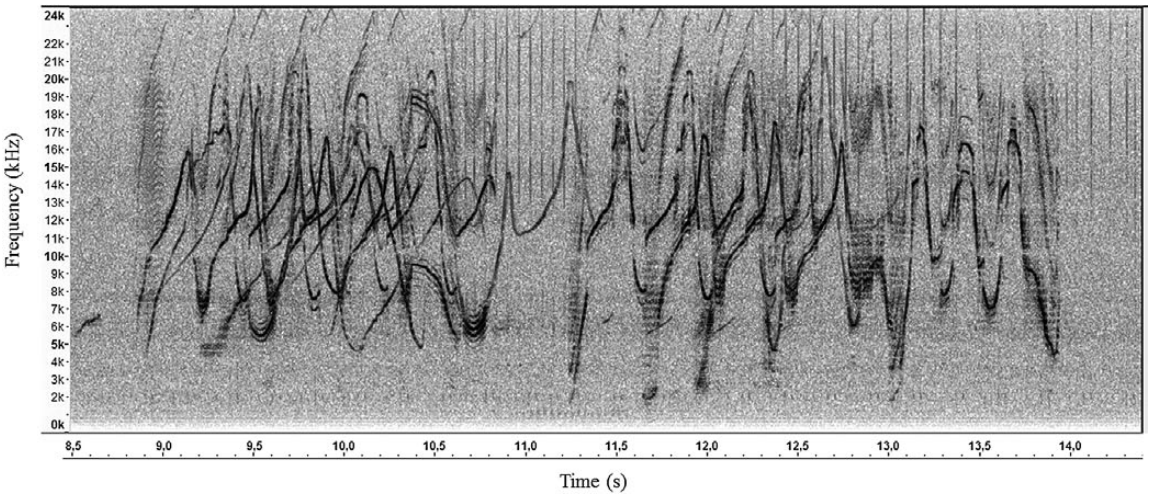

Fig. 5.—Series of overlapped clicks, whistles, and buzzes recorded during succorant social interactions ("standing by" events).

(Caldwell and Caldwell 1966). While "standing by" activities were observed in our study, we were not able to document "supporting behaviors" since we did not have the chance to closely approach and follow the hagfish–dolphin (the animal changed its swimming when accosted by our research vessel). Although intense vocalizations were recorded during proximity phases, we cannot be certain that the injured dolphin also produced whistles. Kuczaj et al. (2015) documented for the 1st time an underwater account of multiple wild bottlenose dolphins providing epimeletic care to a distressed conspecific and highlighted the possible role of distress calls in such scenarios. We are not aware if members of the group performed helping/assisting behaviors at surface or acted to pull out the hagfish from the blowhole of the conspecific; we can only hypothesize that 1) the attachment was recent as no signs of emaciated girth were apparent in the dolphin to suggest poor health and 2) the hagfish removal/loss occurred within a limited amount of time.

Acknowledgments

We are very grateful to Ocean Care and to Associazione Amici di Riccardo Domenici for providing funding to the Ischia Dolphin Project and for the general assistance to the research program. We thank L. Stanzani and all other research assistants, collaborators, and volunteers who contributed to data collection in the field and photo-identification analysis, as well as K. Massaro, M. C. Gambi, L. Bertone, F. Mussi, N. Pace, C. Berardi, and G. Giacomini for their constant encouragements. We also greatly appreciate the logistic support provided by the municipality of Casamicciola Terme, Lacco Ameno and the MPA "Regno di Nettuno." Finally, we are very grateful to S. Kuczaj and the 2 anonymous reviewers for their very useful comments to improve the manuscript.

Literature Cited

Alves, F., C. Nicolau, A. Dinis, C. Ribeiro, and L. Freitas. 2015. Supportive behavior of free-ranging Atlantic spotted dolphins (*Stenella frontalis*) toward dead neonates, with data on perinatal mortality. Acta Ethologica 18:301–304.

Boerjesson, P., P. Berggren, and B. Ganning. 2003. Diet of harbor porpoises in the Kattegat and Skagerrak seas: accounting for individual variation and sample size. Marine Mammals Science 19:38–58.

Brown, D. H., and K. S. Norris.1956. Observations of captive and wild cetaceans. Journal of Mammalogy 37:311–326.

Caldwell, M. C., D. H. Brown, and D. K. Caldwell. 1963. Intergeneric behavior by a captive Pacific pilot whale. Los Angeles County Museum Contributions in Science 70:1–12.

Caldwell, M. C., and D. K. Caldwell. 1966. Epimeletic (care-giving) behavior in Cetacea. Pp. 755–789 in Whales, porpoises and dolphins (K. S. Norris, ed.). University of California Press, Berkeley.

Clark, A. J., and A. P. Summers. 2012. Ontogenetic scaling of the morphology and biomechanics of the feeding apparatus in the Pacific hagfish *Eptatretus stoutii*. Journal of Fish Biology 80:86–99.

Cockcroft, V. G., and W. Sauer. 1990. Observed and inferred epimeletic (nurturant) behavior in bottlenose dolphins. Aquatic Mammals 16:31–32.

de Alteriis, G., and F. Toscano. 2003. Introduzione alla geologia dei circostanti le isole Flegree di Ischia, Procida e Vivara. Pp. 26–33 in Ambiente marino e costiero e territorio delle isole Flegree (Ischia, Procida e Vivara). Risultati di uno studio multidisciplinare (M. C. Gambi, M. De Lauro, and F. Jannuzzi, eds.). Liguori Editore, Napoli, Italy.

de Moura, J. F., É. da Silva Rodrigues, and S. Siciliano. 2009. Epimeletic behaviour in rough-toothed dolphins (*Steno bredanensis*) on the east coast of Rio de Janeiro State, Brazil. Marine Biodiversity Records 2:1–3.

Dral, A. D. G., and J. Verwey. 1977. Breathing and diving in *Tursiops*. Aquatic Mammals 5:18–20.

Essapian, F. S. 1962. Courtship in captive saddle-backed porpoises, *Delphinus delphis*, L. 1758. Zeitschrift für Säugetierkunde 27:211–217.

FAO. 2015. Aquatic species distribution, *M. glutinosa*. http://www.fao.org/geonetwork/srv/en/main.home?uuid=fao-species-map-myg. Accessed 2 October 2015.

Felix, F. 1994. A case of epimeletic behavior in a wild bottlenose dolphin *Tursiops truncatus* in the Gulf of Guayaquil, Ecuador. Investigations on Cetacea 25:227–234.

Ferry, J. D. 1941. A fibrous protein from the slime of the hagfish. Journal of Biological Chemistry 138:263–268.

Fertl, D., and A. Schiro. 1994. Carrying of dead calves by free-ranging Texas bottlenose dolphins (*Tursiops truncatus*). Aquatic Mammals 20:53–56.

Hui, C. A. 1989. Power and speed of swimming dolphins. Journal of Mammalogy 68:126–132.

Karczmarski, L., M. Thornton, and V. G. Cockroft. 1997. Description of selected behaviors of humpback dolphins *Sousa chinensis*. Aquatic Mammals 23:127–133.

Kasuya, T., and N. Miyazaki. 1976. An observation of epimeletic behavior of *Lagenorhynchus obliquidens*. Scientific Report of Whales Research Institute 28:141–143.

Koch, E. A., R. H. Spitzer, R. B. Pithawalla, and S. W. Downing. 1991. Keratin-like components of gland thread cells modulate the properties of mucus from hagfish (*Eptatretus stouti*). Cell Tissue Research 264:79–86.

Kuczaj, S. A., E. E. Frick, B. L. Jones, D. Beecham, and F. Schnöller. 2015. Underwater observations of dolphin reactions to a distressed conspecific. Learning & Behaviour 43:289–300.

Lodi, L. 1992. Epimeletic behavior of free-ranging rough-toothed dolphins, *Steno bredanensis*, from Brazil. Marine Mammal Science 8:284–287.

Lusseau, S. M., and R. Wing. 2006. Importance of local production versus pelagic subsidies in the diet of an isolated population of bottlenose dolphins *Tursiops sp*. Marine Ecology Progress Series 321:283–293.

Martini, F. 1998. The ecology of hagfishes. Pp. 57–77 in The biology of hagfishes (J. M. Jorgensen and H. Malte, eds.). Chapman & Hall, London, United Kingdom.

Nichols, O. C., and P. K. Hamilton. 2004. Occurrence of the parasitic sea lamprey, *Petromyzon marinus*, on western North Atlantic right whales, *Eubalaena glacialis*. Environmental Biology of Fishes 71:413–417.

Nichols, O. C., and U. Tscherter. 2011. Feeding of sea lampreys *Petromyzon marinus* on minke whales *Balaenoptera acutorostrata* in the St Lawrence Estuary, Canada. Journal of Fish Biology 78:338–343.

Norris, K. S., and J. H. Prescott. 1961. Observations on pacific cetaceans of California and Mexican waters. University of California Publications in Zoology 63:291–402.

Ólafsdóttir, D., and A. P. Shinn. 2013. Epibiotic macrofauna on common minke whales, *Balaenoptera acutorostrata*, in Icelandic waters. Parasites & Vectors 6:105.

Pace, D. S., A. Miragliuolo, and B. Mussi. 2012. The case study of the marine Canyon of Cuma (Tyrrhenian Sea, Italy): implication for cetacean conservation off Ischia Island. Pp. 89–97 in Mediterranean submarine canyon. Ecology and governance (M. Würtz, ed.). IUCN, Gland, Switzerland.

Park, K. J., H. Sohn, Y. R. An, D. Y. Moon, S. G. Choi, and D. H. An. 2013. An unusual case of care-giving behavior in wild long-beaked common dolphins (*Delphinus capensis*) in the East Sea. Marine Mammal Science 29:E508–E514.

Pennetta, M., A. Valente, D. Abate, G. Boudillon, T. De Pippo, M. Leone, and F. Terlizzi. 1998. Influenza della morfologia costiera sulla circolazione e sedimentazione sulla piattaforma continentale tra Gaeta e Cuma (Italia Meridionale). Bollettino della Società Geologica Italiana 117:281–295.

Pilleri, G. 1971. On the La Plata dolphin *Pontoporia blainvillei* off the Uruguayan coasts. Investigations on Cetacea 3:69–73.

Pilleri, G., and J. Knuckey. 1969. Behaviour patterns of some Delphinidae observed in the Western Mediterranean. Zeitung für Tierpsychologie 26:48–72.

Rossbach, K. A., and D. L. Herzing. 1997. Underwater observations of benthic-feeding bottlenose dolphins (*Tursiops truncatus*) near Grand Bahama Island, Bahamas. Marine Mammal Science 13:498–504.

Renjun, L., M. Klinowska, and R. J. Harrison. 1986. The behavior of *Lipotes vexillifer* and *Neophocaena phocaenoides* in the Changjiang River and in Captivity in China. Pp. 433–439 in Research on dolphins (M. M. Bryden and R. Harris, eds.). Clarendon Press, Oxford, United Kingdom.

Samarra, F. I. P., A. Fennell, K. Aoki, V. B. Deecke, and P. J. O. Miller. 2012. Persistence of skin marks on killer whales (*Orcinus orca*) caused by the parasitic sea lamprey (*Petromyzon marinus*) in Iceland. Marine Mammals Science 28:395–401.

Sikes, R. S., W. L. Gannon, and The Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92:235–253.

Subramanian, S., N. W. Ross, and S. L. MacKinnon. 2008. Comparison of antimicrobial activity in the epidermal mucus extracts of fish. Comparative Biochemistry and Physiology, B. Comparative Biochemistry 150:85–92.

Whitehead, H. 2004. The group strikes back: follow protocols for behavioural research on cetaceans. Marine Mammals Science 20:664–670.

Würsig, B., and T. A. Jefferson. 1990. Methods of photo-identification for small cetaceans. Reports of the International Whaling Commission Special Issue 12:43–52.

Zintzen, V., C. D. Roberts, M. J. Anderson, A. L. Steward, C. D. Struthers, and E. S. Harvey. 2011. Hagfish predatory behavior and slime defence mechanism. Scientific Reports 1:131.

Submitted 10 November 2015. Accepted 29 January 2016

Associate Editor was Jeanette A. Thomas.