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NOTE

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Mass stranding and unusual sightings of northern bottlenose whales (*Hyperoodon ampullatus*) in Skjálfandi Bay, Iceland

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Inhabiting temperate and subarctic regions of the North Atlantic (Wimmer & Whitehead, 2004), northern bottlenose whales (NBWs; *Hyperoodon ampullatus* [Forster, 1770]) are typically found in open-ocean habitats greater than 500 m depth (Hooker, Whitehead, Gowans, & Baird, 2002; Wimmer & Whitehead, 2004). This offshore distribution is typical of all beaked whales (Cetacea: Ziphiidae) and, in addition to extreme, deep diving (Hooker & Baird, 1999), often prevents effective study of their behavior and ecology (Macleod et al., 2006; Macleod, Pierce, & Santos, 2004). This is reflected in NBWs, and more than 90% of beaked whale species (Parsons, 2016), listed as "Data Deficient" by the IUCN Red List of Threatened Species (Taylor et al., 2008). Moreover, NBWs are likely sensitive to anthropogenic disturbance, including high-frequency-noise pollution and fishery interactions (Miller et al., 2015; Whitehead & Hooker, 2012). Owing to their elusive lifestyle and corresponding lack of species data, any baseline information on NBW occurrence and activity can improve our understanding of species ecology and facilitate conservation decisions.

Due to the challenges of obtaining these data from live beaked whales, strandings represent a crucial source of information for NBW and beaked whale research (Tucker, Santos, Crocetti, & Butcher, 2018), by advancing our knowledge of health, population threats, and species biology (Evans & England, 2001; Geraci & Lounsbury, 2005; Jepson et al., 2016). While it is difficult to determine the principal drivers of beaked whale strandings, individual events have been attributed to disease (Arbelo et al., 2013; Dagleish, Foster, Howie, Reid, & Barley, 2008), vessel collision (Carrillo & Ritter, 2010), and ingestion of marine debris (Arbelo et al., 2013). Atypical mass strandings, occurring over several days and a large geographical area (Frantzis, 1998), are often attributed to naval mid-frequency active sonar (Barlow & Gisiner, 2006; Bernaldo de Quirós et al., 2019; Evans & England, 2001). The specific cause of each stranding likely depends on its context, including geographical location and regional anthropogenic activity (Geraci & Lounsbury, 2005).

Here, we describe a series of sightings and an atypical mass stranding of NBWs in a coastal area of north Iceland in 2018. The contribution of these records to the known sighting and stranding history of an understudied and potentially threatened species is then discussed. The events in north Iceland were contemporary with an unusual mortality event (UME; Marine Mammal Protection Act of the United States, 16 U.S.C. 1421h) of up to 100 beaked whales across the Northeast Atlantic in 2018 (A. Brownlow, personal communication, March 2019).

NBWs were observed in Skjálfandi Bay, Iceland, from vessel- and land-based platforms, and sightings were opportunistically collected from multiple sources. The majority of these reported sightings were made by trained interns, as dedicated cetacean observers, on board commercial whale-watching vessels (as in Klotz, Fernández, & Rasmussen, 2017). Surveys were conducted as part of a broader cetacean study by at least two observers, from an eye height of 4–7 m and in Beaufort sea states of 5 or less, and involved continuous scanning with the naked eye for visual cues of cetacean presence. NBWs were identified by a low, "bushy" blow, bulbous melon, falcate dorsal fin, and brown coloration (Reeves, Stewart, Clapham, Powell, & Folkens, 2002). The following data were then collected when possible: time (UTC) and vessel GPS coordinates of initial confirmed sighting; approximate group size; dive time; surface activity (observed ad libitum; Altmann, 1974); photographs of individual whales; and weather conditions. Sighting data were collected using an iPad with SPOTTER PRO software and photographs were taken with a DSLR camera (Canon 70D, 100–400 mm lens). Surface activity was defined by observation of breaching, tail slapping or head lunging (Reeves et al., 2002). Dive times were frequently not recorded due to the limits of data collection from commercial whale-watching vessels. In addition to systematic observation, opportunistic sightings were reported: from land (by trained researchers) and from whale-watching vessels (by whale-watching guides). Data from whale-watching guides were qualitative, with no GPS coordinates.

Images of individual whales were used for photo-identification, to document the minimum number of animals sighted and resighted, following methods outlined by Gowans and Whitehead (2001) for NBWs. Briefly, each image was assigned a quality rating (on a six-point scale, where 6 denotes highest quality), based on focus, contrast, and angle of the fin relative to the frame (Zaeschmar et al., 2014), and only photographs with a quality of 4 or greater were used. Following this, separate catalogs of recognizable left and right sides were developed using reliable features, namely notches, back indentations, and mottled patches. Due to the short time scale of this study (less than 4 months between first and last sighting), we also included large scars and long scrapes as identification features, which were found to have a loss rate of less than 0.1 marks per year (Gowans & Whitehead, 2001). As we were usually unable to match the left and right sides of a single animal, these two catalogs were kept separate.

Between July and October 2018, multiple NBW strandings were observed within Skjálfandi Bay, both live and dead. Following reports of each stranding, from whale-watching vessels or members of the public, a research team attempted to access the site as quickly as possible. When feasible, the following data were collected for each stranded animal: time (UTC) of first reporting; GPS coordinates of stranding; total length; blubber thickness at the cranial insertion of the dorsal fin; sex; decomposition state (as in Pugliares et al., 2007); and notable markings, such as skin lesions. Samples of skin, blubber, and muscle were also collected where possible.

In order to visualize changes in sightings, behavior, and distribution over time, the study was split into four 28-day periods: 25 June–22 July (period 1); 23 July–19 August (period 2); 20 August–16 September (period 3); 17 September–15 October (period 4, 29 days). Standardizing observation effort across time periods in 2018 was challenging due to the opportunistic collection of data from multiple sources. The number of days in which ≥5 whale-watching tours operated in Skjálfandi Bay ("whale-watching days") was used as a rough estimate of sighting effort, as it is thought that whale-watching guides reported the majority of their NBW sightings.

Further, the frequency of sightings in Skjálfandi Bay and associated effort data were compared between 2010–2017 and 2018. As a species that is rarely observed in this bay (M.H.R., personal observation), dedicated researchers and whale-watching vessels reported all sightings of NBWs during 2010–2017. Duration of the whale-watching season (in weeks) and number of whale-watching vessels operating in the bay were used as crude estimates of sighting effort. Similarly, the number of confirmed, stranded NBWs in Skjálfandi Bay from 2007 (from when strandings were reliably reported) to 2017 was compared with 2018.

Between June 25 and October 15, 2018, live, free-swimming NBWs were sighted in Skjálfandi Bay on 64 occasions and 49 days: 3 days in June, 25 in July, 9 in August, 10 in September, and 2 in October (Figure 1). Forty-nine sightings were reported by researchers (44 from whale-watching vessels, five from land), each with GPS coordinates (Figure 2), and 15 were reported by whale-watching guides without GPS coordinates. Group size, reported by researchers, varied from 1 to 15 animals (mean = 4.6). From suitable photographs captured on 18 separate days, 13 animals were identified with left-side images and 16 animals with right-side images. Six left-side animals were resighted on 14 occasions and six right-sided animals were resighted on 14 occasions (Figure 1a,b). In the study period, at least six NBWs died, or were found dead, in Skjálfandi Bay: four animals live-stranded and subsequently died in two separate events; one dead animal was found stranded; and one additional dead animal was found floating in Skjálfandi Bay (Table 1, Figure 1c). No dead animal could be matched to a live-sighted animal.

During the study period, changes in sighting frequency, behavior, and distribution were observed (Figures 1 and 2). The highest sighting frequency was recorded during periods 1 and 2 (18/27 whale-watching days during each period). In period 1, animals were primarily sighted in the central part of the bay. Groups were generally observed for only one surfacing sequence, which may indicate extended dive times (>15 min). Surface activity peaked in period 2 (5/18 days sighted), when animals were frequently observed performing short dives (estimated <5 min) in the shallow (<50 m), southwest corner of the bay, near the mouth of the river Skjálfandafljót (including five sightings without GPS coordinates). Two live stranding events (July 25 and August 4) also occurred in the southwest during period 2, involving four animals, all of which died on land (Figure 3a,b). Further, a partial live stranding of four animals was reported (July 28, supported by video footage). During period 3, sighting frequency decreased (9/27 whale-watching days) and one dead stranding was reported (September 8). While generally low photograph quality prevented systematic analysis for health indicators, poor body condition was reported by researchers on 5 days during this period (no reports in periods 1 and 2). Postcranial depressions, dorsal ridges (indicating a depleted blubber layer; Bradford et al., 2012), and severe skin lesions were visible (Figure 3c,d). Sighting frequency declined further in period 4 (2/21 sighting days), with one dead animal seen floating in the bay.

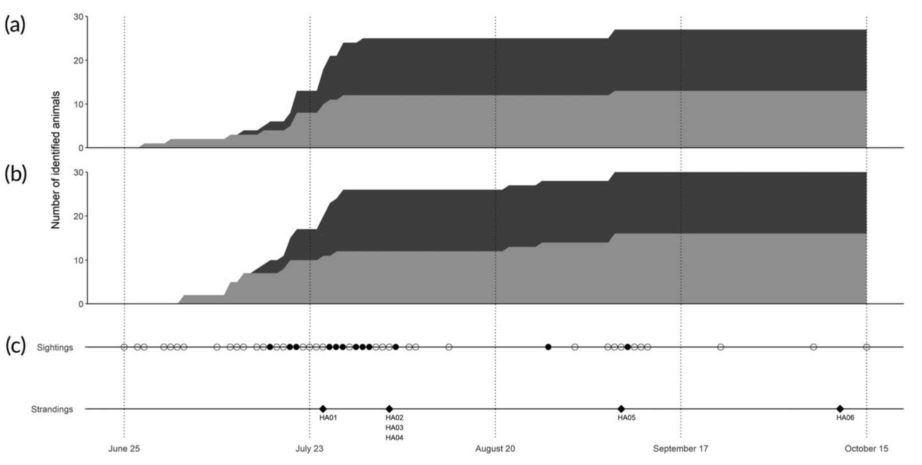

FIGURE 1 Timeline of sightings, surface activity and photo-identification of northern bottlenose whales in Skjálfandi Bay, Iceland, 2018. The study was split into four 28-day periods (period 4 = 29 days). (a) Cumulative number of new sightings (light gray, n = 13) and resightings (dark gray, n = 14) of animals identified from left-side photographs. One resighting corresponds to the observation of one previously identified animal on a single day. (b) Cumulative number of new sightings (light gray, n = 16) and resightings (dark gray, n = 14) of animals identified from right-side photographs. (c) Dates of sightings (circle, n = 49 days) and strandings (diamond, n = 4 days). Black circles denote the observation of surface activity. Strandings are labeled with the identification of each stranded animal. Created in R 3.6.2 (R Core Team, 2019).

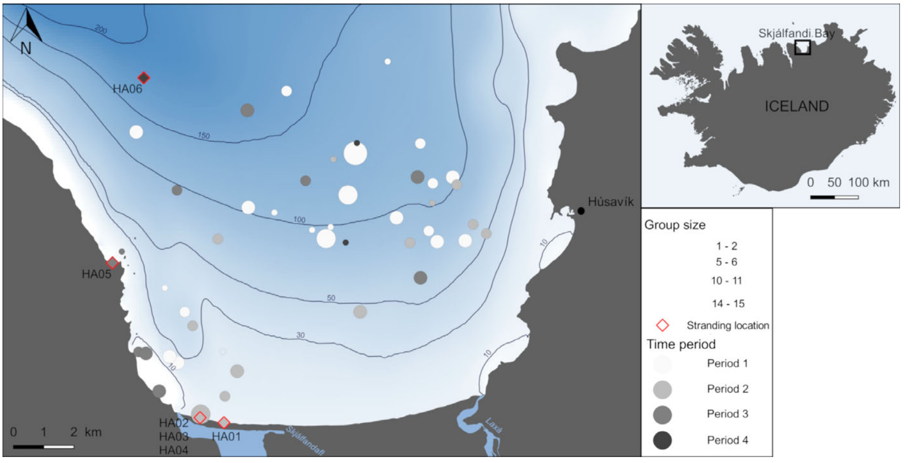

FIGURE 2 Location of each live sighting (circle, *n* = 49) and stranding/dead sighting (diamond, *n* = 4) of northern bottlenose whales in each 28-day period between June 25 and October 15, 2018. Circles represent initial live sighting location; node size corresponds to group size and color corresponds to time period. Diamonds represent the location of stranded or dead animals when first accessed by researchers. Period 1 = June 25–July 22, period 2 = July 23–August 19, period 3 = August 20–September 16, period 4 = September 17–October 15 (29 days). Created in QGIS 2.18.28 (QGIS Development Team, 2018).

TABLE 1 Summary of dead northern bottlenose whales observed in Skjálfandi Bay, 2018. Information on sex, length, blubber thickness, and decomposition state (condition code) was collected on the date of access by researchers. Identification refers only to animals in this table, not to live animals included in the photo-identification catalogs.

Date of report (date of access)	Location type	Number of animals	Identification	Sex (F/M)	Length (m)	Blubber thickness (mm)	Condition code	Samples collected?
25 Jul 2018 (27 Jul 2018)	Stranding	1	HA01	F	8.12	83	4 (advanced)	yes
4 Aug 2018 (5 Aug 2018)	Stranding	3	HA02	F	5.97	75	2b (fresh)	yes
			HA03	F	6.47	85	2b (fresh)	yes
			HA04	F	5.41	69	2b (fresh)	yes
8 Sep 2018 (11 Sep 2018)	Stranding	1	HA05	—	3.80	—	4 (advanced)	no
11 Oct 2018 (no access)	Floating	1	HA06	F	6–8 (estimated)	—	3 (moderate)	no

The frequency of reported sightings and strandings was higher in 2018 than in previous years. Between 2010 and 2017, NBWs were reported in Skjálfandi Bay for 11 days (10 days in 2012 and 1 day in 2013). During the same period, whale-watching effort also increased each year: the whale-watching season lengthened from 28 weeks (2010) to 41 weeks (2018) and the number of whale-watching vessels operating in the bay increased from 7 (2010) to 18 (2018). This change in effort could partially account for an increase in reported sightings but may not fully explain a rise from 11 days in 2010–2017 to 49 days in 2018. Meanwhile, no dead or stranded NBWs were reported between 2007 and 2017 in Skjálfandi Bay.

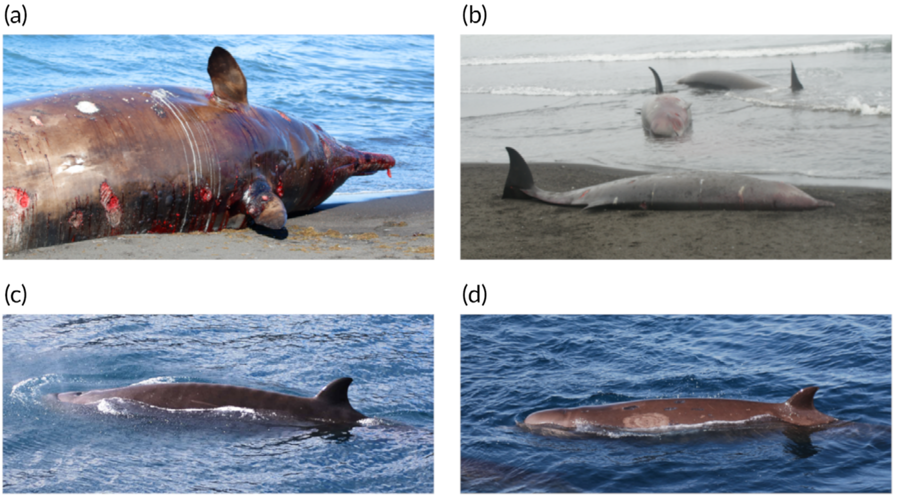

FIGURE 3 Northern bottlenose whales in Skjálfandi Bay, Iceland, 2018. (a, b) Deceased stranded whales: (a) HA01, July 27 (reported July 25); (b) HA02 (back), HA03 (center), HA04 (front), August 5 (reported August 4). (c, d) Evidence of poor body condition of live sighted whales: (c) left flank with dorsal ridges visible, September 9; (d) left flank with skin lesions visible, September 9.

Comparing the results of this study with other occurrences of NBWs is hindered by its opportunistic nature and resulting lack of quantitative sighting and effort data. Nevertheless, in the context of the recorded history of NBWs across their range, the events described above may represent an unprecedented series of coastal sightings and deaths. Previous unusual occurrences and behavioral events include: six whales in Eyjafjörður, Iceland, for 7 weeks in 2008, with frequent surface activity observed (Rasmussen & Miller, 2009); a single animal at Pulleen Harbour, Ireland, for 6 days in 2008, with frequent breaching and short dive times (Ryan & Lyne, 2008); and similar observations of two whales in Broadford Bay, Isle of Skye, Scotland, for over a month in 1998 (Weir, 1999). However, the events of Skjálfandi Bay, 2018, are arguably more extreme than those described above: animals were sighted over a longer period of time (more than three months) and multiple groups were sighted simultaneously on several occasions. Moreover, due to their common occurrence in the bay in 2018, it is considered unlikely that all sightings were reported; thus, the 2018 sighting frequency stated here may be treated conservatively. In addition, it appears that more animals were involved—at least 16 from photo-identification of right sides. However, this may not accurately reflect the total number of individuals photographed as apparently poor body condition during the latter part of the time period potentially obscured identifying marks.

As with unusual sightings, strandings have also been previously reported for this species: between 1800 and 2002, 109 stranded NBWs were reported around the British Isles (Macleod et al., 2004). Within this time, a mass stranding of three animals occurred near Dublin, Ireland, on a single day in 1954 (Berrow & Rogan, 1997). Other strandings of single animals have been reported in The Netherlands, Denmark, Nova Scotia, and Iceland (Mitchell & Kozicki, 1975; Santos et al., 2001; M.H.R., personal observation). In light of these past events, the recorded occurrence of six dead NBWs within three months in a single bay appears highly abnormal for this species and may be considered an unusual mortality event (UME; Marine Mammal Protection Act of the United States, 16 U.S.C. 1421h).

Furthermore, the events of Skjálfandi Bay are not isolated: in 2018, at least eight other NBWs, four Cuvier's beaked whales (*Ziphius cavirostris*), and one Sowerby's beaked whale (*Mesoplodon bidens*) stranded in other locations around Iceland (G. Víkingsson, personal communication, March 2019). Meanwhile, in June and July, free-swimming

NBWs were sighted in coastal areas around Iceland, including Eyjafjörður, Húnaflói, Breiðafjörður, and Borgarfjörður Eystri (local media sources and whale-watching companies). Moreover, these events overlapped in time with the stranding of up to 100 beaked whales—Cuvier's beaked whale, Sowerby's beaked whale, and NBW—around the British Isles during summer 2018 (A. Brownlow, personal communication, February 2019). Interestingly, the last unusual occurrence of NBWs in north Iceland (Rasmussen & Miller, 2009) coincided in time with an atypical mass stranding of at least 56 beaked whales over the first seven months of 2008 across the British Isles (Dolman et al., 2010). No common cause was found (Dolman et al., 2010).

Confidently attributing a cause to the unusual occurrences and UME of NBWs in Skjálfandi Bay, 2018, is not possible due to the opportunistic nature of this study. Significant methodological constraints prevented quantitation of occurrence and behavioral metrics, and little prior research has been conducted on NBWs in the area. Moreover, the potential causes of strandings are numerous, complex, and often interrelated. Several atypical beaked whale mass strandings have been attributed to anthropogenic noise (Arbelo et al., 2013; Bernaldo de Quirós et al., 2019; Evans & England, 2001), one of which included a single NBW (Simmonds & Lopez-Jurado, 1991). Beaked whales, especially NBWs, respond behaviorally to mid-frequency active sonar (MFAS) by performing long, deep dives and directional movement away from the sound source (Miller et al., 2015; Tyack et al., 2011; Wensveen et al., 2019). This response may induce acute, decompression-like disease and lead to increased stranding probability (Bernaldo de Quirós et al., 2019; Fernández et al., 2005; Jepson et al., 2003). There is no conclusive evidence that anthropogenic noise contributed to the sightings and strandings described here. Of note, however, is the temporal coincidence between the first sightings of NBWs in Skjálfandi Bay and the scheduled beginning of a NATO-led maritime Anti-Submarine Warfare exercise in the Norwegian Sea (June 25, 2018; Allied Maritime Command, 2018).

Other beaked whale strandings have been attributed to pathogens, including *Aspergillus* species, herpesvirus, and morbillivirus (Arbelo et al., 2010; Barley, Foster, Reid, Dagleish, & Howie, 2007; West et al., 2013). The prevalence of some diseases, such as morbillivirus, is density-dependent, with pathogens spreading horizontally between individuals of gregarious species (Van Bressem et al., 2014). Poor body condition, exhibited by multiple animals in this study, may further increase individual susceptibility to such diseases (Møller, Christe, Erritzøe, & Mavarez, 1998).

Attributing a cause to these events is also complicated by the occurrence of unusual sightings prior to strandings, with NBWs observed in the bay for one month before the first stranding event. However, biochemical and pathological analyses of samples collected from stranded animals (Table 1) will be conducted in the future and may help to elucidate potential causes of the described events (Geraci & Lounsbury, 2005). Further, these sightings and strandings formed part of a larger mass mortality of beaked whales across the Northeast Atlantic. While we are limited in our ability to assign causes to the events of Skjálfandi Bay specifically, collating our findings with those from other locations may allow determination of the potential drivers of such widespread die-off. This information is potentially crucial in implementing effective species conservation measures in the future (Barbieri et al., 2013), particularly if causes are anthropogenic in origin.

Future studies of stranding events in north Iceland would benefit from improved stranding response and research infrastructure. In this study, it is improbable that all sightings were reported, and sample collection from deceased animals was limited by a lack of expertise. Strandings represent a crucial opportunity to study open-ocean species and the threats they face. Appropriate training of responders and communication between researchers, government agencies, and other relevant parties are necessary to achieve this (Geraci & Lounsbury, 2005; Tucker et al., 2018). Further, we recommend construction of a standard sighting report form and its dissemination to whale-watching companies and the general public, to allow quantitative, spatiotemporal analysis of sightings and behaviors of unusual species. Other countries, such as the United Kingdom and Ireland (Macleod et al., 2004), have implemented successful cetacean sighting and stranding networks, and we encourage the development of a similar system in Iceland.

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