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Stranding of Beaked Whales in Santa Cruz Province, Southern Patagonia, Argentina (1895-2023)

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Abstract

A total of 49 records of beaked whales stranded along approximately 900 km of coast of Santa Cruz Province, Argentina, were documented between 1895 and March 2023. These include 29 previously published and unpublished records (including one specimen re-identified through DNA analysis) and 20 new records. All of these involve at least seven species in five genera. All strandings correspond to single individuals. The most frequent species found stranded were Cuvier's beaked whales (*Ziphius cavirostris*) with 14 records, followed by strap-toothed whales (*Mesoplodon layardii*; n = 13). Species identities were based on skull morphology, tooth morphology and position in the jaw, and morphometric measurements. Additionally, mitochondrial control region DNA was sequenced to confirm species identification for 10 individuals, although confirmation was only possible in seven individuals. This study provides the first record of Arnoux's beaked whale and Hector's beaked whale from Santa Cruz Province and emphasizes the importance of the Southwest Atlantic Ocean for multiple beaked whale species. The potential impacts on these whale species of changing sea surface temperatures and ocean warming are unknown.

Key Words: ecosystem functioning, climate change, seismic exploration, strandings, Southwest Atlantic, Ziphiidae

Introduction

The family Ziphiidae is one of the most wide-ranging families of cetaceans, occurring from the ice edge at both poles to the equator in all the world's oceans (MacLeod et al., 2006). However, of the six genera and 24 extant beaked whale species currently recognized (Committee on Taxonomy, 2023) some are known from less than 20 records and most have only rarely been seen alive (e.g., Dalebout et al., 2004; MacLeod et al., 2006). The Andrews' beaked whale (*Mesoplodon bowdoini*) has never been knowingly seen alive (e.g., MacLeod et al., 2006; Thompson et al., 2012). Beaked whales are a deep-diving species that typically feed at depth on mesopelagic squid, a specialization that seems to make them extremely sensitive to loud human-generated sounds produced at depth such as naval sonar. Multiple studies have suggested this sensitivity from an increase in the number of strandings associated with the use of such technologies (Simmonds & López-Jurado, 1991; Frantzis, 1998; Jepson et al., 2003; Fernández et al., 2005; Hooker et al., 2012; Brownell, 2017; Bernaldo de Quiróz et al., 2019).

Several publications have reported on strandings of Ziphiidae in the Southwest Atlantic (Turner, 1880; Moreno, 1895; Fraser, 1950; Hamilton, 1952; McCann, 1975; Mead & Payne, 1975; Goodall, 1978; Lichter, 1986; Strange, 1992; Baker, 2001; White et al., 2002; Cappozzo et al., 2005; Grandi et al., 2005; MacLeod & Mitchell, 2006; Goodall et al., 2008; Otley et al., 2011; Hevia et al., 2012;

Otley, 2012; Gasparrou, 2017). In this article, we report on beaked whales stranded in Santa Cruz Province in southern Patagonia, Argentina, between 1998 and 2023, including a historical review of all records documented since 1895.

Methods

To collect stranded cetacean specimens, beach surveys of 900 km of the Santa Cruz Province coast were conducted opportunistically. Most surveys were concentrated in the central and southern area of the province from Cabo Dañoso (48° 48' S/67° 11' W) to Cabo Vírgenes (52° 19' S/68° 21' W) (Figure 1).

Between 1998 and 2006, four beach surveys were conducted per month. From 2007 to March 2023, these were reduced to typically only one beach survey per year. In addition to these surveys, data on stranded Ziphiidae were compiled from published and unpublished sources, including conference proceedings, museum records and collections, reports, books, conference abstracts, unpublished data of the authors, and newspaper articles. Government staff, Coast Guard staff, fishermen, or visitors also informed the authors of the presence of stranded animals. Most of these beaches are very isolated and only rarely have visitors. Once a stranded individual was found, morphometric measurements were collected, when possible, following Norris's (1961) protocol, and photographs were taken. In-depth examinations were conducted *in situ* when possible; and skin, teeth, other tissues, and stomach contents were collected for further studies, depending on the decomposition stage (scored for each specimen using the classification of Geraci & Lounsbury, 2005) and the percentage of the carcass remaining. Complete specimens of very large animals could not always be collected, but skulls were recovered, cleaned, classified, and stored by local museums or in the Fundación Cethus collection. Of the 49 specimens, according to the state of decomposition, two were category 2 (freshly dead with little to no decomposition), four were category E3 (little to moderate decomposition), six were category L3 (moderate to late decomposition), 32 were category 4 (advanced decomposition), and five historical specimens were of unknown decomposition stage. An effort was also made to document the colouration pattern of relatively fresh Cuvier's beaked whale (*Ziphius cavirostris*; FCSCZC081012) and Hector's beaked whale (*Mesoplodon hectori*; FCSJMH250223) specimens from this region; both were scored as decomposition category 2.

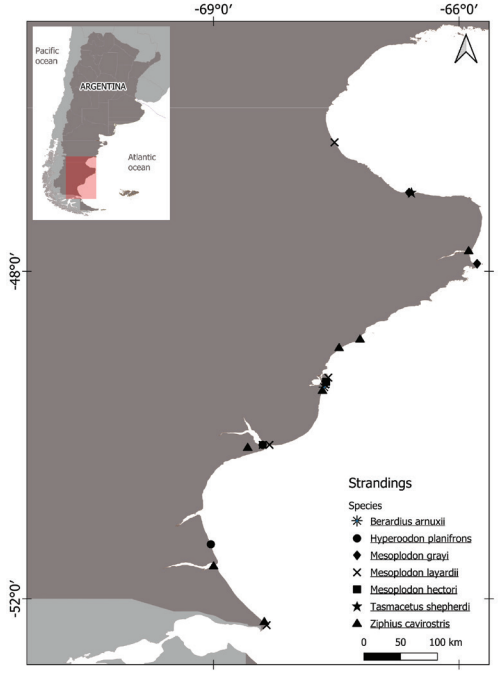

Figure 1. Locations of beaked whale strandings in the Santa Cruz Province reported by or to Fundación Cethus

Species and Sex Identification

During in-depth examination of specimens with a degree of decomposition up to stage E3 (Geraci & Lounsbury, 2005), external morphological features, tooth morphology and location, and cranial features, taking into account the arrangement and shape of bones, were used to provisionally identify the species, which were later confirmed by genetic analysis whenever possible. Genetic methods were also used to sex those specimens with an advanced degree of decomposition (stages L3 to 4; Geraci & Lounsbury, 2005) as well as those for which remains were incomplete, not allowing morphological sex determination.

Sex bias in stranded specimens was only assessed for the two species in this study with more than 10 specimens documented: Cuvier's beaked whale (n = 14) and strap-toothed beaked whale (*Mesoplodon layardii*; n = 13).

Genetic Analysis

Specimen Sources—Tissue samples have been collected from 15 beaked whale specimens from strandings and skeletal material collected along the coast of Santa Cruz Province between 45° 59' S/67° 35' W and 52° 19' S/68° 21' W (Table 3; specimens with Fundación Cethus assigned under columns "Material Stored and Location" or "Collector"). For this study, out of those 15 specimens, 10 were

analyzed from four locations: (1) Bahía San Julián (n = 5), (2) Ría Santa Cruz (n = 3), (3) Estancia La Angelina (n = 1), and (4) Cabo Vírgenes (n = 2).

Tissue Samples and DNA Extraction—DNA was isolated using standard methods via capture on glass fiber columns (DNEasy Animal Tissue extraction kit; Qiagen Corporation, Valencia, CA, USA) from frozen, ethanol preserved, and naturally mummified tissue samples and bone powder obtained by drilling into dense skull bones with a low speed drill (Pichler et al., 2001). When possible, several extractions from different tissue types were included to check for consistency in the sequences and genetic identification results, and to check for potential contamination, especially when bone powder drilled from skulls was analyzed. Extracted genomic DNA was stored frozen (at -20°C) prior to PCR amplification and has been archived at the Fundación Cethus headquarters in Buenos Aires, Argentina.

PCR Amplification and Sequencing—The 5' half of the mitochondrial control region was amplified in 25 µL reaction mixtures using Bioneer AccuPower HotStart PCR mix (Bioneer, Emeryville, CA, USA) and primers dlp1.5 (5'-GCACCCAAAGCTGAARTTCTA-3') and dlp5 (5'-GATGTCTTATTTAAGGGGAACG-3') (Dalebout et al., 2004). Thermal cycling conditions were 94°C/30 s initial denaturing, 35 cycles of 94°/30 s, 55°/30 s, "ramp" to 72° at 0.5°/s, then 72°/45 s, and final extension at 72°/5 min. Negative control reactions were included in each set of PCR reactions. PCR products were purified using ExoSAP-it (USB Corporation, Cleveland, OH, USA), then sequenced using BigDye 3.1 reagents with sequencing reaction products run on a 3500 Genetic Analyzer (Applied Biosystems, Foster City, CA, USA) at the Unidad de Genómica, Instituto de Biotecnología, Instituto Nacional de Tecnología Agropecuaria (Castelar, Buenos Aires, Argentina).

Sequence Analysis and Specimen Identification—Consensus sequences were compiled for both strands using *FinchTV*, Version 1.5.0 (Geospiza, Inc., Seattle, WA, USA) to view, edit, and trim sequences, and the online tool "SMS" (www.bioinformatics.org/sms2/index.html; Stothard, 2000) to align and combine forward and reverse reads. Combined sequences were then submitted to the DNA Surveillance website (www.dna-surveillance.auckland.ac.nz/wftw/index.html; Ross et al., 2003) for species identification. Each test sequence was analyzed individually with a suite of mtDNA control region reference sequences (Version 4.3) from all recognized species of beaked whales to make a species identification. Reference sequences derived from validated voucher specimens identified by experts in beaked whale morphology and phylogenetic analysis of those sequences showed that all beaked whale species currently recognized were genetically distinct at this locus (Dalebout et al., 2004). Phylogenetic reconstruction analysis was carried out separately for each unknown specimen vs the reference database. Neighbor-joining bootstrap consistency estimates for each species identification were generated using 500 replicates. Sequences from all specimens were also submitted to a GenBank BLAST search (www.ncbi.nlm.nih.gov:80/BLAST) which returns the best-matching sequences and a comparison alignment. Table 1 shows species identifications, the bootstrap resampling percentage from the DNA surveillance analysis, and the % match for the closest sequence in GenBank from the BLAST search.

Results

A total of 49 records of beaked whales stranded in Santa Cruz Province, Argentina, were registered for the period 1895 to March 2023. These include 29 previously published or unpublished records (Moreno, 1895; Goodall & Galeazzi, 1986; Lichter, 1986; Goodall et al., 1988, 2008; Mead, 1989; Grandi et al., 2005; Reyes, 2006), including one specimen re-identified through DNA analysis and 20 new records (Figure 1). All strandings were of single individuals. A vertebra and a scapula of two unknown Ziphiidae were collected by R. N. P. Goodall at Punta Desengaño and Bahía Medialuna, respectively, in April 1986 (Goodall & Galeazzi, 1986).

Definitive species identification through genetic analysis was completed for seven specimens out of the 10 attempted (Table 1). Additionally, a *M. layardii*, a *Z. cavirostris*, a Gray's beaked whale (*Mesoplodon grayi*), a *M. hectori*, and a southern bottlenose whale (*Hyperoodon planifrons*) specimen were identified morphologically. During the 1998-2023 beach surveys, specimens of five genera and seven species of beaked whales were collected:

1. *Southern bottlenose whale* – Table 2 summarizes the strandings reported for the Santa Cruz Province. Figure 2a shows a typical skull of this species for specimen FCLAHP260116.

2. *Arnoux's beaked whale* – On 17 February 2014, a *Berardius arnuxii* specimen with a decomposition state of 4 was found at 49° 22' S/67° 39' W. The specimen was classified as FCSJBA200214, and the skull, teeth, and tissue were collected (Figure 2b). This is the first record of Arnoux's beaked whale for Santa Cruz Province.

Table 1. Results from the phylogenetic affinity and genetic similarity species identification analyses for Santa Cruz Province specimens collected or identified. *Only a 331 bp sequence fragment was amplified from this bone sample; a larger fragment from a frozen tissue extraction was definitive.

Specimen number	Species ID from DNA surveillance	Bootstrap %	Closest species from BLAST search	BLAST % match
FCSCHP090115 (f2017)	*Hyperoodon planifrons*	94	*Hyperoodon planifrons*	99.75
FCSJBA200214 (f2017)	*Berardius arnuxii*	99	*Berardius arnuxii*	99.76
FCCVZC1004111	*Mesoplodon layardii*	99	*Mesoplodon layardii*	99.75
FCSCZC081012	*Ziphius cavirostris*	100	*Ziphius cavirostris*	100.00
FCSJZC120112	*Z. cavirostris*	100	*Z. cavirostris*	99.51
FCSJXX230117A2 (b2019)	*Z. cavirostris*	99	*Z. cavirostris*	99.05
FCSJXX230117A2 (b2019)	*Z. cavirostris*	100	*Z. cavirostris*	99.29
FCSJXX230117A2 (dt2017))	*Z. cavirostris*	100	*Z. cavirostris*	99.06
FCSCXX2001153 (b2019)	Not resolved	--	*Mesoplodon mirus*	77.94*
FCSCXX200115 (f2017)	*M. layardii*	99	*M. layardii*	99.26

Notes: FCCVZC100411 was originally used before determining the species genetically. The new code is FCCVML100411. In Hevia et al. (2012), (SC/63/SM3) was identified as FCCVZC100411.

FCSJXX230117A (b2019) was originally used before determining the species genetically. The new code is FCSJZC230117A. Also note that all three are (1) the same individual but have different tissues (bone: [b2019] & dried tissue: [dt2017]) and (2) same individual, same tissue, but with different PCR product for sequencing (1st and 2nd FCSJXX230117A [b2019]).

FCSCXX200115 (b2019) was originally used before determining the species genetically. The new code is FCSCML200115. Further note that both are the same individual but different tissues (bone: [b2019] & frozen tissue [f2017]).

3. *Hector's beaked whale* – On 25 February 2023, a 368-cm-long male *Mesoplodon hectori* with an E3 state of decomposition was found at 49º 21' S/67º 37' W by park rangers from the Makenke Marine Interjurisdictional Park. The specimen was recovered and classified as FCSJMH250223. Photographs of the specimen were taken (Figure 2c), and samples of teeth, tissue, and the complete skeleton were obtained. Only the left side of the animal could be observed and described. Morphologically, it was observed that compared to other beaked whales, it had a small head with a slight melon and a medium sized-beak. It had a dark black eye patch, and a dark grey to black beak and front of melon. The tip of the left lower jaw was dark grey to black as were the upper sides up to the middle of the left jaw, with the rest being light grey to white extending to the beginning of both small, narrow, and dark grey flippers. It had a pale neck-sides. The triangular teeth located just behind the tip of the mandible were only recently recovered after the cleaning of the skull. This is the first record of this species for Santa Cruz Province.

4. *Strap-toothed beaked whale* – Table 3 summarizes records of *Mesoplodon layardii* stranded in Santa Cruz Province. For those strap-toothed beaked whales for which morphometric measures could be obtained (n = 6), the length ranged from 287 to 610 cm. Of the 13 specimens reported in this article, the sex could only be determined in eight (6 females and 2 males). Figure 2d shows the skull of a strap-toothed beaked whale (FCSJML070114).

5. *Gray's beaked whale* – Records of *Mesoplodon grayi* are summarized in Table 4. Figure 2e shows the skull of a Gray's beaked whale stored at the Museo Municipal "Mario Brozoski," Puerto Deseado.

6. *Shepherd's beaked whale* – Table 5 summarizes records of *Tasmacetus shepherdi*. Figure 2f shows the Shepherd's beaked whale (FCBMTS080208) stranded at Mazzarredo.

7. *Cuvier's beaked whale* – Table 6 summarizes the records of *Ziphius cavirostris* from Santa Cruz Province. Lengths for *Z. cavirostris* specimens ranged from 345 to 622 cm. One individual first seen beached and alive in

Table 2. Southern bottlenose whale (*Hyperoodon planifrons*) strandings found in the Santa Cruz Province, southern Patagonia, Argentina (1895-2023)

#	Date	Location	Sex	Length (cm)	Condition and completeness	Identification	Stranded photograph	Material stored and location	Collector	References
1	--	Ría Santa Cruz	--	--	4/Incomplete	--	--	Left mandible	Museo La Plata	Moreno, 1895
2	1979/1980	Punta Desengaño	--	620	--	--	Yes	--	J. M. Fernández	Goodall & Galeazzi, 1986
3	Dec. 1981	Puerto San Julián	M	700	2/Complete	--	Yes	Photo MACN-BA	M. S. Gerpe, D. H. Rodríguez	Lichter, 1986
4	12 Nov. 1983	Punta Loyola	--	--	4/Broken skull	RNP1080	--	Skull/ Museo Provincial Río Gallegos	R. N. P. Goodall	Goodall & Galeazzi, 1986
5	3 April 1986	Cabo Curioso	--	--	4/Skull and mandibles	RNP1223	Yes	Periotic	R. N. P. Goodall	Goodall & Galeazzi, 1986
6	3 April 1986	Cabo Curioso	--	--	4/Skull and bulla	RNP1226	Yes	Ear bones	R. N. P. Goodall	Goodall & Galeazzi, 1986
7	6 Jan. 2015	Ría Santa Cruz area (50° 07' S/68° 24' W)	F	657	L3/Complete	FCSCHP090115	Yes	Tissue/ Fundación Cethus	Fundación Cethus	This article
8	21 Jan. 2016	Estancia La Angelina (51° 20' S/69° 2' W)	--	--	4/Skull	FCLAHP210116	No	Skull/ Personal collection	Fundación Cethus	This article

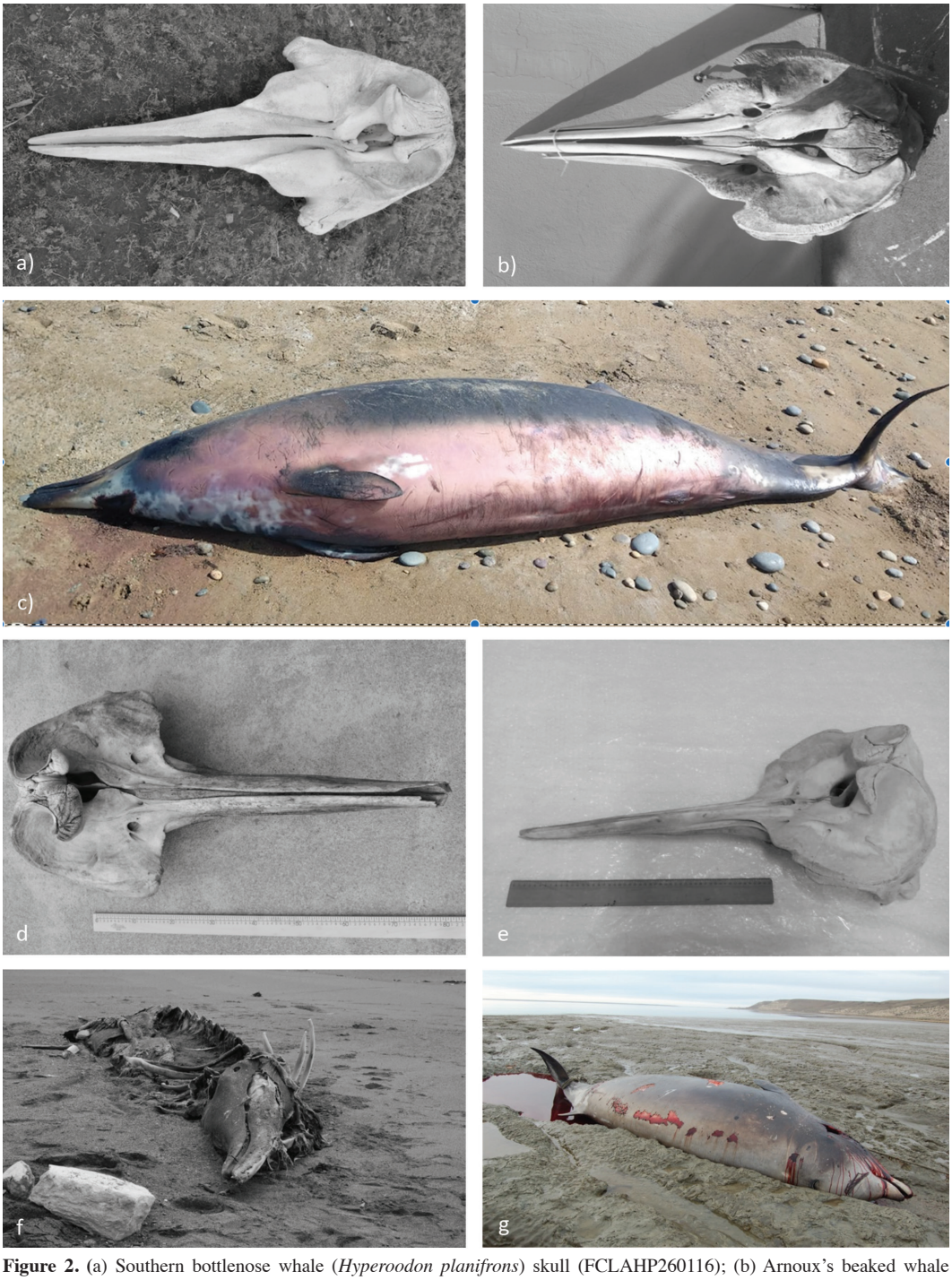

Figure 2. (a) Southern bottlenose whale (*Hyperoodon planifrons*) skull (FCLAHP260116); (b) Arnoux's beaked whale (*Berardius arnuxii*) skull (FCSJBA200214); (c) Hector's beaked whale (*Mesoplodon hectori*) stranded (FCSJMH250223) near Bahía San Julián; (d) strap-toothed whale (*Mesoplodon layardii*) skull (FCSJML070114); (e) Gray's beaked whale (*Mesoplodon grayi*) skull (Museo Municipal "Mario Brozoski," Puerto Deseado); (f) shepherd's beaked whale (*Tasmacetus shepherdi*; FCBMTS080208) stranded at Mazzarredo; and (g) Cuvier's beaked whale (*Ziphius cavirostris*; FCSCZC081012) stranded at Ría Santa Cruz.

Table 3. Strap-toothed whale (*Mesoplodon layardii*) strandings found in the Santa Cruz Province, southern Patagonia, Argentina (1895-2023)

#	Date	Location	Sex	Length (cm)	Condition and completeness	Identification	Stranded photograph	Material stored and location	Collector	References
1	March 1972	Punta Loyola	F	--	--	USNM484891	Yes	Photo MACN-BA	--	Lichter, 1986; Mead, 1989
2	July 1982	Cabo Vírgenes	F	549	4/Incomplete	RNP 1075	Yes	Skull/ Museo Acatushún	R. N. P. Goodall	Goodall & Galeazzi, 1986; Goodall et al., 1988, 2008
3	13 Nov. 1983	Cañadón Palos 51° 29' S/68° 58' W	--	--	4/Incomplete	RNP1089	--	Three vertebrae/ Museo Acatushún	R. N. P. Goodall	Goodall et al., 1988, 2008
4	4 April 1986	Punta Desengaño S 49° 20' S/67° 36' W	M	--	4/Incomplete	RNP1231	--	Skull and ear bones/ Museo Acatushún	R. N. P. Goodall	Goodall et al., 1988, 2008
5	4 April 1986	Punta Desengaño S 49° 19' S/67° 36' W	--	--	4/Incomplete	RNP1232	--	Incomplete skull/ Museo Acatushún	R. N. P. Goodall	Goodall et al., 1988, 2008
6	April 1986	Bahía Media Luna 50° 45' S/69° 07' W	--	--	4/Incomplete	RNP1241	--	Three fused cervicals and one thoracic/ Museo Acatushún	R. N. P. Goodall	Goodall et al., 1988, 2008
7	7 April 1986	Cabo Buen Tiempo 51° 35' S/68° 58' W	--	--	4/Incomplete	RNP1258	--	Lumbar vertebra/ Museo Acatushún	R. N. P. Goodall	Goodall et al., 1988, 2008
8	Feb. 1998	Ría Santa Cruz area (50° 07' S/68° 24' W)	M	526	E3/Complete	FCSCML120298	Yes	Complete/ Museo Regional Carlos Borgialli	Fundación Cethus	This article
9	14 Jan. 2007	Bahía San Julián area (49° 22' S/67° 38'W)	F	414	4/Incomplete	FCSJML250107	Yes	Tissue	Fundación Cethus	This article
10	11 Feb. 2011	Caleta Olivia	F	510	--	FCCOML110211	Yes	--	C. Berenguel	This article
11	8 April 2011	Cabo Vírgenes area (52° 18' S/68° 21' W)	F	287	E3/Complete	FCCVML100411 (previously in Hevia et al., 2012 [SC/63/SM3], as FCCVZC100411)	Yes	Tissue (Fundación Cethus) and skull (Cabo Virgenes Protected Area)	Fundación Cethus	This article
12	7 Jan. 2014	Bahía San Julián area (49° 20' S/67° 37' W)	F	610	L3/Complete	FCSJML070114	Yes	Tissue and skull/ Fundación Cethus	Fundación Cethus	This article
13	20 Jan. 2015	Ría Santa Cruz area (50° 07' S/68° 19' W)	--	--	4/Skull	FCSCML200115	Yes	Tissue and skull/ Fundación Cethus	Fundación Cethus	This article

Table 4. Gray's beaked whale (*Mesoplodon grayi*) strandings found in the Santa Cruz Province, southern Patagonia, Argentina (1895-2023)

#	Date	Location	Sex	Length (cm)	Condition and completeness	Identification	Stranded photograph	Material stored and location	Collector	References
1	2 April 1986	Cerro Trapecio	--	--	4/Skull	RNP1222	--	Skull/Museo Acatushún	R. N. P. Goodall	Goodall & Galeazzi, 1986; Goodall et al., 2008
2	7 April 1986	Cabo Buen Tiempo	--	--	4/Lumbar vertebrae	RNP1258	--	Vertebrae/ Museo Acatushún	R. N. P. Goodall	Goodall & Galeazzi, 1986; Goodall et al., 2008
3	1 Nov. 1988	Ría Deseado	F	440	4/Complete carcass	FCPDMG011188	--	None	M. Oliva Day	This article
4	12 April 1992	46° 06' S/67° 37' W	--	--	--	--	--	--/Museo of Caleta Olivia	L. Reyes	Reyes, 2006
5	Before 1994	--	--	--	4/--	--	Yes	Postcranial/--	R. N. P. Goodall	Goodall et al., 2008
6	Before 1994	--	--	--	4/--	--	Yes	Postcranial/--	R. N. P. Goodall	Goodall et al., 2008
7	--	Mazzaredo	--	--	4/Skull	--	No	Skull/Museo Municipal "Mario Brozoski," Puerto Deseado	Museo Municipal "Mario Brozoski"	This article

Table 5. Shepherd's beaked whale (*Tasmacetus shepherdi*) strandings found in the Santa Cruz Province, southern Patagonia, Argentina (1895-2023)

#	Date	Location	Sex	Length (cm)	Condition and completeness	Identification	Stranded photograph	Material stored and location	Collector	References
1	6 April 1986	Bahía Media Luna	--	--	4/Skull	RNP1244	--	Skull/Museo Acatushún	R. N. P. Goodall	Goodall & Baker, 1988; Goodall et al., 2008
2	Sept. 2003	Parque Nacional Monte León (50° 09' S/68° 21' W)	M	660	L3/ Complete	Collection number pending	Yes	Skeleton/Monte León National Park	CENPAT	Grandi et al., 2005
3	10 Aug. 2007	Bahía Mazzaredo (47° 02' S/66° 36' W)	M	657	L3/ Incomplete	FCBMTS080208	Yes	1 tooth and tissue/ Fundación Cethus	Fundación Cethus	This article

Table 6. Cuvier's beaked whale (*Ziphius cavirostris*) strandings found in the Santa Cruz Province, southern Patagonia, Argentina (1895-2023)

#	Date	Location	Sex	Length (cm)	Condition and completeness	Identification	Stranded photograph	Material stored and location	Collector	References
1	June 1972	Ea Punta Loyola	M	--	4/ Incomplete	MACN-BA16198	--	Skull/Museo Argentino de Ciencias Naturales	MACN-BA	Lichter, 1986
2	13 Nov. 1983	Cañadón Palos	--	--	4/ Incomplete skull	RNP1092	--	Incomplete skull/ Museo Provincial Río Gallegos	R. N. P. Goodall	Goodall & Galeazzi, 1986; Goodall et al., 2008
3	13 Nov. 1983	Cañadón Palos	--	--	4/Rostrum	RNP1093	--	Rostrum/ Museo Provincial Río Gallegos	R. N. P. Goodall	Goodall & Galeazzi, 1986; Goodall et al., 2008
4	Jan. 1985	Puerto San Julián	M	400	--	--	Yes	Photo MACN-BA	J. M. Fernández	Goodall & Galeazzi, 1986; Lichter, 1986; Goodall et al., 2008
5	Jan. 1985	Puerto San Julián	--	--	4/--	--	--	--	--	Goodall & Galeazzi, 1986; Goodall et al., 2008
6	3 April 1986	Cabo Curioso	--	--	4/Skull	RNP1224	Yes	Skull/ Museo Acatushún	--	Goodall & Galeazzi, 1986; Goodall et al., 2008
7	4 April 1986	Puerto San Julián	F	--	4/Mandibles	RNP1229	--	Mandibles/ Museo Acatushún	R. N. P. Goodall	Goodall & Galeazzi, 1986; Goodall et al., 2008
8	1 Jan. 1989	Ría Deseado area (47° 45' S/65° 53' W)	--	--	4/Incomplete	FCPDZC010189	--	Incomplete skull	Fundación Cethus	This article
9	7 May 2005	Punta Loyola (51° 36' S/69° 00' W)	F	622	E3/Complete	FCPLZC100505	Yes	None	Fundación Cethus	This article
10	20 Feb. 2010	Cabo Vírgenes area (52° 20' S/68° 21' W)	M	578	L3/Complete	FCCVZC200210	Yes	Tissue (Fundación Cethus) and skull (Cabo Virgenes Protected Area)	Fundación Cethus	This article
11	12 Jan. 2012	Bahía San Julián area (48° 56' S/67° 28' W)	F	345	L3/Complete	FCSJZC120112	Yes	Tissue and skull/ Fundación Cethus	Fundación Cethus	This article
12	8 Oct. 2012	Ría Santa Cruz area (50° 09' S/68° 35' W)	F	558	2/Complete	FCSCZC081012	Yes	Tissue and skull/ Fundación Cethus	Fundación Cethus	This article
13	23 Jan. 2017	Bahía San Julián area (49° 24' S/67° 40' W)	--	588	4/Complete	FCSJZC230117	Yes	Tissue and skull/ Fundación Cethus	Fundación Cethus	This article
14	16 Jan. 2018	Bahía San Julián area (48° 51' S/67° 16' W)	--	--	4/Skull	FCSJZC160118	No	Skull/Fundación Cethus	Fundación Cethus	This article

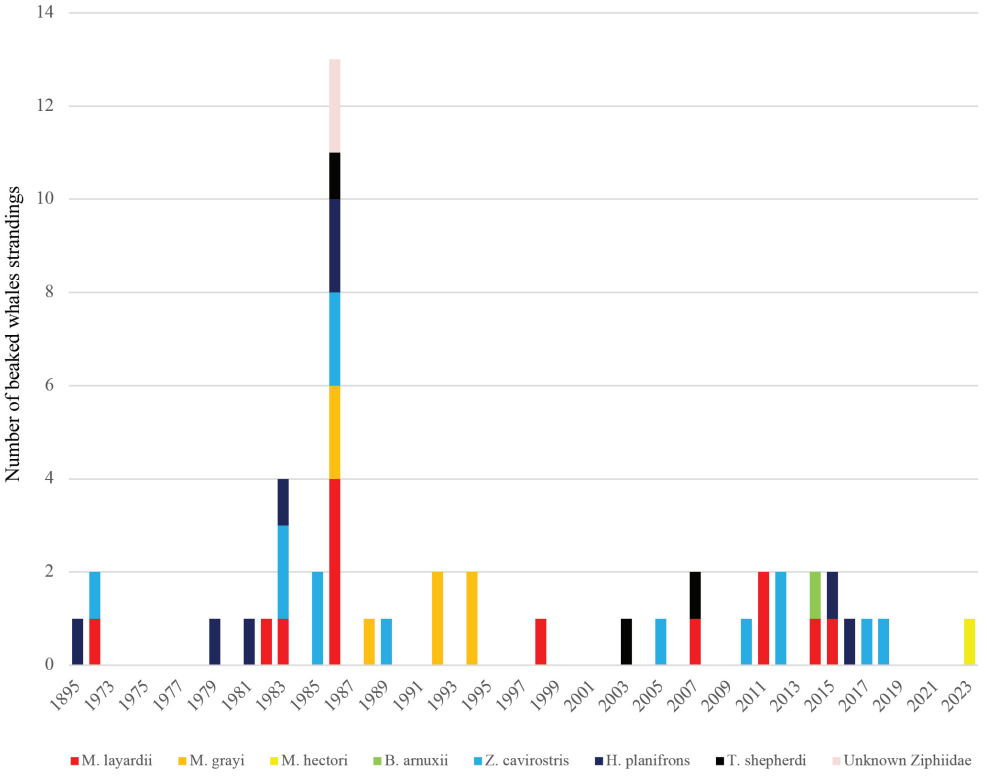

Figure 3. Number of beaked whale strandings by species per year

Ría Santa Cruz was rescued and released by the Prefectura Naval Argentina (Coast Guard), but the following day the individual beached again and died (Figure 2g). This individual was classified as FCSCZC081012, and its state of decomposition was 2. The beak was short and white with the upturned mouthline typical of Cuvier's beaked whale. The melon was prominent and pale grey; the left eye was surrounded by darker coloration; and its teeth were concealed by the gums. The body colour was brown except for a pale area that extended on the upper side as far back as the dorsal fin. The left flipper was small and dark, and oval white scarring was also present. A 622-cm female had two upper and two lower beaks of a long-armed octopus squid (*Moroteuthopis longimana*) in its stomach. Of the 14 specimens reported, the sex could only be determined in seven of them (4 females and 3 males).

Figure 3 shows the number of beaked whale strandings by species per year between 1895 and 2023. The peak of stranded specimens corresponds to the year 1986 with 13 records.

Discussion

Species Identified in Santa Cruz Province and Previously Known Distributions

Southern Bottlenose Whale—The southern bottlenose whale has a circumpolar distribution throughout the Southern Hemisphere, with strandings as far north as 20° S in Northwestern Australia (MacLeod et al., 2006; Lowry & Brownell, 2020). Most at-sea records are from 57° to 70° S, but this might be due to higher research effort at these latitudes (MacLeod et al., 2006). The southern bottlenose whale appears to be one of the most abundant beaked whales and, indeed, one of the most abundant cetacean species in Antarctic waters (Kasamatsu & Joyce, 1995). At least in summer, they occur mostly in Antarctic waters south of the Antarctic Convergence (Kasamatsu & Joyce, 1995). Although wintering areas are not known, there is some evidence of winter movements to southern Africa from

higher latitudes (Sekiguchi et al., 1993). For the Southwest Atlantic, there are records of strandings in Argentina, Antarctica, and the South Atlantic Islands (including Islas Malvinas [Falkland Islands] and Islas Georgias del Sur [South Georgia Islands]); as well as sightings in the vicinity of Islas Malvinas (Falkland Islands), Islas Shetland del Sur (South Shetland Islands), Islas Georgias del Sur (South Georgia Islands), Islas Orcadas del Sur (South Orkney Islands), and Drake Passage, and also from 44° to 45° S east of the continental shelf (Goodall, 1978; Bastida & Bastida, 1984; Lichter, 1986; White et al., 2002; Goodall et al., 2008; Otley et al., 2011; Scheidat et al., 2011; Santora & Veit, 2013). There were six previous stranding records of *H. planifrons* from Santa Cruz Province (Moreno, 1895; Goodall & Galeazzi, 1986; Lichter, 1986). Two more records are added by this study, including a female with a total length of 657 cm, which was found at Ría Santa Cruz. These whales are thought to be able to make movements of up to approximately 1,000 km, but it is not known whether such movements would be part of a sustained pattern (Gowans, 2008).

Arnoux's Beaked Whale—This species has been recorded throughout the cold waters of the Southern Hemisphere, with strandings as far north as southern Brazil (24° S) (MacLeod & Mitchell, 2006; Brownell & Taylor, 2021). The northern limit of Arnoux's beaked whale is unclear throughout much of its range, but most records are from latitudes south of approximately 40° S based on sightings; the southern limit for this species is the ice edge and the continental shore of Antarctica (MacLeod et al., 2006). For Argentina, its presence has been reported mainly through strandings in Buenos Aires, Chubut, and Tierra del Fuego Provinces (Marelli, 1920; Bastida & Bastida, 1984; Lichter, 1986; Goodall et al., 2008; Otley, 2012; Zuazquita et al., 2016). For the Islas Malvinas (Falkland Islands), it is considered an occasional species (Otley et al., 2011). This study reports the first record of Arnoux's beaked whale for Santa Cruz Province.

Hector's Beaked Whale—Hector's beaked whale occurs in cool-temperate waters of the Southern Hemisphere (Mead, 1989; MacLeod et al., 2006; Van Waerebeek et al., 2010; Pitman & Brownell, 2020a). An individual from southern Brazil (32° S) is considered to be extralimital (Zerbini & Secchi, 2001). There are less than 20 records for the Southwest Atlantic (Fraser, 1950; Hamilton, 1952; Lichter, 1986; Goodall & Lichter, 1988; Cappozzo et al., 2005; Otley et al., 2011). This study reports a 368-cm male being the first record of this species for Santa Cruz Province.

Strap-Toothed Whale—The strap-toothed whale is endemic to cold-temperate waters of the Southern Hemisphere and has a broadly circumpolar distribution (MacLeod & Mitchell, 2006; MacLeod et al., 2006; Pitman & Brownell, 2020b). With the exception of specimens from Western Australia, all other records are south of 32° S (MacLeod et al., 2006). It is possible that some older osteological records previously identified as strap-toothed whales are actually the recently redescribed spade-toothed whale (*Mesoplodon traversii*), which is morphologically similar (van Helden et al., 2002) and apparently circumpolar in the southern oceans but with distributional details almost completely unknown (MacLeod et al., 2006). For the Southwest Atlantic, 53 strandings have been reported in Argentina and the South Atlantic Islands (including Islas Malvinas [Falkland Islands] and Islas Georgias del Sur [South Georgia Islands]; Lichter, 1986; Bordino & González, 1992; Fraga, 1994; Goodall et al., 2008; Otley et al., 2011). This study adds six new stranding records to the seven *M. layardii* individuals reported previously for Santa Cruz Province (Lichter, 1986; Goodall et al., 1988, 2008; Mead, 1989). Of the total strandings, 20% were male, 43% were female, and 37% were of unknown sex, so we are unable to say there is sex bias. This was the second most frequently found beaked whale species stranded along the Santa Cruz Province in the last 20 years. The shortest strap-toothed whale calf reported in the literature was 280 cm long (Mead, 1984). The 287-cm female strap-toothed whale specimen presented in this study can therefore be considered a calf. This animal was found just 32 km north of Tierra del Fuego, supporting the hypothesis that some ziphiid species (at least Cuvier's, Hector's, and Gray's beaked whales and strap-toothed whales) reproduce in the waters off the southernmost tip of South America (Goodall et al., 2008) or use shallower inshore waters for reproduction (Otley, 2012)—observations that should be further investigated.

Gray's Beaked Whale—*Mesoplodon grayi* is widely distributed in cool-temperate waters of the Southern Hemisphere, mainly between 30° and 45° S. In summer months, it has been seen close to the Antarctic Peninsula and other Antarctic coastlines (MacLeod et al., 2006; Reyes Reyes & Iñíguez, 2013; Pitman & Taylor, 2020). Along the eastern coast of South America, Gray's beaked whale has stranded from the far south of Brazil (31.8° S; Pinedo et al., 2001) to Tierra del Fuego (53.3° S; Goodall, 1978). There were five records of Gray's beaked whale previously reported from Santa Cruz Province (Goodall & Galeazzi, 1986; Reyes, 2006; Goodall et al., 2008); this study provides two new records for this species.

Shepherd's Beaked Whale—Tasmacetus shepherdi is known only from a small number of strandings and a few probable or possible sightings at sea, and apparently has a circumpolar distribution in cold waters between 30° to 46° S of the Southern Hemisphere (MacLeod & Mitchell, 2006; MacLeod et al., 2006; Braulik, 2018). In southern Australian and New Zealand waters, Shepherd's beaked whales are found in areas that seasonally experience enhanced productivity and are associated with waters of the mid to upper continental slope and/or submarine canyons (Donnelly et al., 2018). For the Southwest Atlantic, there are records of strandings for central and southern Argentina, Islas Malvinas (Falkland Islands), and Islas Georgias del Sur (South Georgia Islands) (Mead & Payne, 1975; Goodall, 1978; Lichter, 1986; Grandi et al., 2005; Pitman et al., 2006). Two records of *T. shepherdi* from the Santa Cruz Province were reported previously (Goodall & Baker, 1988; Grandi et al., 2005; Goodall et al., 2008); this study provides a new record for this species.

Cuvier's Beaked Whale—Ziphius cavirostris is the most widely distributed beaked whale, with a cosmopolitan distribution throughout almost all temperate, subtropical, and tropical waters of the world as well as subpolar and even polar waters in some areas (MacLeod & Mitchell, 2006; MacLeod et al., 2006; Baird et al., 2020). The species has been recorded around Tierra del Fuego and Islas Malvinas (Falkland Islands), mainly through stranding records (Goodall, 1978; Bastida & Rodríguez, 2003; Goodall et al., 2008; Otley et al., 2011; Wojtek & Norman, 2013; Vilches et al., 2018). On the mainland, five strandings were recorded between 41° to 42° S in Río Negro and Chubut Provinces—in most cases, these were adult females and one adult male (Cáceres-Saez et al., 2019). This study adds seven new records to the seven previous strandings registered for Santa Cruz Province (Goodall & Galeazzi, 1986; Lichter, 1986; Goodall et al., 2008). For the Southwest Atlantic, 66 strandings of *Z. cavirostris* have been recorded (Lichter, 1986; Goodall et al., 2008; Otley et al., 2011; Vilches et al., 2018; Cáceres-Saez et al., 2019; this article) of which 40% were females and 30% were males. However, due to the high number of unsexed specimens (30%), sex bias cannot be assumed. The stomach contents of a Cuvier's beaked whale specimen (FCPLZC100505) from Santa Cruz Province contained long-armed octopus squid, which is an Antarctic/sub-Antarctic circumpolar squid (Seco et al., 2016; Xavier & Cherel, 2021); this squid was also found in the diet of southern bottlenose whales (Clarke & Goodall, 1994). This may suggest a seasonal movement between the Antarctic/sub-Antarctic and southern Patagonia.

New Insights into Distribution of Beaked Whales in Southern Patagonia

The small amount of information available for most beaked whale species has come mainly from stranded individuals or from a few sightings. Many aspects of their behavior and life history make beaked whales particularly cryptic, including long dive times, short surface durations, and inconspicuous behavior when at the surface (Barlow et al., 2006; Barlow, 2015). The fact that they live in deep waters (and usually far from shore) makes it even more difficult to obtain information (MacLeod, 2000; Baird, 2019). The results presented herein provide new information from southern Patagonia, including 20 new records of beaked whales known to have stranded in Santa Cruz Province from 1895 to 2023, and the first records of an Arnoux's beaked whale and Hector's beaked whale for the province.

For Tierra del Fuego waters, the most frequently stranded species of beaked whales was Cuvier's beaked whale, followed by Gray's beaked whale and strap-toothed whale (Goodall et al., 2008); while for Islas Malvinas (Falkland Islands) waters (located approximately 460 km east of Santa Cruz Province), the most frequent species recorded was the strap-toothed whale (Otley et al., 2011). The species most frequently found stranded in the Santa Cruz Province was Cuvier's beaked whale, closely followed by strap-toothed whale, showing similarities to what was found for both Tierra del Fuego and Islas Malvinas (Falkland Islands).

Sighting records of cetaceans observed in the deep-water sectors to the south, east, and north of Islas Malvinas (Falkland Islands) (White et al., 2002) were found in areas influenced by the Malvinas Current, which flows northward along the continental slope of Argentina (Piola & Matano, 2017). Given the direction of that current, whale carcasses are likely to be lost in deep waters rather than carried toward the coastal mainland. In this regard, the number of individuals found stranded along the coast of Santa Cruz, Tierra del Fuego, and Islas Malvinas (Falkland Islands) could be only a fraction of the ones that die in this area. The removal of even a few individuals from such small populations could have significant negative effects on their conservation status and on the genetic and ecological diversity to which they contribute.

Climate Change

The influences that water bodies, boundaries, and temperature regimes exert on the distribution of cetaceans has long been recognized (e.g., Gaskin, 1982). Ocean warming and changing sea surface temperatures (SST) are thus likely

to have concomitant effects on cetacean distributions. In the Southern Hemisphere, ocean warming is predicted across all latitudes, with the greatest warming between 40° and 60° S by the end of the 21st century (Tulloch et al., 2019). Simmonds (2016) suggested that species with restricted habitats, where there is little opportunity to disperse to new similar habitat areas, may be particularly affected. For example, it has been suggested that beaked whales which rely on deep sea trenches for foraging might be unable to adapt to changes in conditions such as temperature increases or reduction of prey. Deep diving beaked whales may be of particular importance for vertical nutrient cycling within such ecosystems.

Recent studies have shown that strong El Niño events (1972/1973, 1982/1983, 1997/1998, and 2015/2016) may lead to a marked decrease in population growth of southern right whales due to a reduction in prey abundance (krill [*Euphasia superba*]) as a consequence of ocean warming (Agrelo et al., 2021). Similar situations could occur with beaked whales; and, in particular, authors note this potential for *Z. cavirostris* and *H. planifrons*, considering that one of their preferred cephalopod prey species, the long-armed octopus squid, feeds on krill in addition to fish, crustaceans, and other invertebrates (Barratt & Allcock, 2014). For cooler water cetacean species such as the northern bottlenose whale (*Hyperoodon ampullatus*), increased sea temperatures will lead to a contraction in their range (Lambert et al., 2014). For the Islas Malvinas (Falkland Islands) region, an increase in the number of records of warmer than normal sea conditions documented since the 1960s could result in the exclusion of predominantly cold-water species such as Arnoux's beaked whales, while attracting cool-temperature species such as Andrew's and Gray's beaked whales (Otley et al., 2011). For the Patagonian shelf region, two areas of statistically significant trends of sea surface temperature anomalies were found: (1) a warming area delimited between 42° and 45° S (northern Patagonian shelf [NPS]) with a warming rate increase of 0.52°C, and (2) a cooling area between 49° and 52° S (southern Patagonian shelf [SPS]) with a cooling rate increase of 0.42°C between 1982 and 2017 (Risaro et al., 2022). This could explain the presence of Arnoux's beaked whale and the absence of *M. grayi* since the mid-1990s. At the moment, however, there are no known studies that demonstrate the effects that climate change could have on beaked whales in the Southwest Atlantic; thus, further studies are urgently needed.

Conclusions

Important Beaked Whale Areas—MacLeod & Mitchell (2006) proposed 23 known key areas worldwide for beaked whales. One of these areas is the Islas Malvinas (Falkland Islands)/Tierra del Fuego region which includes Tierra del Fuego and the coast of South America from 48.5° to 59.5° S east to 54.50° W. This area was designated using 61 records that incorporate sightings and strandings (Goodall, 1978; White et al., 2002), with eight species of beaked whale of five genera, giving it a high diversity of species. Subsequent studies conducted for Tierra del Fuego (Goodall et al., 2008) and for the Islas Malvinas (Falkland Islands) (Otley et al., 2011; Otley, 2012) reaffirmed the importance of the southern sector of the South American coast for these species. This suggests that systematic studies on these species should be carried out to determine if there are specific areas of importance to them where mitigation and conservation measures should be implemented. Passive acoustic monitoring (PAM) has been shown to offer an efficient alternative to detect cryptic species such as beaked whales since they are difficult to see but have characteristic and distinctive acoustic signals (e.g., Baumann-Pickering et al., 2013, 2014; Trickey et al., 2015). Environmental DNA (eDNA) is another potential new tool that is being used for detecting whales, even in coastal ocean environments (e.g., Baker et al., 2018; Alter et al., 2022), and might be used in conjunction with acoustic monitoring.

Stranding and Sighting Networks—It is also essential to continue strengthening and expanding cetacean stranding and rescue networks as highlighted in one of the recommendations arising from the Fifth International Congress of Marine Mammals Protected Areas (Spring et al., 2019). This recommendation emphasized performing a variety of pathology examinations of stranded cetaceans, especially of beaked whales and any atypical strandings.

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