


MARINE RECORD

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The first record of a Longman's beaked whale (*Indopacetus pacificus*) newborn neonate found on Miyako Island, Okinawa, Japan

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Abstract

The Longman's beaked whale (*Indopacetus pacificus*) is one of the rarest cetaceans worldwide. Since it was first described as its own species in 1926, they have been observed alive at sea on several occasions, and less than 20 strandings have been reported worldwide to date. Thus, basic information regarding this species, such as the maximum size of adult individuals or body length at birth, remains unknown. In this study, the external appearance and DNA analysis of a female Longman's beaked whale stranded on Miyako Island, Okinawa, Japan, are reported. The external appearance of the specimen matched the features of the Longman's beaked whale presented in previous studies. The mitochondrial DNA control-region sequences obtained from the specimen also matched the reference sequences of the species deposited in GenBank. Based on these features, the specimen was confirmed as a Longman's beaked whale. The specimen was estimated to be neonate because of its body length (235 cm) and the clear several fetal folds observed on its body surface. To the best of our knowledge, this is the first report of a confirmed new born neonate of Longman's beaked whale in the world.

Keywords: External appearance, Fetal folds, Fetal lines, Genetic analysis, *Indopacetus pacificus*, Longman's beaked whale, Miyako Island, Neonate, Stranding, Okinawa

Introduction

The Longman's beaked whale (*Indopacetus pacificus*), also known as the Indo-Pacific beaked whale or tropical bottlenose whale, is considered one of the rarest cetacean species worldwide. The first specimen was found in Queensland, Australia. Longman (1926) described it as a member of the genus *Mesoplodon* based on the skull characters of the specimen. Then, Moore (Moore 1968; Moore 1972) elevated it as its own genus *Indopacetus* in later years, based on the discovery of the second skull in

Somalia (Azzaroli 1968). Dalebout et al. (2003) first reported on the external appearance, osteological analysis, and DNA analysis of this species. In recent years, Longman's beaked whale are generally found in deep pelagic waters in tropical and subtropical regions of the Indian and Pacific oceans (Pitman et al. 1999; Pitman 2009). In the western North Pacific, few sighting records for this species exist in Japanese waters (Ministry of Agriculture, Forestry and Fisheries: <https://www.jfa.maff.go.jp/j/sigen/20170321redlist.html>), though detailed information is not known. Even though the sighting information is increasing in recent years, the total number of strandings reported for this species is less than 20 cases worldwide. Therefore, the basic information for this species, such as

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the maximum, minimum, and average body lengths, are still not certain.

To date, there are 17 cases (with 24 animals) of strandings for Longman's beaked whales confirmed worldwide, all of which were in the Indian or Pacific Ocean (Yamada et al. 2012; Acebes et al. 2019). Most of the strandings were reported as single animals, while there were two exceptions of a mother and calf pair in Taiwan in 2005 (Yao et al. 2012), and seven animals were stranded at once in New Caledonia in 2013 (Garrigue et al. 2016). Within the reported stranding records, the body length for adult females ranged between 565 and 648 cm, and the average size was 616 cm. The body lengths of the two adult males found were 590 cm and 608 cm, from New Caledonia (Garrigue et al. 2016) and China (Peng et al. 2009), respectively. The smallest Longman's beaked whale specimen was 291 cm, which was found in South Africa (Ross 1984). This specimen was believed to be a neonate (Dalebout et al. 2003); however, Yao et al. (2012) suggested that this specimen was much larger than the estimated neonatal length of 275 cm, obtained from the average size of the adult Longman's beaked whale female using Ohsumi's (1966) equation. Additionally, there were no fetal folds or fetal lines confirmed or reported for the South African specimen. Fetal folds or fetal lines are known to observe on the body surface of neonate cetaceans for several months after birth. Mann and Smuts (1999) reported that the fetal folds of bottlenose dolphins are pronounced for the first week after birth, but may not be detectable in the second week. In contrast, fetal lines, resulting from the folds, remain for many weeks. Considering these features, the South African specimen is considered to be a neonate which is several months old. Therefore, the body length at birth for this species should be smaller than the South African specimen, and remains unknown (Acebes et al. 2019). Yamada et al. (2012) suggested that records of smaller individuals, which are not currently sufficient, may make it possible to estimate the neonate size of Longman's beaked whale.

In this study, we report a female Longman's beaked whale stranded on Miyako Island, Okinawa, Japan in 2020. The specimen was confirmed as a Longman's beaked whale from the characteristic features of its external appearance, as well as genetic analysis. The proportion of the body length of neonates of species in the family Ziphiidae are also discussed to examine the range of body lengths of Longman's beaked whale neonates. The Miyako specimen was estimated to be a newborn from its body length and the fetal folds on its body surface. To the best of our knowledge, this is the first report providing detailed information on a Longman's beaked whale new born neonate.

Methods

Study site and data collection

An unidentified cetacean carcass was found on a beach on Miyako Island, Okinawa, Japan (24° 43' 08'' N, 125° 19' 33'' E), on 27 July, 2020 (Fig. 1). Photos of the carcass were taken at the study site. Soft tissues specimens were collected from the body surface for genetic analysis and fixed with 100% ethanol at the study site.

Analysis of external appearance

The external appearance of the specimen was examined from the photos taken at the study site. Eleven external measurements were also taken from the photos. These measurements were compared to the values for 11 specimens of Longman's beaked whale found in South Africa, Maldives, Taiwan, Hawaii, New Caledonia, and Okinawa in Japan to compare the external appearance of the Miyako specimen with the characteristic features of the Longman's beaked whale reported in previous studies (Dalebout et al. 2003; Yao et al. 2012; West et al. 2013; Garrigue et al. 2016; Kobayashi et al. 2020).

Genetic analysis

Total genomic DNA was extracted from the soft tissue samples collected from the Miyako specimen using the HotSHOT method (Truett et al. 2000). The mitochondrial DNA control region was amplified using polymerase chain reaction (PCR) with a KOD FX Neo DNA polymerase kit (TOYOBO, Osaka, Japan), using two primers, t-PRO (Árnason et al. 1993) and P2 (Hoelzel et al. 1991). The PCR product was sequenced with an Applied Biosystems 3730xl DNA Analyzer performed by a sequencing service company (Macrogen Japan, Tokyo, Japan).

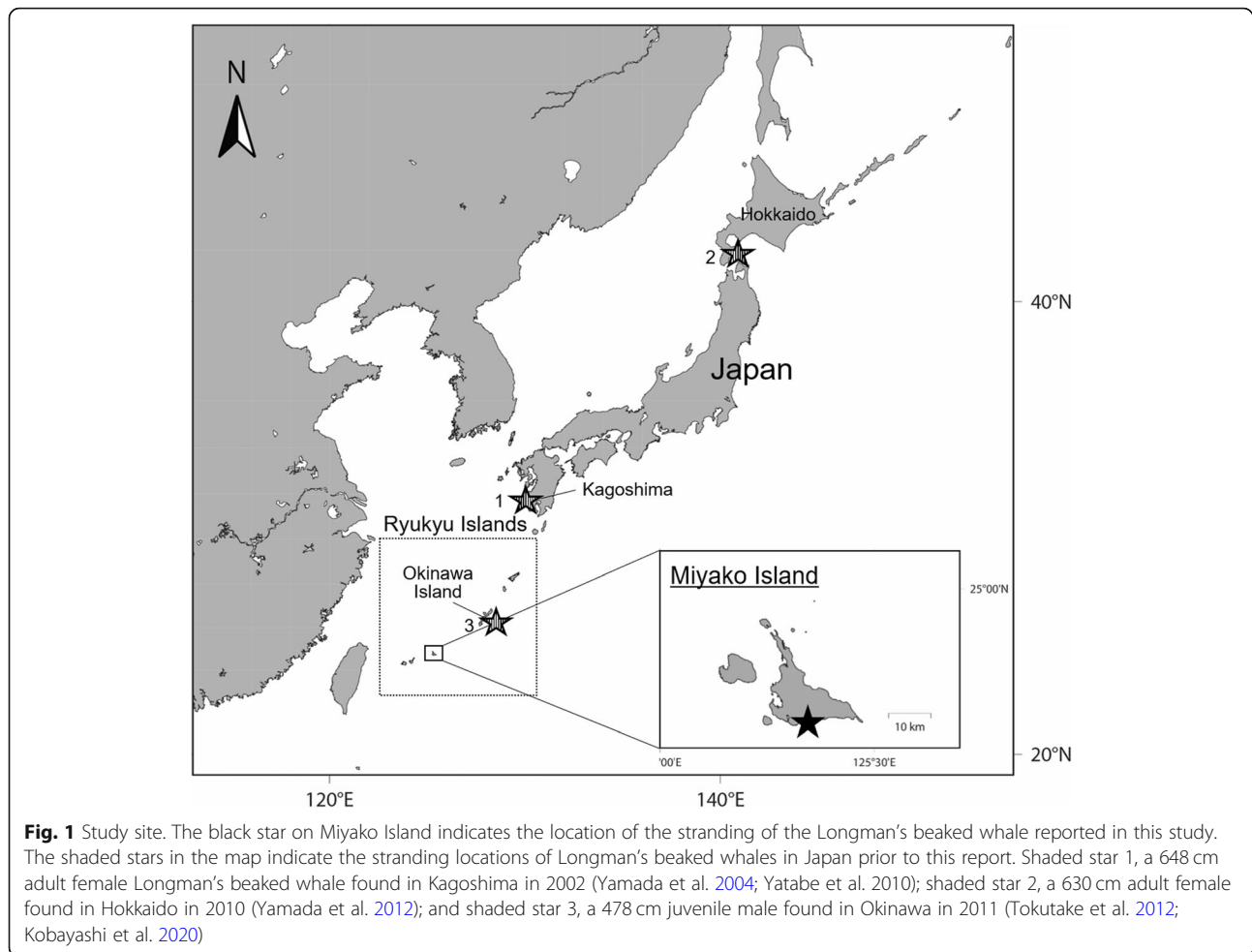
To confirm species identification, the obtained sequence (accession no: LC584181) was compared to the reference sequences of 23 species in the family Ziphiidae submitted to GenBank (Table 1). The phylogenetic relationships were reconstructed with the maximum likelihood (ML) method using MEGA X software (Kumar et al. 2018) with 1000 bootstrap replicates. Following the criterion of Dalebout et al. (2004), the Hasegawa–Kishino–Yano + G + I model (Hasegawa et al. 1985) was selected.

Results

External appearance

External figures

The cetacean stranded on a beach on Miyako Island, Okinawa, Japan was a female specimen with a body length of 235 cm. The carcass condition was determined as a "fresh carcass (code 2)" when it was found. The specimen had a round shaped body (Fig. 2a, b) with a large melon and distinguished long beak (Fig. 3a). The



boundary between the beak and the melon was very clear, with the steep angle of the anterior edge of the melon (Fig. 3a, arrow 1). The lower jaw extended beyond the upper jaw. No teeth were confirmed on the tip of the lower or upper jaw (Fig. 3a). There was a pair of V-shaped grooves on the ventral side of the throat (Fig. 3b, arrows). The pectoral fins were characteristic of ziphiids and relatively small (Fig. 2b, arrow 1). There was no notch confirmed in the middle of its fluke (Fig. 3d, arrow). The dorsal fin was falcate, relatively large, and set far back on the body (Fig. 2b, arrow 2). There were several fetal folds confirmed on the lateral and ventral side of the body surface (Fig. 3e, f, arrows). The umbilicus was not closed (Fig. 2a, arrow 1). The sex of the specimen was confirmed as female from the features of its genital slit (Fig. 2a, a). Most of the external measurements and the proportions of the body length of the Miyako specimen was similar to those of Longman's beaked whales presented in previous studies (Dalebout et al. 2003; Yao et al. 2012; West et al. 2013; Garrigue et al. 2016; Kobayashi et al. 2020). However, the percentages of neither the anterior nor posterior flipper lengths

relative to the body length of the Miyako specimen fell within the range of proportions reported in previous studies, with the values in both cases being higher than those determined for previously examined specimens (Table 2).

Body color

The features of the body color of the Miyako specimen matched the characteristic features of the neonate Longman's beaked whale presented by Dalebout et al. (2003), especially in the following ways: (1) posterior to the eye, the black of the dorsum extended ventrally in a broad band toward the anterior insertion of the pectoral fins, and a dark band of black extended ventrally from the blowhole to join a black patch surrounding the eye (Fig. 3a, c); (2) a small lighter patch was embedded in the area of dark pigmentation posterior to the eye (Fig. 3a, arrow 2); (3) anterior to the blowhole, dark gray pigment extended along the mid-line as far as the apex of the melon, in an antero-lateral streak over the upper half of the melon and anterior to the eye (Fig. 3c); (4) the lower jaw and throat were white (Fig. 3a, b); (5) the outer

Table 1 GenBank accession numbers of 23 species in the family Ziphiidae, including the Miyako specimen, used for comparisons in this study

Species (Ziphiidae)	GenBank accession number (Locality)
<i>Indopacetus pacificus</i>	LC584181 (Okinawa, Japan)
	KY364702 (Taiwan)
	KP892561 (New Caledonia)
	AB572012 (Kagoshima, Japan)
	AY162435 (Australia)
	AY162436 (Somalia)
	AY162437 (Blythesdale Beach, South Africa)
	AY162438 (Sodwana Bay, South Africa)
<i>Mesoplodon bidens</i>	AY162439 (Maldives)
	AY579507
<i>Mesoplodon bowdoini</i>	AY579508
	AY579509
<i>Mesoplodon carlhubbsi</i>	AY579510
	AY579511
<i>Mesoplodon densirostris</i>	AY579512
	AY579513
<i>Mesoplodon europaeus</i>	AY579514
	AY579515
<i>Mesoplodon ginkgodens</i>	AY579516
	AY579517
<i>Mesoplodon grayi</i>	AY579518
	AY579519
<i>Mesoplodon hectori</i>	AY579520
	AY579521
<i>Mesoplodon layardii</i>	AY579522
	AY579523
<i>Mesoplodon mirus</i>	AY579524
	AY579525
<i>Mesoplodon peruvianus</i>	U70465
	AF492413
<i>Mesoplodon stejnegeri</i>	AY579526
	AY579527
<i>Mesoplodon traversii</i>	AY579528
	AF439992
<i>Mesoplodon perrini</i>	AF439994
	AF441256
<i>Mesoplodon hotaula</i>	AF441258
	JX470543
<i>Hyperoodon ampullatus</i>	KF027298
	AF350440
	AF350437

Table 1 GenBank accession numbers of 23 species in the family Ziphiidae, including the Miyako specimen, used for comparisons in this study (*Continued*)

Species (Ziphiidae)	GenBank accession number (Locality)
<i>Hyperoodon planifrons</i>	AF036224
	AY579529
<i>Ziphius cavirostris</i>	AY579530
	AY579531
<i>Tasmacetus shepherdi</i>	AF036226
	AF036227
<i>Berardius arnuxii</i>	AF036229
<i>Berardius bairdii</i>	AY579532
	U70467
<i>Berardius minimus</i>	AY579533
	AB572006
	LC175772

surfaces of the pectoral fins were black (Fig. 3c), while the inner surface was white (Fig. 2a, arrow 2); and (6) on the ventral surface of the flukes, the margins were black, and in the middle third of the trailing edge of the flukes, the dark margin broadened anteriorly as far as the junction of the caudal peduncle and the fluke surface. From the anterior margin of the flukes, numerous fine gray streaks radiated across the white background of the ventral surface as far as the leading edge of the flukes (Fig. 3d). In the case of the Miyako specimen, the skin of the beak tip, anterior side of the melon and some parts of the ventral side of the flukes were already peeled off upon discovery. In addition, the photos of the dorsal fin were unclear. Therefore, the colors of these parts were unclear. The margins of the outer surface of the pectoral fins were black but there were lighter colored patches confirmed in the center of the pectoral fins (Fig. 2b, arrow 1). This feature was also confirmed for the juvenile Longman's beaked whale found in Taiwan (Watson et al. 2008).

From these features, the Miyako specimen is estimated to be Longman's beaked whale. Additionally, considering the fetal folds observed on its body surface, body length, and unclosed umbilicus, it is estimated to be a neonate that became stranded shortly after its birth.

Genetic analysis

The phylogenetic tree (Fig. 4) reconstructed using the mitochondrial DNA control region (435 bp) indicated that the Miyako specimen was placed in a clade with other published Longman's beaked whales. The genetic analysis confirmed the Miyako specimen as a Longman's beaked whale, *Indopacetus pacificus*.



Fig. 2 A neonate female Longman's beaked whale found on Miyako Island, Okinawa, Japan. **(A)** Photo of the ventral view of the body taken on the first day the specimen was found; arrow 1 indicates the unclosed umbilicus; arrow 2 indicates the color of the inner side of the pectoral fin. **(a)** Close up view of the genital slit. **(B)** Photo of the lateral view of the body taken the day after the specimen was found; arrow 1 indicates the color, size, and shape of the outer side of the pectoral fin; arrow 2 indicates the size, shape, and position of the dorsal fin

Discussion

The cetacean carcass stranded on Miyako Island, Okinawa, Japan on July 27, 2020 was confirmed to be a female Longman's beaked whale based on its external appearance and genetic analysis. The specimen is the smallest reported individual of this species to date. Several clear fetal folds observed on its lateral and ventral body surface suggest that the specimen was a neonate, possibly stranded soon after its birth. This report obtained important previously unknown information on the body size of Longman's beaked whale neonates. This report also obtained information on its distribution trend of this species, especially in the waters of the western North Pacific, including Okinawa, Japan.

Yao et al. (2012) estimated the body length of Longman's beaked whale neonates as 275 cm based on Osumi's (Osumi 1966) equation and suggested that the 291-cm South African specimen, which was assumed to be a neonate, was in fact larger than the established neonate size range. The Miyako specimen reported here is much smaller than the estimated size. Therefore, we compared the proportions of both the Miyako and South African specimens with those of neonates in the family Ziphiidae to examine the fitness of the proportion of these two specimens as neonates. The known body length of adult females and neonates of 18 species in the family Ziphiidae are shown in Table 3. The calculated

proportion of the body length of neonates against its adult females are also presented in the table. Then, the proportions of body lengths of neonates were between 25.6 and 53.2% of the body lengths of adult females. The average proportion within the 18 species was 43.0%. For Longman's beaked whale, the proportion of the two neonates ranged between 36.3 and 51.5%, and the average was 43.6%. The proportion for the Miyako specimen ranged between 36.3 and 41.6%, while that for the South African specimen ranged between 44.9 and 51.5% (Table 3). Both of these proportions were well within the range of the proportion for neonates of Ziphiidae species. Considering these results, it is possible to consider from their body lengths that both the Miyako and South African specimens were Longman's beaked whale neonates. However, it was not possible to determine whether the Miyako specimen was alive after its birth. Therefore, there is a possibility that the Miyako specimen was a stillborn calf or premature delivery. Additional samples and information are needed for a more detailed estimation of the body length of Longman's beaked whale neonates.

The specific external measurements for 11 specimens have been reported in previous studies and are presented herein in Table 2. We found that the proportions of both the anterior and posterior flipper lengths for the Miyako specimen were higher than the values determined for all previously reported specimens. Among the

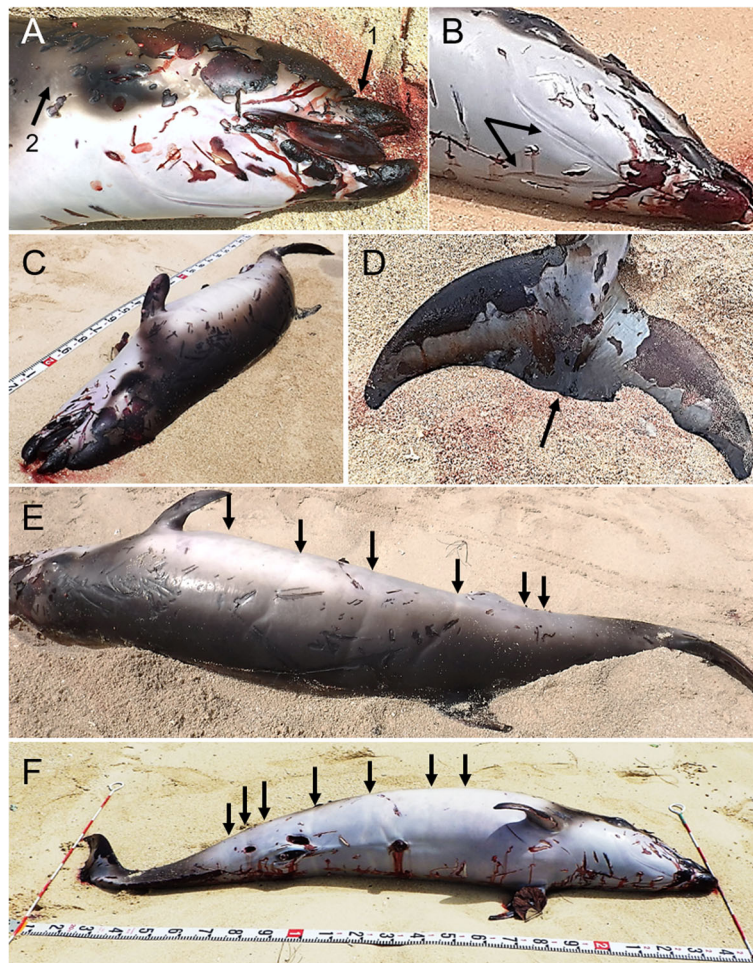
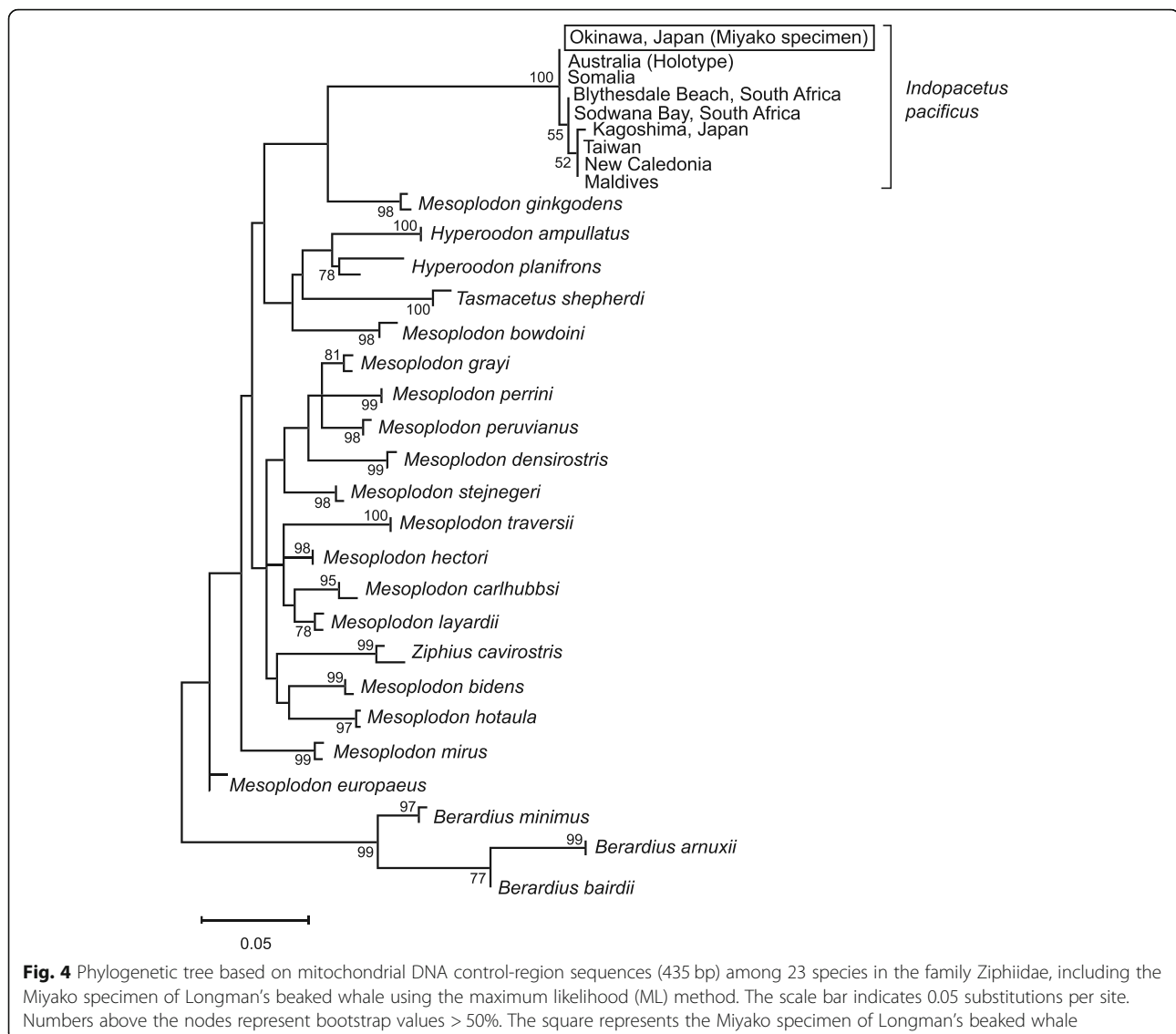


Fig. 3 Female Longman's beaked whale neonate found on Miyako Island. **a** Right lateral side of the head. Arrow 1 indicates the point where the melon and rostrum meet and arrow 2 indicates the point where lighter color patch is confirmed; **b** ventral view of head, with arrows indicating the grooves under the jaw; **c** dorsal view of the body; **d** ventral side of the fluke, with an arrow indicating the flukes with no notch in the middle; **e** dorsal side of the body, with arrows indicating the fetal folds; **f** ventral side of the body, with arrows indicating the fetal folds. Photos **(a)** and **(b)** were taken on the second day of the stranding, and **(c)–(f)** were taken on the first day of the stranding

specimens reported from South Africa, Taiwan, and Okinawa, the proportions of flipper lengths for the smaller specimens were invariably found to be higher than those of larger specimens found in the same area (Table 2). These observations thus indicate that the proportions of flipper lengths relative to body length tend to become smaller as the animal grows, possibly due to the lower growth rate of flipper length compared with that of body length. The finding that the Miyako specimen, which has the smallest body length among all specimens examined to date, has the highest values of proportional flipper lengths among these specimens is consistent with this assumption. However, Yao et al. (2012) noted that some external measurements for the Taiwanese specimens were distinctly longer than those obtained for the South African specimens, which may reflect geographical variation. Accordingly, it is conceivable

that the flipper length proportions determined for the Miyako specimen may be indicative of the geographical variation in this species. However, due to the small number of specimens that have been examined to date, it is difficult to determine whether the observed differences in external characteristics among the specimens are attributable to age-related differences, individual characteristics, or geographical variation. Thus, it will be necessary to determine the external measurements of a larger number of specimens, as well as establish the characteristic features of Longman's beaked whale to enable further analysis of the geographical variation in this species.

In the western North Pacific, 11 specimens in 10 cases of stranding have been confirmed for Longman's beaked whales, including the Miyako specimen in this report (Table 4). Strandings of this species have been observed in different seasons (from January to September) in the



past 18 years. Sea surface temperatures of the waters in this area are well within the range of sea surface temperatures recorded for Longman's beaked whale distribution, at 21–31 °C (Pitman et al. 1999). From these results, it is assumed that Longman's beaked whales are commonly distributed around the waters of the western North Pacific. In Japan, three cases of Longman's beaked whale strandings have been reported prior to the Miyako specimen; the first record was a 648 cm adult female found in Kagoshima in 2002, the second was a 630 cm adult female found in Hokkaido in 2010 (Yamada et al. 2012), and the third was a 478 cm juvenile male found on Ukibaru Island in Okinawa in 2011 (Tokutake et al. 2012; Kobayashi et al. 2020), (Fig. 1). Thus, the Miyako specimen was the second and fourth specimen found in Okinawa and Japan, respectively. It is the most southern

record of this species in Japan. Additionally, this report suggest that there is a possibility that this specimen was birthed in Okinawan waters.

Interestingly, the majority of strandings in the western North Pacific, including around Japan, occurred during the summer (four cases in July) and fall (four cases in September), (Table 4). It is not known whether Longman's beaked whales are distributed in the same area throughout the year or not; however, there is a possibility that they might be distributed in the waters around the area or come closer to the shore in the summer and fall seasons. However, because strandings and sightings of this species in the western North Pacific, especially in Okinawan waters, are limited, detailed information on this species remains unknown. Further surveys, such as boat sighting and acoustic monitoring surveys, for

Table 3 Body lengths of adult females and neonates of 19 out of 23 species of the family of Ziphiidae, including Longman's beaked whale. The proportions of the body length of neonates against the body length of adult females within the 19 species are calculated (%)

Species name	Body length (cm)			Proportion of neonate, NBL*/FBL*2 (%)						Average (%)		Min & Max in the Family (%)		Source
	Adult female		Neonate	Min FBL	Min NBL/Max FBL	Min FBL	Min NBL/Max FBL	Max FBL	Max NBL/Max FBL	Species	Family	Min	Max	
	Min	Max	Min											
Sowerby's Beaked Whale	510	-	240	-	47.1	-	-	-	-	47.1	43.0	25.6	53.2	Jefferson et al. (2015)
Andrews' Beaked Whale	440	-	220	-	50.0	-	-	-	-	50.0	-	-	-	-
Hubb's Beaked Whale	530	540	250	-	47.2	46.3	-	-	-	46.7	-	-	-	-
Blainville's Beaked Whale	470	-	200	250	42.6	-	53.2	-	-	47.9	-	-	-	-
Gervais' Beaked Whale	480	-	210	-	43.8	-	-	-	-	43.8	-	-	-	-
Ginkgo-toothed Beaked Whale	530	-	200	250	37.7	-	47.2	-	-	42.5	-	-	-	-
Gray's Beaked Whale	530	-	210	220	39.6	-	41.5	-	-	40.6	-	-	-	-
Hector's Beaked Whale	430	-	190	200	44.2	-	46.5	-	-	45.3	-	-	-	-
Strap-toothed Beaked Whale	620	-	300	-	48.4	-	-	-	-	48.4	-	-	-	-
True's Beaked Whale	530	540	200	250	37.7	37.0	47.2	46.3	-	42.1	-	-	-	-
Pygmy Beaked Whale	370	390	160	-	43.2	41.0	-	-	-	42.1	-	-	-	-
Stejneger's Beaked Whale	570	-	230	250	40.4	-	43.9	-	-	42.1	-	-	-	-
Northern Bottlenose Whale	860	-	300	350	34.9	-	40.7	-	-	37.8	-	-	-	-
Southern Bottlenose Whale	750	780	200	300	26.7	25.6	40.0	38.5	-	32.7	-	-	-	-
Cuvier's Beaked Whale	850	-	270	-	31.8	-	-	-	-	31.8	-	-	-	-
Shepherd's Beaked Whale	660	-	300	340	45.5	-	51.5	-	-	48.5	-	-	-	-
Arnoux's Beaked Whale	930	-	400	-	43.0	-	-	-	-	43.0	-	-	-	-
Baird's Beaked Whale	1110	-	460	-	41.4	-	-	-	-	41.4	-	-	-	-
Longman's Beaked Whale	565	648	235	291	41.6	36.3	51.5	44.9	43.6	43.6	-	36.3	51.5	Dalebout et al. (2003); Yamada et al. (2004); Yang et al. (2008); Yatabe et al. (2010); This publication

※1NBL:neonate's body length

※2FBL:female's body length

Table 4 Stranding records of Longman's beaked whales confirmed in the western North Pacific to date, including the Miyako specimen in this publication. The locations of Longman's beaked whales stranded in Japan are indicated as stars on the map in Fig. 1

Case #	Date of Stranding	Location	Sex	Age class	Body length (cm)	Specimen ID	Source
1	2002-07-26	Japan	Female	Adult	648	KGA M14	Yamada et al. (2004); Yatabe et al. (2010)
2	2002-09-09	China	Male	Adult	608	–	Peng et al. (2009)
3	2004-01-13	Philippines	Male	Sub adult	573	–	Acebes et al. (2005)
4	2005-07-22	Taiwan	Female	Adult	565	IL 2005-23-1	Yang et al. (2008); Watson et al. (2008)
		Taiwan	Male	Juvenile	420	IL 2005-23-2	
5	2010-09-25	Japan	Female	Adult	630	NSMT36311	Yamada et al. (2012)
6	2011-07-31	Japan	Male	Juvenile	478	OCF-MM20110730	Tokutake et al. (2012); Kobayashi et al. (2020)
7	2016-02-07	Philippines	Male	Sub adult	502	–	Acebes et al. (2019)
8	2018-09-15	Philippines	Male	Sub adult	540	–	
9	2018-09-16	Philippines	Male	Sub adult	560	–	
10	2020-07-27	Japan	Female	Neonate	235	OCF-MM20200727	This publication

Longman's beaked whales around Okinawa are crucial to elucidate the detailed distribution trends, life history, and estimated population of this species.

Conclusion

This paper has provided the first information of a new born neonate of Longman's beaked whale. The study extended our knowledge on the body length at birth for this species which was remain unknown. The neonate of this species found in Okinawan waters also suggests that there is a possibility that Longman's beaked whale give birth around the area. However, the information regarding this species is still very limited especially around the Japanese waters. More information is needed before we can determine the body length at birth for this species, as well as if the area could be a potential breeding area for Longman's beaked whale.

Abbreviations

cm: centimeter; mtDNA: mitochondrial deoxyribonucleic acid; bp: base pair; RNA: ribonucleic acid; PCR: polymerase chain reaction; ML: maximum likelihood method; C: degree Celsius; %: percentage

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Authors' contributions

TK and KI took photographs and collected samples. NK, SO, NH, KT, HO, KM, and KU wrote the manuscript together. All authors have read and approved the final version of the manuscript.

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Availability of data and materials

The dataset supporting the conclusions of this article is included within the article as photographs.

Ethics approval and consent to participate

This study was part of the routine work of the Okinawa Churashima Research Center, Okinawa Churashima Foundation, Okinawa, Japan. For the stranded animal management, relevant approval were issued to Okinawa Churashima Research Center by the Okinawa Prefectural Government.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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