

SKELETAL MEASUREMENTS ON SOME LARGE CETACEAN SPECIES DONE BY SCIENTISTS OF TUMSAT AND ICR

Gen NAKAMURA^{1*}, Ryoko ZENITANI^{1,2†}, Takeharu BANDO², Yoshihiro FUJISE², Ryuuji YAMAMOTO^{1,3}, Futaba NISHIMURA¹, Ayumi HIROSE¹, Yujin KIM¹ and Hidehiro KATO^{1,2}

¹Laboratory of Cetacean Biology, Tokyo University of Marine Science and Technology,
4-5-7 Konan, Minato-ku, Tokyo 108-8477, Japan

²Institute of Cetacean Research, Toyomi Shinko Building 5F,
4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

³Association of Ayukawa Town Planning,
43-1 Ayukawahama minami, Ishinomaki city, Miyagi 986-2523, Japan

[†]Current address: 7-22-303 Akineshinmachi, Shimonoseki city, Yamaguchi 751-0874, Japan

*Corresponding author: gnakam1@kaiyodai.ac.jp

Abstract

In the present paper, detailed measurements of the cranium and mandible of the following large cetacean species and subspecies have been assembled: Antarctic minke whale (*Balaenoptera bonaerensis*; $n=7$), dwarf minke whale (*B. acutorostrata* subsp.; $n=8$), North Pacific common minke whale (*B. a. scammoni*; $n=15$), sei whale (*B. borealis*; $n=1$), Bryde's whale (*B. edeni*; $n=1$) and gray whale (*Eschrichtius robustus*; $n=5$).

Key words: skeletal measurement, Balaenopteridae, Eschrichtiidae, morphometric, large whale.

The head of an animal contains indispensable organs for survival, such as the feeding apparatus, sensory and respiratory organs. Because the skeleton supports and protects these organs, its shape provides a lot of information about the lifestyle of an animal. Furthermore, the skeleton remains as a fossil for hundreds of millions of years and can be used for phylogenetic studies. Therefore, the characteristics of the skeleton, particularly the cranial skeleton, are very important for taxonomical, morphological, anatomical, and paleobiological studies (Miyazaki, 1994). However, skeletal specimens of large whales are quite scarce globally owing to difficulties in acquiring the dead bodies of large whales, high cost and longtime involved in their preservation compared with other mammals, and the large space required for their preservation and storage. In addition, the skeletal specimens of large whales that are available are often assembled and hung in very high places in museums, such as in exhibition halls, making it difficult for scientists to gain access to them for observation.

Dr. Hideo Omura, ex-director of the Whales Research Institute (WRI), vigorously collected skeletal specimens of large whales from the 1950s onward and published many papers on his findings (e.g., Omura and Sakiura, 1956; Omura, 1957, 1975; Omura *et al.*, 1962, 1969, 1970, 1981). The authors of this paper inherited his techniques of skeletal measurements that were directly or indirectly adapted from those he had developed and would like to make the datasets on the skeletal measurements of the following large whale species and subspecies available to others: Antarctic minke whale (*Balaenoptera bonaerensis*; $n=7$), dwarf minke whale (*B. acutorostrata* subsp.; $n=8$), North Pacific common minke whale (*B. acutorostrata scammoni*; $n=15$), sei whale (*B. borealis*; $n=1$), Bryde's whale (*B. edeni*; $n=1$) and gray whale (*Eschrichtius robustus*; $n=5$).

The Antarctic and dwarf minke whales were collected from the Japanese Whale Research Pro-

gram under Special Permit in the Antarctic (JARPA), which was conducted in the Antarctic Ocean (35°E – 145°W) between 1987/88 and 2004/05. The common minke and sei whales were collected from the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) and the Japanese Whale Research Program under Special Permit in the Western North Pacific-Phase II (JARPN II), which were conducted in the North Pacific during 1994–2016. These surveys were conducted in accordance with Article VIII of the International Convention for the Regulation of Whaling and all relevant Japanese regulations, and the study protocol was approved by the Government of Japan (2004). The surveys were planned and conducted by the Institute of Cetacean Research, the National Research Institute of Far Seas Fisheries, and the Fisheries Research Agency (IWC, 2001; 2008; 2017).

After external measurements and predetermined observations had been made, the carcasses were buried in the ground for approximately 2–3 years for the removal of the soft tissues attached to the skeletons. Subsequently, skeleton was dug out and washed to remove any soil and remaining soft tissues on it. It was then dried, fixed with stainless steel straps, and impregnated with resin to prevent it from curving. Then, measurements were made, and the methodology and measurement points determined by Omura (1975) as well as some additional points (Figs. 1, 2) were utilized for further assessments. The cranium was oriented so that the tip of the premaxilla and the right and left squamosals touched the ground, as shown in Fig. 1f, and the straight length of the mandible was measured with the mandible set flat. Measurements were taken as the distance from point to point down to the nearest millimeter scale. A stainless-steel caliper was used for straight distances $<50\text{ cm}$, a large 3.5 m anthropometer was used for straight distances $>50\text{ cm}$, and a measuring tape was used for curved lengths.

We provided the measurements of the craniums and mandibles of the Antarctic minke whales, dwarf minke whales, common minke whales, sei whale and gray whales (Tables 1–5). In each table, the specimen ID is the number that was assigned to the specimen by the institute or museum storing the skeleton and the body length is the distance from the tip of the snout to the notch of the flukes.

Skeletal measurements of the gray whales were collected from the animals, stranded or bycaught around the Japanese coast. These measurements were cited from Nakamura and Kato (2014) with some minor corrections.

Acknowledgements

We would like to thank the captains, crews, and researchers who were involved in the JARPA, JARPN, and JARPN II surveys. We also express our gratitude to the staff of Nishio Biological Models Co. Ltd and the members of the laboratory of Cetacean Biology of Tokyo University of Marine Science and Technology for their assistance in measuring the whale skeletons. The authors would like to express our sincerely thanks to the anonymous reviewers.

References

- Government of Japan. 2004. Revised research plan for cetacean studies in the western North Pacific under special permit (JARPN II). Paper SC/56/O1 submitted to the 56th IWC Scientific Committee, 2004 Jun 29–Jul 12. Sorrento, Italy. 14 p.
- International Whaling Commission. 2001. Report of the workshop to review the Japanese Whale Research Programme under Special Permit for North Pacific Minke Whales (JARPN), Tokyo, 7–10 February 2000. *J. Cetacean Res. Manage.* 3 (Suppl.): 375–413.
- International Whaling Commission. 2008. Report of the Intersessional workshop to review data and results from special permit research on minke whales in the Antarctic, Tokyo, 7–8 December 2006. *J. Cetacean Res. Manage.* 10 (Suppl.): 411–445.
- International Whaling Commission. 2017. Report of the expert panel of the final review on the Western North Pacific Japanese Special Permit Programme (JARPN II). *J. Cetacean Res. Manage.* 18 (Suppl.): 529–592.
- Miyazaki, N. 1994. Skull morphology of small cetacea. A consideration of taxonomic problems in the Short-finned Pilot Whale, *Globicephala macrorhynchus*, in Japanese waters. *Honyurui Kagaku [Mammalian Science]* 34: 31–42 (in Japanese with English abstract).
- Nakamura, G. and Kato, H. 2014. Osteological characteristics of gray whales *Eschrichtius robustus* collected from the coast of Japan (1990–2005) and possible population mixing with eastern gray whales in the western North Pacific. *Honyurui*

SKELETAL MEASUREMENTS OF LARGE CETACEANS

- Kagaku [Mammalian Science]* 54: 73–88 (in Japanese with English abstract).
- Omura, H. and Sakiura, H. 1956. Studies on the little piked whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.* 11: 1–37.
- Omura, H. 1957. Osteological study of the little piked whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.* 12: 1–21.
- Omura, H. 1975. Osteological study of the minke whale from the Antarctic. *Sci. Rep. Whales Res. Inst.*, 27: 1–36.
- Omura, H., Nishiwaki, M., Ichihara, T. and Kasuya, T. 1962. Osteological note of a sperm whale. *Sci. Rep. Whales Res. Inst.*, 8: 35–45.
- Omura, H., Ohsumi, S., Nemoto, T., Nasu, K. and Kasuya, T. 1969. Black right whales in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 21: 1–78.
- Omura, H., Ichihara, T. and Kasuya, T. 1970. Osteology of pygmy blue whale with additional information on external and other characteristics. *Sci. Rep. Whales Res. Inst.*, 22: 1–27.
- Omura, H., Kasuya, T., Kato, H. and Wada, S. 1981. Osteological study of the Bryde's whale from the central South Pacific and eastern Indian Ocean. *Sci. Rep. Whales Res. Inst.*, 33: 1–26.

Received: October 5, 2020

Accepted: November 6, 2020

Published online: January 31, 2021

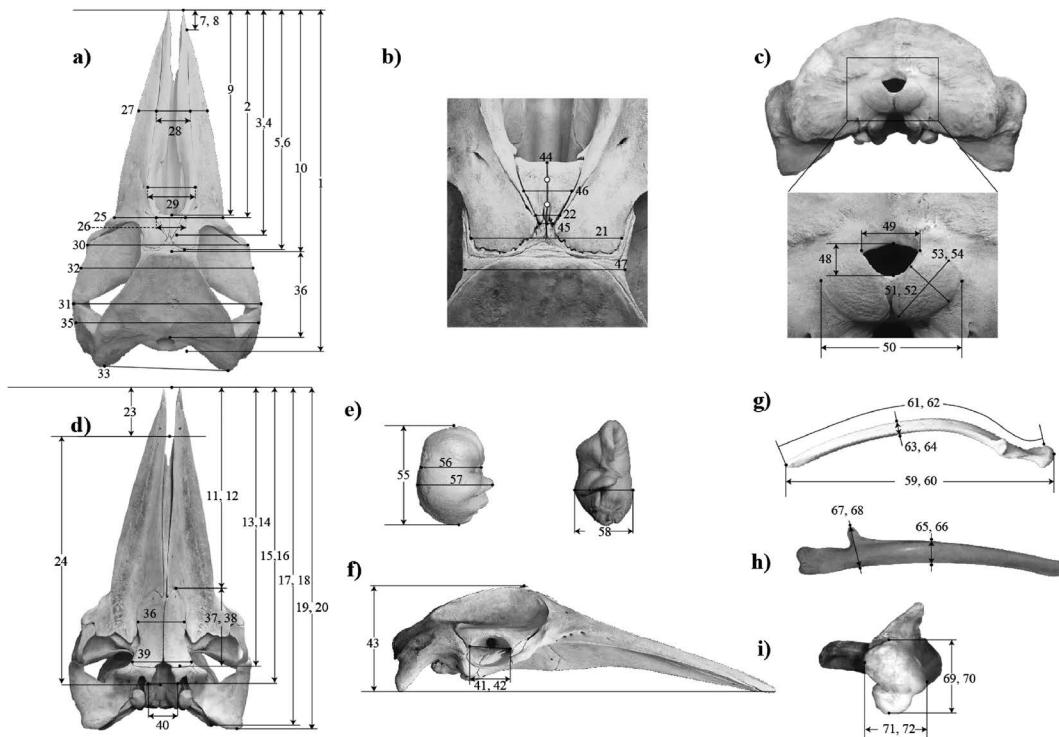


Fig. 1. Measurement points of the cranium and mandible of balaenopterid species. a) dorsal view of cranium, b) vertex of cranium, c) caudal view of cranium, d) ventral view of cranium, e) tympanic bullae, f) lateral view of cranium, g) dorsal view of mandible, h) lateral view of mandible, i) caudal view of mandible.

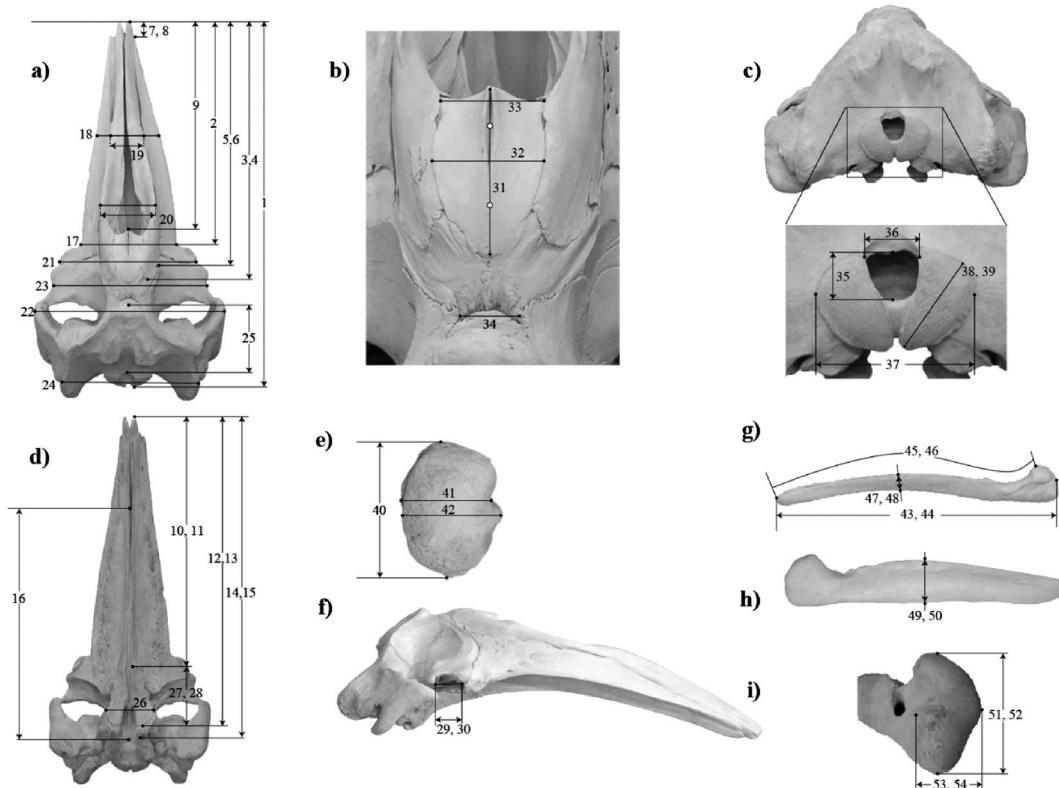


Fig. 2. Measurement points of the cranium and mandible of gray whales. a) dorsal view of cranium, b) vertex of cranium, c) caudal view of cranium, d) ventral view of cranium, e) tympanic bullae, f) lateral view of cranium, g) dorsal view of mandible, h) lateral view of mandible, i) caudal view of mandible.

SKELETAL MEASUREMENTS OF LARGE CETACEANS

Table 1. Measurements on cranium and mandible with some biological information on Antarctic minke whales.

Scientific name Locality	<i>Balaenoptera bonaerensis</i>						
	Antarctic						
Body length (m)	8.88	8.05	8.53	9.38	9.08	9.28	8.97
Sex	M	M	M	M	M	F	F
Current affiliation*	ICR	ICR	ICR	NA	ICR	NA	ICR
Specimen number	87/88 053	87/88 102	87/88 229	89/90 272	93/94 287	89/90 292	01/02 039
1. Condyllobasal length	217.8	186.3	213.6	226.4	208.2	223.7	216.3
2. Length of rostrum	146.0	115.6	136.9	152.4	135.0	145.2	143.4
3. Length of premaxillary (L)	159.0	135.3	151.3	165.3	149.7	161.7	155.0
4. Length of premaxillary (R)	159.2	133.6	151.9	166.0	148.3	162.5	155.5
5. Length of maxillary (L)	149.4	130.6	144.8		139.9	148.9	147.0
6. Length of maxillary (R)	148.1	131.8	142.3	158.2	138.0	152.6	144.1
7. Tip of premaxillary to tip of maxillary (L)	11.7	7.3	8.7		12.3	10.7	11.6
8. Tip of premaxillary to tip of maxillary (R)	8.9		8.7	13.0	10.3	10.1	13.8
9. Tip of premaxillary to nares, anterior	148.2	118.2	134.9	151.0	132.6	143.0	136.8
10. Tip of premaxillary to vertex	157.8	135.6	153.9	169.2	150.8	167.1	157.9
11. Tip of premaxillary to palatine, anterior (L)	154.2	119.3	142.6	148.0	140.3	151.7	146.2
12. Tip of premaxillary to palatine, anterior (R)	154.3	121.6	143.2	146.9	139.2	151.4	146.4
13. Tip of premaxillary to palatine, posterior (L)	191.5	160.8	184.9	196.2	178.8	198.1	188.4
14. Tip of premaxillary to palatine, posterior (R)	191.8	160.2	185.2	196.1	177.0	198.4	189.0
15. Tip of premaxillary to pterygoid process (L)	198.6	168.0	193.6	205.6	187.5	206.0	196.0
16. Tip of premaxillary to pterygoid process (R)	198.6	169.0	193.8	205.3	185.4	205.7	195.7
17. Tip of premaxilla to posterior edge of occipital bone (L)					216.0		224.5
18. Tip of premaxilla to posterior edge of occipital bone (R)					214.2		224.3
19. Tip of premaxilla to posterior edge of temporal bone (L)					207.0		216.5
20. Tip of premaxilla to posterior edge of temporal bone (R)					205.3		216.2
21. Breadth of maxillary, posterior edge		21.6	17.4	19.1	16.5	21.2	17.0
22. Breadth of premaxillary, posterior edge	4.6	3.6	3.5	2.7	5.3		3.7
23. Tip of premaxillary to anterior end of vomer, median		24.9	30.6	28.2	25.3	21.5	30.9
24. Length of vomer					167.6		170.9
25. Breadth of rostrum at base	64.7	65.7	63.6	69.7	67.4	68.5	64.7
26. Breadth of premaxillary at base	11.3	14.0	13.1	18.9	14.4	18.5	12.7
27. Breadth of rostrum at middle	38.5	44.2	41.6	44.2	43.3	46.8	39.2
28. Breadth of premaxillary at middle	16.6	16.4	15.9	19.1	19.5	17.8	17.6
29. Greatest breadth of premaxillary	25.7	25.8	24.8	26.1	25.8	25.5	24.2
30. Breadth of cranium, maxillaries	98.9	97.6	101.7	105.6	103.3	107.6	98.3
31. Breadth of cranium, anterior edge of zygomatic process	110.5	106.6	108.5	119.5	116.6	114.9	109.3
32. Breadth of cranium, middle of orbital foramen	101.4	100.1	104.0	108.9	107.3	106.9	99.4
33. Breadth of occipital bone	91.3	81.6	85.9	101.8	90.3	81.9	81.8
34. Breadth of cranium, middle of zygomatic process	111.1	108.9	110.8	121.4	114.7	118.3	111.7
35. Length from upper ridge of foramen magnum to superior part of occipital bone	60.0	53.9	61.2	63.6	62.4		61.1
36. Greatest breadth of palatine					28.2		27.7
37. Length of palatine (L)	42.3	46.1	46.4		43.0	49.5	47.4
38. Length of palatine (R)	41.7	45.6	46.6		42.8	49.0	47.9
39. Breadth of palatine, posterior	31.8	35.1	33.3		34.4	32.6	30.4
40. Breadth across hamular processes of pterygoid	18.4	19.2	14.3	18.8	21.9	22.0	19.8
41. Length of orbit (L)	19.3	19.6	18.8	18.7	21.5	20.9	20.0
42. Length of orbit (R)	19.0	19.3	19.1	19.0	20.5	20.8	20.0
43. Height of cranium					60.8		59.6
44. Length of nasals	14.0	17.7	16.3	14.8	19.5	20.3	20.7
45. Breadth of nasal, posterior	4.6	3.5	3.4	2.7	1.8	1.1	1.5
46. Breadth of nasal at middle	8.6	6.8	5.7	8.4	8.0	7.3	

Table 1. Continued.

	Specimen number	87/88 053	87/88 102	87/88 229	89/90 272	93/94 287	89/90 292	01/02 039
47. Minimum breadth of parietal bones		24.6	22.4	20.6		16.3	22.2	18.7
48. Height of foramen magnum		8.6	6.6	9.3		8.5		9.0
49. Breadth of foramen magnum		9.0	6.9	8.6		8.1		6.6
50. Breadth across occipital condyles		21.5	19.6	22.8	23.0	22.7	20.3	21.4
51. Breadth of occipital condyle (L)			8.1	9.9		8.9		9.8
52. Breadth of occipital condyle (R)			8.7	10.2		9.5		9.5
53. Height of occipital condyle (L)		14.9	11.8	12.7	12.6	12.8	14.1	14.5
54. Height of occipital condyle (R)		14.5	12.2	12.0	13.3	13.0	12.9	14.4
55. Length of tympanic bullae (L)		10.2	9.1	8.4	9.7	8.9	9.3	9.4
56. Minimum breadth of tympanic bullae (L)						5.5		5.7
57. Greatest breadth of tympanic bullae (L)		7.4	7.6	6.9	7.5	6.8	7.5	6.8
58. Thickness of tympanic bullae at middle (L)						4.8		4.9
59. Length of mandible, straight (L)		222.0	195.0	218.5	231.1	215.5	227.0	217.0
60. Length of mandible, straight (R)		211.0	184.7	206.4	212.0	201.6	220.0	206.0
61. Length of mandible, curved (L)		210.8	185.1	207.2	215.6	200.0	219.2	206.5
62. Length of mandible, curved (R)		218.8	192.8	217.4	227.9	213.5	228.3	216.0
63. Breadth of mandible at middle (L)			8.0	8.0	8.8	8.1	8.3	7.6
64. Breadth of mandible at middle (R)			8.1	8.2	8.9	8.3	8.3	7.6
65. Height of mandible at middle (L)			16.2	15.8	16.9	17.7	16.0	16.1
66. Height of mandible at middle (R)			15.8	16.7	17.4	17.7	16.4	15.6
67. Height of mandible at coronoid process (L)		26.4	29.3	30.4	30.7	29.3	31.6	28.8
68. Height of mandible at coronoid process (R)		27.7	29.4	30.5	31.1	29.2	30.9	29.1
69. Height of mandible at coronoid (L)		19.6	18.9	20.8	20.2	19.4	22.4	21.3
70. Height of mandible at coronoid (R)		20.1	19.3	20.9	19.5	19.1	21.5	21.3
71. Breadth of mandible at coronoid (L)		14.5	14.3	14.2	14.8	14.7	15.1	16.1
72. Breadth of mandible at coronoid (R)		15.3	13.9	15.3	16.2	14.0	14.5	15.2

* ICR: Institute of Cetacean Research, NA: Nagoya Public Aquarium

Table 2. Measurements on cranium and mandible with some biological information on dwarf minke whales.

Scientific name	<i>B. acutorostrata</i> subsp.								
	Locality		Antarctic						
Body length (m)	7.01	6.60	5.41	6.99	7.02	5.94	7.07	7.17	
Sex	M	M	M	F	F	F	F	F	
Current affiliation*	TUMSAT	ICR	ICR	ICR	ICR	ICR	ICR	ICR	ICR
Specimen number	87/88 273	88/89 014	89/90 199	88/89 013	88/89 227	88/89 070	89/90 215		92/93 330
1. Condyllobasal length	159.7	149.0	122.3	163.4	164.7	133.1	169.2	156.1	
2. Length of rostrum	101.4	97.7	81.6	106.0	111.0	83.4	112.0	106.8	
3. Length of premaxillary (L)	119.3	109.8		119.4	120.0	97.9	122.8	119.8	
4. Length of premaxillary (R)	120.0	109.3	92.0	121.3	120.8	98.5	122.4	120.2	
5. Length of maxillary (L)	117.2	105.5		114.3	115.2	94.3	119.3	111.4	
6. Length of maxillary (R)	117.3	105.0		114.8	115.4	94.1	119.3	112.8	
7. Tip of premaxillary to tip of maxillary (L)	4.5	8.3		8.4	10.7	8.7	9.6	10.3	
8. Tip of premaxillary to tip of maxillary (R)	4.9	9.2		9.8	10.7	5.7	8.3	10.5	
9. Tip of premaxillary to nares, anterior	109.0	96.8	82.2	106.2	109.1	85.9	110.4	104.2	
10. Tip of premaxillary to vertex	123.7	116.0	96.3	126.5	128.3	103.7	131.7	125.5	
11. Tip of premaxillary to palatine, anterior (L)	99.5	97.8		102.3	108.2	85.8	108.0	100.2	
12. Tip of premaxillary to palatine, anterior (R)	99.8	97.8	78.7	105.2	107.6	86.9	108.3	100.1	
13. Tip of premaxillary to palatine, posterior (L)	134.5	128.1		137.4	142.2	111.7	145.3	135.2	
14. Tip of premaxillary to palatine, posterior (R)	134.5	127.6	102.8	139.2	141.3	111.7	143.2	135.5	
15. Tip of premaxillary to pterygoid process (L)	144.0	134.6		146.3	150.3	119.7	153.8	143.1	
16. Tip of premaxillary to pterygoid process (R)	143.8	134.8	108.4			119.3	152.3	143.3	
17. Tip of premaxilla to posterior edge of occipital bone (L)	170.0	156.8		165.7	173.4	139.1	177.8	165.3	
18. Tip of premaxilla to posterior edge of occipital bone (R)	169.4	155.9	127.4	166.1	172.0	138.7	176.8	165.3	
19. Tip of premaxilla to posterior edge of temporal bone (L)	164.2	153.5		168.7	169.4	136.5	172.2	162.7	
20. Tip of premaxilla to posterior edge of temporal bone (R)	164.8	152.2	124.0	171.2	168.2	136.5	170.7	162.7	
21. Breadth of maxillary, posterior edge	19.0	14.3	11.6	14.2	19.0	14.0	15.3	17.9	
22. Breadth of premaxillary, posterior edge	3.0	3.2	1.3	3.4	4.8	2.1	3.2	3.0	
23. Tip of premaxillary to anterior end of vomer, median	21.2	18.3	17.9	17.7	21.7	19.3	18.5	16.3	
24. Length of vomer	122.4	116.2	93.7	131.3	127.6	107.0	136.5	126.1	
25. Breadth of rostrum at base	55.1	51.2	43.8	50.7	53.8	49.2	59.3	58.2	
26. Breadth of premaxillary at base	17.3	12.8	11.3	15.4	13.7	11.7	12.8	13.2	
27. Breadth of rostrum at middle	31.4	30.5	23.7	30.7	34.2	28.7	36.4	34.8	
28. Breadth of premaxillary at middle	12.6	12.7	9.8	12.7	15.2	11.8	16.5	15.4	
29. Greatest breadth of premaxillary	22.2	19.2	15.9	20.2	22.3	17.4	22.0	22.8	
30. Breadth of cranium, maxillaries	79.1	73.8	57.6	76.0	78.7	65.9	82.8	80.5	
31. Breadth of cranium, anterior edge of zygomatic process	89.1	80.8	64.7	84.5	86.3	72.8	91.5	89.4	
32. Breadth of cranium, middle of orbital foramen	80.1	72.3	58.6	77.5	77.7	66.7	83.0	80.4	
33. Breadth of occipital bone	69.5	59.3	49.4	63.3	66.4	51.2	62.6	61.7	
34. Breadth of cranium, middle of zygomatic process	89.3	79.4	64.6	82.1	85.3	71.8	88.5	87.7	
35. Length from upper ridge of foramen magnum to superior part of occipital bone	40.4	36.4	27.7	40.4	40.2	31.4	43.2	37.3	
36. Greatest breadth of palatine	24.8	23.8	18.5	23.3	22.7	21.8	26.5	25.3	
37. Length of palatine (L)	36.8	32.3	26.6	37.4	36.2	28.3	37.8	37.7	
38. Length of palatine (R)	37.1	32.3	27.0	36.1	35.8	27.3	36.4	37.1	
39. Breadth of palatine, posterior	25.3	23.1	21.7	22.8	27.3	21.3	27.7	26.7	
40. Breadth across hamular processes of pterygoid	12.9	11.7	11.6	12.7	13.8	11.3	14.4	12.8	

Table 2. Continued.

	Specimen number	87/88 273	88/89 014	89/90 199	88/89 013	88/89 227	88/89 070	89/90 215	92/93 330
41. Length of orbit (L)		17.0	16.5	14.5	15.0	16.5	15.5	16.5	16.5
42. Length of orbit (R)		16.5	15.5	14.0	16.0	17.0	15.5	16.0	16.5
43. Height of cranium			45.1	37.2	50.0	49.4	34.3	51.5	53.4
44. Length of nasals		14.9	14.5	10.8	16.3	17.8	14.0	18.7	17.8
45. Breadth of nasal, posterior		1.1	1.3	0.8	2.0	2.6	1.1	1.2	1.9
46. Breadth of nasal at middle		4.4	4.9	3.3	5.8	7.1	4.5	6.5	5.3
47. Minimum breadth of parietal bones		18.5	15.3	12.8	16.4	20.1	16.5	19.4	20.0
48. Height of foramen magnum		6.4	7.3	6.3	5.9	6.3	6.6	6.3	6.7
49. Breadth of foramen magnum		8.2	6.0	7.4	7.8	7.1	7.3	6.5	7.3
50. Breadth across occipital condyles		17.0	15.7	13.3	16.7	14.3	15.8	16.8	17.2
51. Breadth of occipital condyle (L)		6.8	6.2	5.3	7.0	6.8	6.6	6.7	6.3
52. Breadth of occipital condyle (R)		6.9	6.5	5.3	7.0	6.3	6.2	6.5	6.8
53. Height of occipital condyle (L)		10.9	10.1	8.6	9.8	8.8	9.2	10.0	9.8
54. Height of occipital condyle (R)		11.1	10.0	8.4	10.0	8.9	9.2	10.0	9.8
55. Length of tympanic bullae (L)		8.3	7.9	7.3	8.2	7.7	8.2	8.3	7.6
56. Minimum breadth of tympanic bullae (L)		4.8	4.9	4.5	5.1	5.1	5.2		4.8
57. Greatest breadth of tympanic bullae (L)		6.1	6.1	5.7	6.3	5.9	6.2		5.9
58. Thickness of tympanic bullae at middle (L)			4.3	3.8		4.3	4.5	4.2	4.0
59. Length of mandible, straight (L)		164.5	155.0	127.0	167.0	170.8	140.0		165.0
60. Length of mandible, straight (R)		155.4	146.0	120.7	157.4	161.0	133.5		154.8
61. Length of mandible, curved (L)		156.2	145.8	121.5	158.0	162.0	133.5	167.0	154.5
62. Length of mandible, curved (R)		164.5	154.0	126.0	166.4	170.8	139.9	167.5	165.5
63. Breadth of mandible at middle (L)		7.0	6.4	4.7	6.8	7.5	6.0	6.8	6.8
64. Breadth of mandible at middle (R)		7.0	6.5	4.7	7.1	7.3	6.2	6.8	7.0
65. Height of mandible at middle (L)		10.4	9.8	7.6	10.0	11.1	9.7	11.8	10.6
66. Height of mandible at middle (R)		10.5	10.2	7.7	10.3	11.2	9.5	12.0	10.7
67. Height of mandible at coronoid process (L)		21.5	19.3	16.0	21.0	23.3	18.4	23.2	21.4
68. Height of mandible at coronoid process (R)		21.4	19.4	16.3	21.2	23.2	18.5	23.7	21.6
69. Height of mandible at coronoid (L)		16.8	14.3	12.1	16.1	18.3	14.4	17.3	17.7
70. Height of mandible at coronoid (R)		16.4	14.8	12.3	16.1	18.5	14.4	18.3	17.3
71. Breadth of mandible at coronoid (L)		10.2	9.4	7.7	10.0	10.7	9.3	11.5	11.7
72. Breadth of mandible at coronoid (R)		11.0	9.3	8.0	9.9	10.7	9.1	11.3	11.2

* ICR: Institute of Cetacean Research, TUMSAT: Tokyo University of Marine Science and Technology

SKELETAL MEASUREMENTS OF LARGE CETACEANS

Table 3. Measurements on cranium and mandible with some biological information on common minke whales from the North Pacific.

Scientific name Locality	<i>B. a. scammoni</i>								
	North Pacific								
Body length (m)	7.31	7.38	7.25	7.53	7.65	7.52	7.51	7.70	4.49
Sex	M	M	M	M	M	M	M	M	M
Current affiliation*	ICR	ICR	ICR	ICR	ICR	KCM	HM	AMP	AMP
Specimen number	94NP 011	94NP 009	94NP 012	97NP 068	97NP 070	05NPCK M001	08NPCK M030	10NPCK M047	10NPCK M054
1. Condyllobasal length	145.3	149.8	154.3	160.0	156.7	154.5	152.4	160.2	95.9
2. Length of rostrum	90.7	93.5	88.4	104.4	99.3	96.8	97.0	108.4	59.0
3. Length of premaxillary (L)	107.0	106.8	105.2	116.8	113.9	109.8	109.7	119.3	64.4
4. Length of premaxillary (R)	107.0	106.9	103.9	116.2	113.1	109.9	109.5	119.2	64.0
5. Length of maxillary (L)	101.3		100.7	111.3		103.5	104.3	113.2	63.4
6. Length of maxillary (R)			98.4	112.3	108.3	103.4	105.5	114.5	63.0
7. Tip of premaxillary to tip of maxillary (L)	8.3		11.6	10.1	10.6	9.3	9.6	8.7	5.2
8. Tip of premaxillary to tip of maxillary (R)			9.0	9.5	9.0	9.2	8.2	7.7	6.2
9. Tip of premaxillary to nares, anterior	94.2	95.2	91.3	106.3	103.2	95.6	97.8	107.5	57.2
10. Tip of premaxillary to vertex	113.0	113.0	110.5	122.0	119.3	114.0	117.1	125.0	70.9
11. Tip of premaxillary to palatine, anterior (L)	87.2	94.3	90.6	100.9	99.8	93.4	93.0	98.6	55.3
12. Tip of premaxillary to palatine, anterior (R)	88.7	92.8	92.0	101.3	99.4	93.8	93.0	99.4	55.0
13. Tip of premaxillary to palatine, posterior (L)	120.6	125.4	127.2	135.7	133.0	129.4	127.2	134.6	76.0
14. Tip of premaxillary to palatine, posterior (R)	121.1	125.0	128.0	135.4	133.1	129.6	126.9	136.0	76.0
15. Tip of premaxillary to pterygoid process (L)	128.1		134.9	142.0	140.6	137.3	135.1	143.2	82.0
16. Tip of premaxillary to pterygoid process (R)	128.8		136.0		140.5	138.3	135.0	140.0	81.6
17. Tip of premaxilla to posterior edge of occipital bone (L)	154.0	157.1		167.6	166.4		162.7	171.9	98.4
18. Tip of premaxilla to posterior edge of occipital bone (R)	155.7	157.6		166.8	166.0		161.4	172.8	98.0
19. Tip of premaxilla to posterior edge of temporal bone (L)	150.0	153.4		163.7	162.3		159.0	167.0	96.2
20. Tip of premaxilla to posterior edge of temporal bone (R)	151.5	153.6		162.4	162.3		158.0	167.9	95.4
21. Breadth of maxillary, posterior edge	18.7	15.9	15.5	19.4	14.7		22.0	17.0	7.2
22. Breadth of premaxillary, posterior edge	5.7	2.8	3.2	4.3	3.8	2.3	2.9	3.0	2.1
23. Tip of premaxillary to anterior end of vomer, median	23.9	19.3	20.3	34.7	27.7	23.3	31.4	33.3	15.8
24. Length of vomer	108.5	116.3		111.8	114.9		108.6	112.5	69.5
25. Breadth of rostrum at base	50.7	51.1	47.8	54.6	48.6	49.6	50.1	55.0	30.5
26. Breadth of premaxillary at base	17.2	16.7	16.7	16.7	14.8	16.6	17.2	12.8	7.3
27. Breadth of rostrum at middle	29.0	28.7	29.4	29.2	28.3	24.5	33.5	32.3	18.4
28. Breadth of premaxillary at middle	12.3	12.3	15.7	12.5	12.4		14.9		8.7
29. Greatest breadth of premaxillary	20.9	21.3	21.1	21.7	20.2	20.2	22.0	21.6	13.0
30. Breadth of cranium, maxillaries	75.2	71.8	73.9	79.4	72.5	71.6	77.7	80.9	44.0
31. Breadth of cranium, anterior edge of zygomatic process	87.3	83.2	85.9	89.6	83.8	80.7		89.0	50.5
32. Breadth of cranium, middle of orbital foramen	77.6	75.3	77.8	80.9	76.7	74.0	80.4	82.5	44.5
33. Breadth of occipital bone	68.8	63.7	66.7	62.7	67.3	63.1	66.7	70.0	39.2
34. Breadth of cranium, middle of zygomatic process	87.4	83.4	84.7	89.3	84.7	82.8	86.6	87.9	49.5
35. Length from upper ridge of foramen magnum to superior part of occipital bone	41.3	37.8	43.0	41.6	39.8	40.5	39.2	42.1	26.0
36. Greatest breadth of palatine	24.7	20.7	23.6	24.8	24.0	22.4	23.3	24.4	14.0
37. Length of palatine (L)	37.4	34.4	39.0	37.0	36.8	39.1	36.8	38.6	21.7
38. Length of palatine (R)	36.6	35.0	37.5	36.2	37.2	37.7	35.9	38.5	22.6

Table 3. Continued.

Specimen number	94NP 011	94NP 009	94NP 012	97NP 068	97NP 070	05NPCK M001	08NPCK M030	10NPCK M047	10NPCK M054
39. Breadth of palatine, posterior	28.7	27.6	28.9	25.7	26.9	30.9	28.5	32.7	16.6
40. Breadth across hamular processes of pterygoid	13.0		10.5		14.3	12.9			
41. Length of orbit (L)	18.0	16.0	17.4	17.7	19.5	17.1		17.9	13.4
42. Length of orbit (R)	18.0	16.0	17.6	17.5	19.0	17.9	16.5	17.9	13.4
43. Height of cranium	49.8	44.4		48.5	45.9				
44. Length of nasals	13.8	12.8	14.3	11.4	11.8	13.2	13.0	14.5	7.7
45. Breadth of nasal, posterior	3.5	1.3	2.5	2.4	2.0	1.4	1.8	2.1	1.0
46. Breadth of nasal at middle	7.1	5.4	6.0	7.8	5.9	5.9	8.7	6.5	3.8
47. Minimum breadth of parietal bones	19.8	19.3	17.2	21.6	17.7	15.2	24.2	19.5	10.4
48. Height of foramen magnum	7.3	7.1	9.7	7.7	6.7		6.4	7.2	5.5
49. Breadth of foramen magnum	7.6	7.3	8.0	7.0	7.0		8.0	7.4	6.9
50. Breadth across occipital condyles	18.3	18.3	18.5	17.7	16.7	17.9	20.1	18.0	13.7
51. Breadth of occipital condyle (L)	7.1	6.9	7.6	7.0	6.3	7.9	8.1	7.7	5.2
52. Breadth of occipital condyle (R)	6.7	7.1	7.5	7.2	6.7	7.6	7.8	7.6	5.5
53. Height of occipital condyle (L)	10.3	10.7	11.0	10.9	9.5	10.4	10.9	11.2	8.7
54. Height of occipital condyle (R)	10.3	10.8	10.9	10.7	9.7	10.7	10.7	10.8	9.0
55. Length of tympanic bullae (L)	8.7	9.1	9.3	9.2	8.8	8.9	9.1		9.2
56. Minimum breadth of tympanic bullae (L)	5.3	5.8		5.7	5.6		5.8		5.7
57. Greatest breadth of tympanic bullae (L)	6.5	6.9		6.2	6.7	6.9	7.0		7.1
58. Thickness of tympanic bullae at middle (L)	4.9	5.0		4.8	4.8				
59. Length of mandible, straight (L)	148.0	152.5	148.8	160.0	159.4	154.5	155.0	161.5	96.0
60. Length of mandible, straight (R)	142.0	145.8	149.0	151.8	153.2	152.0	148.7	155.0	92.6
61. Length of mandible, curved (L)	142.2	146.0	155.4	152.4	152.8	151.5	149.8	154.0	92.2
62. Length of mandible, curved (R)	149.0	152.6	153.2	160.4	158.8	156.0	154.6	162.5	95.6
63. Breadth of mandible at middle (L)	6.2	6.3	6.3	7.0	6.2	6.3	6.4	7.1	4.2
64. Breadth of mandible at middle (R)	6.1	6.1	6.9	7.0	6.3	6.3	6.6	7.2	4.1
65. Height of mandible at middle (L)	11.4	10.3	10.8	11.2	10.2	11.4	11.3	11.7	6.4
66. Height of mandible at middle (R)	11.7	10.3	10.3	11.2	10.3	11.5	11.5	11.8	6.5
67. Height of mandible at coronoid process (L)	20.7	19.0	20.2	21.0	21.0	20.2	22.0	20.4	13.4
68. Height of mandible at coronoid process (R)	20.1	18.6	20.6	20.7	21.2	20.9	22.1	20.1	13.3
69. Height of mandible at coronoid (L)	14.6	15.3	15.4	14.4	14.6	13.3	15.7	14.7	8.9
70. Height of mandible at coronoid (R)	14.2	15.5	15.6	14.7	14.8	13.7	15.5	14.0	9.3
71. Breadth of mandible at coronoid (L)	11.3	10.6	11.5	10.3	9.8	10.3	10.3	10.4	6.8
72. Breadth of mandible at coronoid (R)	11.3	10.7	11.2	10.0	10.2	10.8	10.3	10.4	6.8

* ICR: Institute of Cetacean Research, HM: The Hagi Museum, AMP: Ashoro Museum of Paleontology

SKELETAL MEASUREMENTS OF LARGE CETACEANS

Table 4. Measurements on cranium and mandible with some biological information on common minke, sei and Bryde's whale from the North Pacific.

Scientific name Locality	<i>B. a. scammoni</i>						<i>B. borealis</i>	<i>B. edeni</i>
	North Pacific						North Pacific	
Body length (m)	8.09	7.60	7.75	7.31	7.30	7.11	13.37	12.41
Sex	F	F	F	F	F	F	M	F
Current affiliation *	ICR	ICR	ICR	ICR	ICR	ICR	MBIK	MBIK
Specimen number	94NP 021	95NP 048	97NP 078	99NP 063	99NP 073	99NP 098	03NP SE045	00NP B006
1. Condyllobasal length	167.3	156.7	166.8	161.4	161.5	151.9	306.5	297.6
2. Length of rostrum	101.4	105.7	107.5	103.0	102.8	95.8	203.9	195.8
3. Length of premaxillary (L)	119.5	119.2	123.1	117.8		112.1	233.8	
4. Length of premaxillary (R)	119.7	119.8	122.3	118.7	118.7	113.0		
5. Length of maxillary (L)	115.2	112.6		110.5	113.3	106.3	226.3	225.2
6. Length of maxillary (R)	115.0	112.6	117.2	111.6	112.0	106.5	224.3	225.0
7. Tip of premaxillary to tip of maxillary (L)	7.9	10.2		10.4		9.3	17.3	8.2
8. Tip of premaxillary to tip of maxillary (R)	8.1	10.6		10.2	9.0	9.3	16.7	
9. Tip of premaxillary to nares, anterior	107.6	104.4	111.6		104.6	98.8	213.5	212.2
10. Tip of premaxillary to vertex	123.2	125.3	129.8	123.8	123.8	117.3	238.3	235.3
11. Tip of premaxillary to palatine, anterior (L)	104.0	98.4	103.8	99.8		92.7	213.1	207.8
12. Tip of premaxillary to palatine, anterior (R)	104.7	98.0	104.9	101.4	100.8	92.1	211.0	207.6
13. Tip of premaxillary to palatine, posterior (L)	142.4	135.3	139.0	136.3		126.9	267.7	256.4
14. Tip of premaxillary to palatine, posterior (R)	143.3	135.4	139.3	137.3	135.8	127.7	266.2	257.4
15. Tip of premaxillary to pterygoid process (L)	150.6	143.3	146.6	143.8		134.0	281.5	275.0
16. Tip of premaxillary to pterygoid process (R)	150.7	143.6	147.1	144.3	144.5	134.7	279.9	274.9
17. Tip of premaxilla to posterior edge of occipital bone (L)	170.6	173.6	170.1			154.3		
18. Tip of premaxilla to posterior edge of occipital bone (R)	170.9	172.6	170.7	167.2		154.3		
19. Tip of premaxilla to posterior edge of temporal bone (L)	168.9	169.9	164.8			158.6		
20. Tip of premaxilla to posterior edge of temporal bone (R)	169.0	168.3	165.2	163.2		159.0		
21. Breadth of maxillary, posterior edge	17.6	13.3	18.7	15.2	14.3	16.4	27.8	24.0
22. Breadth of premaxillary, posterior edge	5.4	3.2	5.2	2.4		3.1		
23. Tip of premaxillary to anterior end of vomer, median	24.6	24.6	27.6	25.8	30.0	29.4	22.8	33.4
24. Length of vomer		119.7	123.8	119.0	118.2	108.1	265.3	241.3
25. Breadth of rostrum at base	53.3	60.3	53.1	53.4	50.3	48.3	92.2	94.2
26. Breadth of premaxillary at base	22.3	14.5	21.6	17.6	15.3	17.2	27.9	22.1
27. Breadth of rostrum at middle	32.2	34.7	32.1	32.7	29.2	26.7	51.9	55.8
28. Breadth of premaxillary at middle	13.8	14.8	14.9	15.0	12.3	10.7	28.4	17.6
29. Greatest breadth of premaxillary	25.8	24.6	25.3	22.7	21.3	20.3	34.5	24.0
30. Breadth of cranium, maxillaries	80.1	85.4	77.7	79.4	75.8	73.7	130.0	128.8
31. Breadth of cranium, anterior edge of zygomatic process	92.8	96.5	90.5	87.7	83.4	83.0	148.9	136.6
32. Breadth of cranium, middle of orbital foramen	85.9	89.3	81.4	80.8	76.0	74.4	134.4	131.2
33. Breadth of occipital bone	65.5	72.4	67.3	68.6	61.7	61.8	105.6	100.3
34. Breadth of cranium, middle of zygomatic process	92.4	94.6	91.8	86.5	83.3	81.4	154.1	142.6
35. Length from upper ridge of foramen magnum to superior part of occipital bone	44.6	39.3	42.9	39.2		36.3	78.4	67.5
36. Greatest breadth of palatine	28.0	27.4	26.8	23.8	22.6	21.8	31.7	37.4
37. Length of palatine (L)	41.1	40.2	37.8	38.8		37.3	62.5	52.5
38. Length of palatine (R)	41.6	39.7	36.7	38.4	36.8	38.2	63.3	53.0
39. Breadth of palatine, posterior	30.2	29.4	29.5	28.4		25.8	41.9	41.4
40. Breadth across hamular processes of pterygoid	13.4	14.3	14.3	13.1	14.8	13.8	26.3	23.0
41. Length of orbit (L)	17.9	16.0	17.5	17.5	17.0	16.0	23.9	23.8
42. Length of orbit (R)	18.4	16.5	17.5	17.5	17.0	16.0	24.8	23.0
43. Height of cranium		54.4	52.2	51.4	48.5	47.8		
44. Length of nasals	13.7	16.0	13.9	13.1	14.7	13.8	22.4	
45. Breadth of nasal, posterior	3.9	1.3	1.3	1.5	1.8	0.8	2.6	

Table 4. Continued.

	Specimen number	94NP 021	95NP 048	97NP 078	99NP 063	99NP 073	99NP 098	03NP SE045	00NP B006
46. Breadth of nasal at middle		8.3	5.7	8.1	5.5	5.3	6.0	10.6	
47. Minimum breadth of parietal bones		21.5	16.4	21.5	17.2	16.5	19.4	29.7	26.3
48. Height of foramen magnum		12.0	6.6	6.3	6.6	6.7	7.0	7.5	6.5
49. Breadth of foramen magnum		10.0	6.8	6.7	7.3	7.1	7.8	7.0	5.9
50. Breadth across occipital condyles		19.6	16.6	18.3	17.5	16.2	17.0	28.0	26.5
51. Breadth of occipital condyle (L)		7.7	6.8	7.0	7.1	7.3	6.4	13.6	11.7
52. Breadth of occipital condyle (R)		7.7	6.7	7.0	7.1	7.3	6.4	13.2	11.1
53. Height of occipital condyle (L)		11.3	10.5	10.9	10.7	10.7	9.8	16.7	18.1
54. Height of occipital condyle (R)		11.2	10.4	10.8	10.8	10.7	9.9	17.0	17.9
55. Length of tympanic bullae (L)		9.3		9.0	9.3		9.3	12.1	12.1
56. Minimum breadth of tympanic bullae (L)				5.8	5.2		5.8	7.1	
57. Greatest breadth of tympanic bullae (L)		7.3		7.0	6.8		7.0	9.0	7.9
58. Thickness of tympanic bullae at middle (L)				4.7	5.3		5.2	5.8	
59. Length of mandible, straight (L)		164.6	168.5	168.0	163.5	160.4	155.0	302.0	287.5
60. Length of mandible, straight (R)		164.0	161.6	159.0	158.0	153.0	147.5	292.3	286.9
61. Length of mandible, curved (L)		170.4	163.0	159.5	158.0	154.5	148.0	293.3	305.5
62. Length of mandible, curved (R)		170.0	167.5	167.8	164.5	159.5	154.0	301.0	306.5
63. Breadth of mandible at middle (L)		7.1	7.1	6.7	7.1	6.3	6.2	12.3	13.6
64. Breadth of mandible at middle (R)		7.2	7.1	6.7	7.0	6.4	6.3	12.2	14.8
65. Height of mandible at middle (L)		12.5	13.5	11.1	11.7	10.3	10.0	23.3	21.0
66. Height of mandible at middle (R)		12.6	13.7	11.2	11.6	10.7	10.2	23.1	19.8
67. Height of mandible at coronoid process (L)		21.2	23.3	20.2	21.4	20.0	20.5	38.2	34.6
68. Height of mandible at coronoid process (R)		21.2	23.3	20.3	21.8	20.6	20.1	38.6	35.4
69. Height of mandible at coronoid (L)		15.0	15.4	16.5	16.0	16.0	15.8	27.4	25.0
70. Height of mandible at coronoid (R)		16.1	17.4	16.1	15.3	16.3	15.4	27.3	24.7
71. Breadth of mandible at coronoid (L)		13.6	12.0	11.9	10.2	10.7	10.3	22.5	18.4
72. Breadth of mandible at coronoid (R)		12.0	11.9	11.6	10.0	10.6	10.3	22.1	18.4

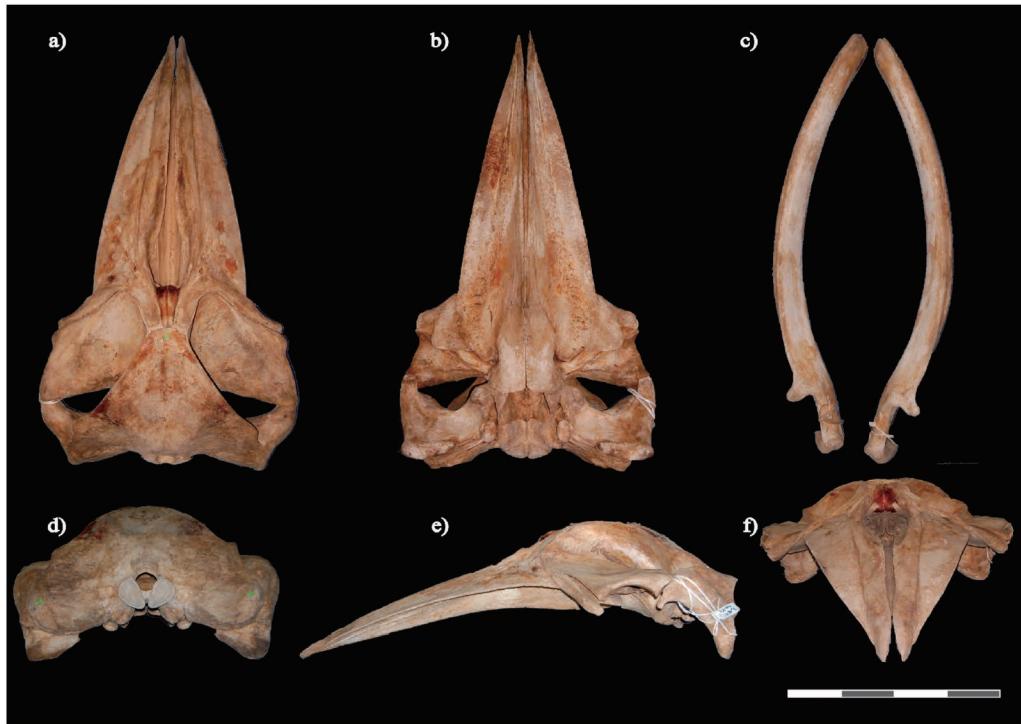
* ICR: Institute of Cetacean Research, KCM: Kushiro City Museum, MBIK: Marine Biodiversity Institute of Korea

Table 5. Measurements on cranium and mandible with some biological information on gray whales.

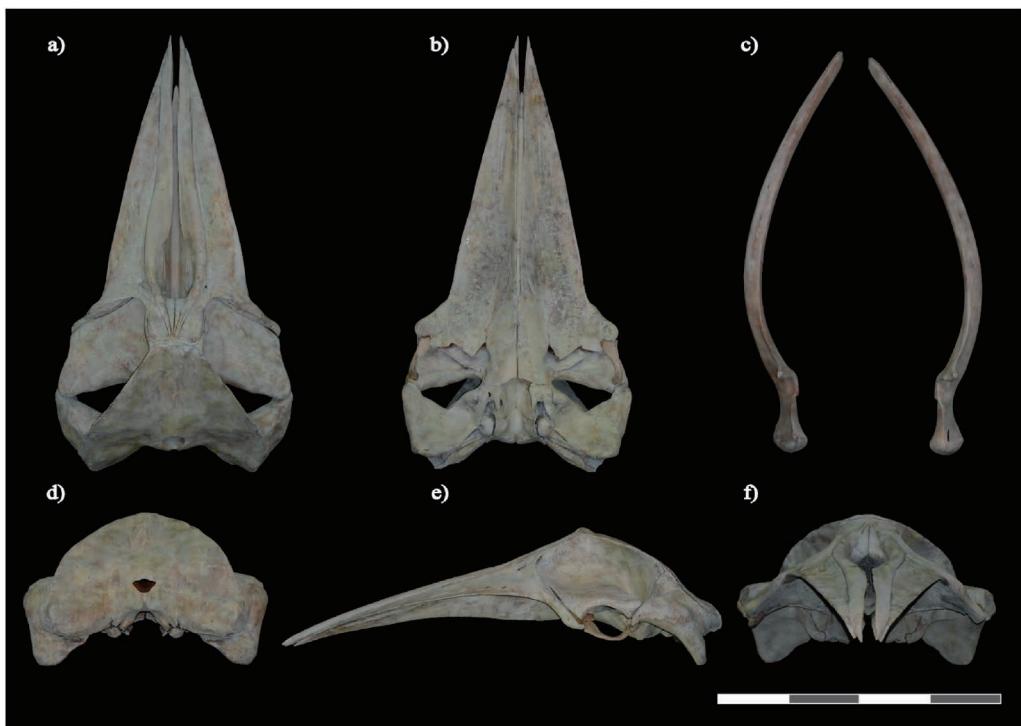
Locality	<i>Eschrichtius robustus</i>				
	Enoshima, Onagawa, Miyagi pref.	Toyokoro, Obihiro, Hokkaido	Kohzu, Kanagawa pref.	Miyazaki beach, Miyazaki pref.	
Sex	F	F	M	UNK	
Body length (m)	12.79	7.75	9.50	8.00	Est. 7.7
Current affiliation*	TUMSAT	Ishinomaki city	AMP	KPM	NZM
ID	M804A	M804B	AMP-R9	KPM-NF1001969	NZM-159
1. Condylo-basal length	259.5	146.1	187.5	145.8	
2. Length of rostrum (median)	181.9	91.1	125.3	89.3	
3. Length of premaxillary (L)	213.4	112.1	146.2	105.0	
4. Length of premaxillary (R)	212.4	111.7	149.5	103.8	
5. Length of maxillary (L)	190.0	98.3	137.9		
6. Length of maxillary (R)	192.8	98.4	135.4		
7. Tip of premaxillary to tip of maxillary (L)	11.7	6.0	6.0	4.2	
8. Tip of premaxillary to tip of maxillary (R)	10.1	5.8	7.4	2.5	
9. Tip of premaxillary to nares, anterior	179.4	94.3	126.5	88.8	
10. Tip of premaxillary to palatine, anterior (L)	180.5	91.0	126.6	89.1	
11. Tip of premaxillary to palatine, anterior (R)	182.3	90.7	125.9	90.9	
12. Tip of premaxillary to palatine, posterior (L)	219.3	116.5	157.8	117.4	
13. Tip of premaxillary to palatine, posterior (R)	220.4	117.5	158.3	117.8	
14. Tip of premaxillary to pterygoid process (L)	231.2	124.8	166.2	123.0	
15. Tip of premaxillary to pterygoid process (R)	230.2	124.1	166.0	122.6	
16. Length of vomer	177.0	91.3	128.5		
17. Breath of rostrum at base	61.5	34.7	42.9	35.0	
18. Breath of rostrum at middle	39.7	20.2	26.2	22.8	
19. Breath of premaxillary at middle	15.6	12.3	11.6	13.1	
20. Greatest width of premaxilla	34.8	20.4	27.3	22.4	
21. Breadth of cranium, maxillaries	87.6	50.7	64.1	52.0	
22. Breadth of cranium, anterior edge of zygomatic process	120.5	72.2	83.4	71.2	80.3
23. Breadth of cranium, middle of orbital foramen	96.8	50.8	67.8	55.7	65.3
24. Breadth of occipital bone	87.6	51.0	63.7	50.6	57.9
25. Length from upper ridge of foramen magnum to superior part of occipital bone	53.6	34.7	43.7	34.7	38.8
26. Greatest breadth of palatine	36.0	22.6	26.1	25.1	
27. Length of palatine (L)	43.9	28.9	36.6	27.2	
28. Length of palatine (R)	41.8	28.4	36.6	27.0	33.9
29. Length of orbit (L)	17.5	13.5	15.6	13.8	
30. Length of orbit (R)	17.1	13.0	15.7	14.6	14.7
31. Length of nasals, curved	34.0	16.8	24.4	20.3	
32. Breadth of nasal at middle	18.2	7.7	11.2		
33. Breadth of nasal, anterior	18.9	10.8	16.8	11.6	13.8
34. Minimum breadth of parietal bones	24.7		22.6	17.1	
40. Height of foramen magnum	10.4	7.7	12.0	8.1	9.9
41. Breadth of foramen magnum	10.4	9.0	9.9	6.9	8.9
42. Breadth across occipital condyles	30.5	20.5	25.2	19.5	23.3
43. Height of occipital condyle (L)	20.9	15.4	17.8	14.9	17.8
44. Height of occipital condyle (R)	21.0	15.6	17.4	14.5	18.2
45. Length of tympanic bullae (L)	10.5	9.0	9.5	9.1	10.8
46. Minimum breadth of tympanic bullae (L)	7.8				
47. Greatest breadth of tympanic bullae (L)	9.8	8.4	8.3	8.3	9.2
48. Length of mandible, straight (L)	249.8	133.5	173.2	138.4	156.5
49. Length of mandible, straight (R)	246.6	131.5	173.7	139.5	158.9
50. Length of mandible, curved (L)	253.6	136.0		138.5	157.2
51. Length of mandible, curved (R)	254.0	136.0		139.8	155.6
52. Breadth of mandible at middle (L)	10.4	5.8	7.3	5.3	6.9
53. Breadth of mandible at middle (R)	12.3	5.6	6.9	5.1	6.8
54. Height of mandible at middle (L)	33.8	13.8	18.5	15.3	17.6
55. Height of mandible at middle (R)	33.3	14.1	18.0	15.3	16.7
56. Height of mandible at coronoid (L)	44.3	23.2	31.4	21.5	26.2
57. Height of mandible at coronoid (R)	45.4	23.4	30.8	22.1	26.5
58. Breadth of mandible at coronoid (L)	20.9	10.1	14.7	10.4	11.8
59. Breadth of mandible at coronoid (R)	21.3	10.2	15.3	10.8	12.0

*TUMSAT: Tokyo University of Marine Science and Technology, AMP: Ashoro Museum of Paleontology, KPM: Kanagawa Prefectural Museum of Natural History, NZM: Miyazaki Prefectural Museum of Natural History

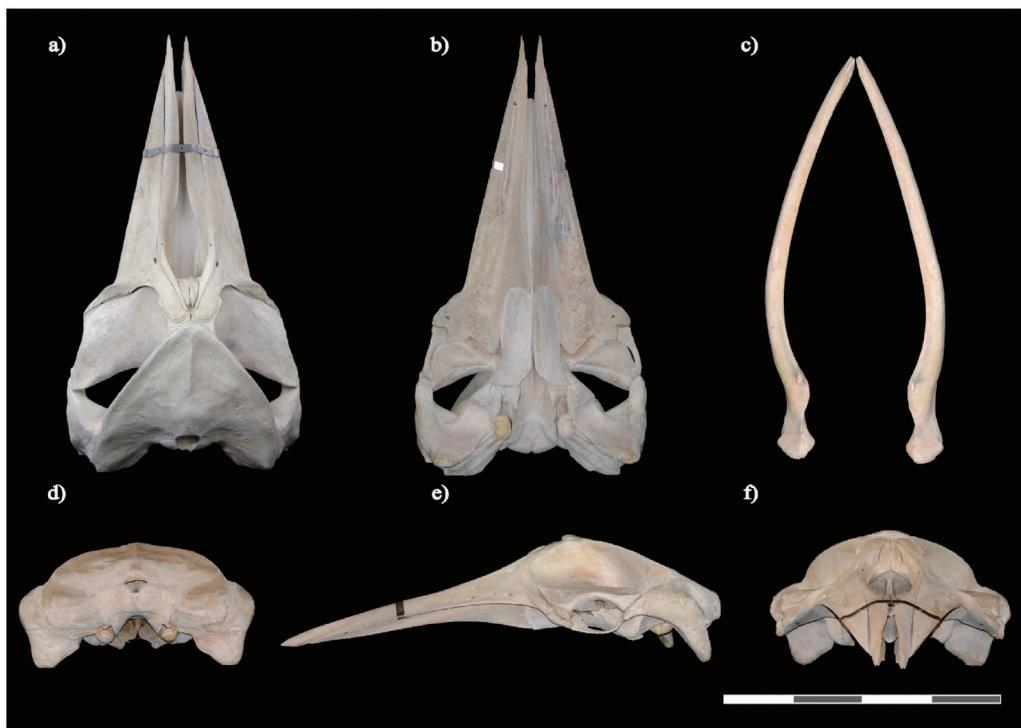
Appendix 1. Photographs of the cranium and mandible of Antarctic minke whale (93/94–287). a) dorsal view of cranium, b) ventral view of cranium, c) dorsal view of mandibles, d) caudal view of cranium, e) lateral view of cranium and f) frontal view of cranium. Scale bar indicates one meter.



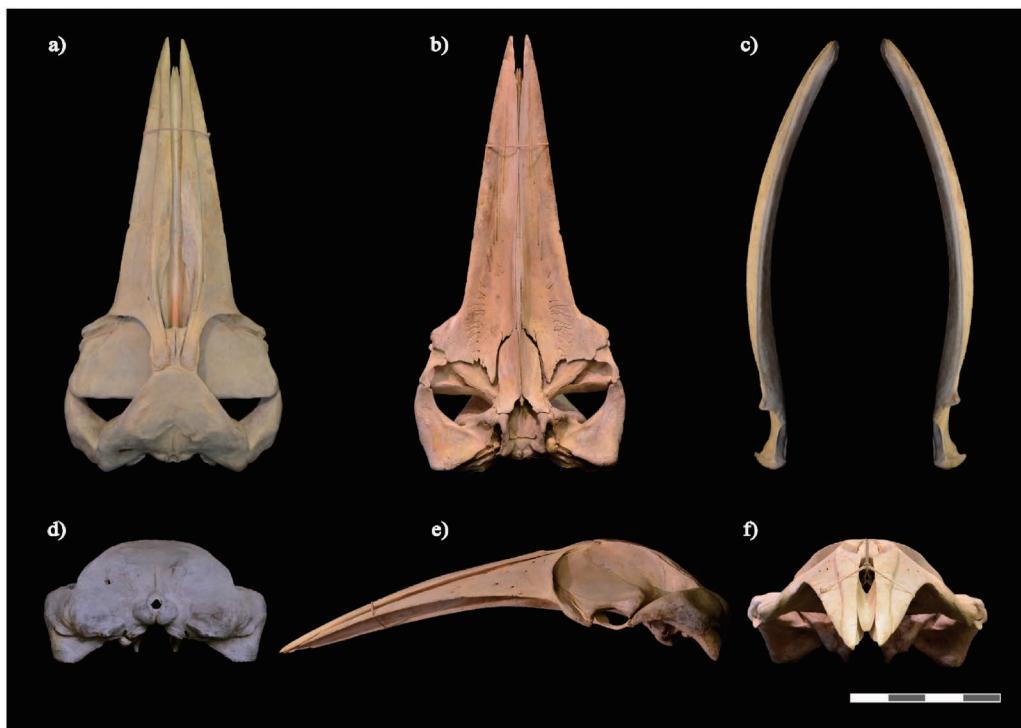
Appendix 2. Photographs of the cranium and mandible of dwarf minke whale (87/88–273). a) dorsal view of cranium, b) ventral view of cranium, c) dorsal view of mandibles, d) caudal view of cranium, e) lateral view of cranium and f) frontal view of cranium. Scale bar indicates one meter.



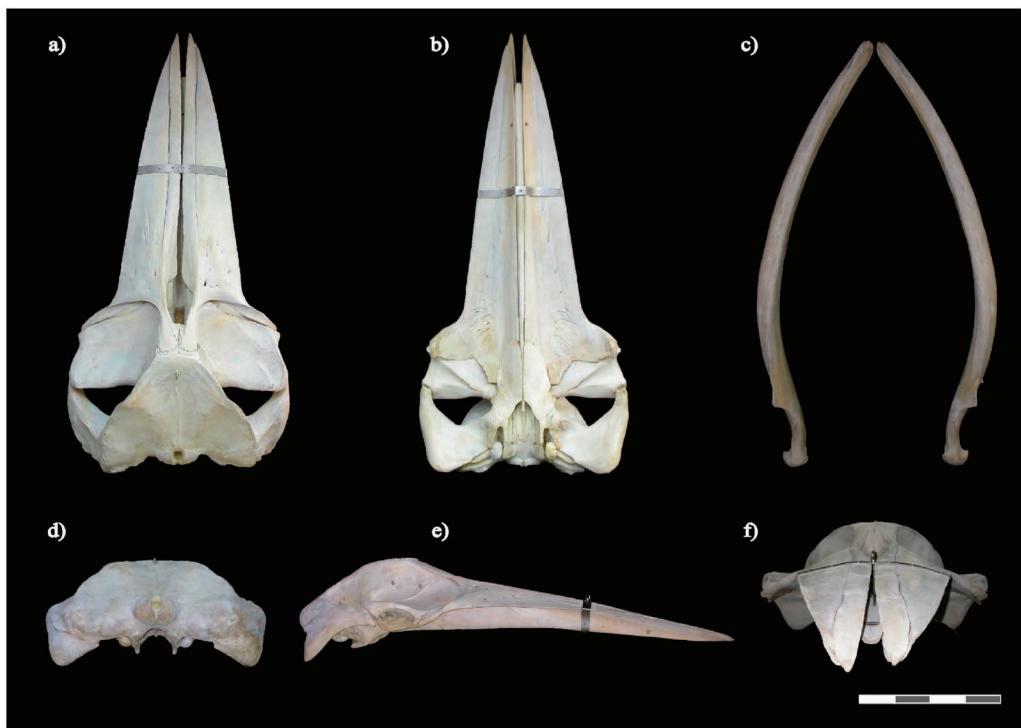
Appendix 3. Photographs of the cranium and mandible of common minke whale from the North Pacific (05NPCK-M001). a) dorsal view of cranium, b) ventral view of cranium, c) dorsal view of mandibles, d) caudal view of cranium, e) lateral view of cranium and f) frontal view of cranium. Scale bar indicates one meter.



Appendix 4. Photographs of the cranium and mandible of sei whale from the North Pacific (03NP-SE045). a) dorsal view of cranium, b) ventral view of cranium, c) dorsal view of mandibles, d) caudal view of cranium, e) lateral view of cranium and f) frontal view of cranium. Scale bar indicates one meter.



Appendix 5. Photographs of the cranium and mandible of Bryde's whale from the North Pacific (00NP-B006). a) dorsal view of cranium, b) ventral view of cranium, c) dorsal view of mandibles, d) caudal view of cranium, e) lateral view of cranium and f) frontal view of cranium. Scale bar indicates one meter.



Appendix 6. Photographs of the cranium and mandible of gray whale (M804A). a) dorsal view of cranium, b) ventral view of cranium, c) dorsal view of mandibles, d) caudal view of cranium, e) lateral view of cranium and f) frontal view of cranium. Scale bar indicates one meter.

