A COMPARISON OF THE SIZE OF VERTEBRAE AMONG SOME SPECIES OF THE BALEEN WHALES WITH SPECIAL REFERENCE TO WHALE MOVEMENTS

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ABSTRACT

In the baleen whales the caudal region occupies about 30% of the total combined length of the skull and vertebrae, notwithstanding the different size of the skull and regardless of the number of vertebrae. Long distant migrating species and fast swimmers have more developed vertebrae in the posterior portion of the lumbar and in the anterior portion of the caudal regions than in the other species.

INTRODUCTION

In the past the osteological studies of whales were carried out mainly from the taxonomic viewpoint and most of the authors deal with skull in detail, but they placed lesser weight on the vertebrae except their number. Consequently only a few papers report detailed measurements of each vertebra, but now they cover seven species of baleen whales i.e. Greenland right, black right, gray, pygmy blue, sei, Bryde's, and minke whales. In this paper these measurements are treated for the comparison of vertebrae among these species, in a hope that such study may give a basis for the ecological study of baleen whales e. g. feeding, swimming or migration. As to the three remaining important species, ordinary blue, fin, and humpback whales, no material is still available for inclusion in this study.

MATERIAL

In order to compare the size of vertebrae among different species it is desirable to use fully grown up or physically matured specimens, because it is well established that the proportions of the whale body are changeable during the course of growth in almost all species, but this is not possible at present. The materials used in this study are shown in Table 1. As seen in this table the Greenland right and gray whale specimens are very small and young. Nishiwaki and Kasuya (1970a, 1970b) presume on their ages about 1.36 years for the Greenland right whale and between one and two years for the gray whale. In addition to this for the size of the vertebral body they present only the length of the centra and no figure of their height and breadth is given. Accordingly these two species are treated separately from others in detailed calculation of the size of vertebrae.

Among the other species only the black right and pygmy blue whale specimens are physically matured, since all of the vertebral epiphyses are fused completely to

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TABLE 1. LIST OF MATERIALS USED IN THIS STUDY

Species	Common name	Sex	Body length (m)	Maturity	Author
Balaena mysticetus	Greenland right whale	M	6.4	Very young	Nishiwaki and Kasuya 1970a
Eubalaena glacialis	Black right whale	M	17.1	Physically mature	Omura *et al.*, 1969
*Eschrichtius robustus**	Gray whale	F	9.0	Very young	Nishiwaki and Kasuya, 1970b
Balaenoptera musculus brevicauda	Pygmy blue whale	M	18.6	Physically mature	Omura *et al.*, 1970
B. borealis	Sei whale	F	12.9	Physically immature	Omura, 1959
B. edeni	Bryde's whale	F	13.5	Physically immature	Omura, 1959
B. acutorostrata	Minke whale	M	7.5	Physically immature	Omura, 1957

* After Kasuya and Rice, 1970.

their centra. Specimens of the sei, Bryde's, and minke whales are all physically immature, though in the latter two specimens sexual maturity was already attained, and for the sei whale the specimen is thought at or approaching puberty.

In the light of the different stages of growth the conclusion derived from these specimens are consequently premature.

LENGTH OF SKULL AND VERTEBRAE

Table 2 shows the lengths of the skull and vertebrae, in actual length in mm as well

TABLE 2. SKULL AND VERTEBRAL LENGTH IN SEVEN SPECIES OF BALEEN WHALES

Species	Skull	Cervical	Dorsal	Lumbar	Caudal	Total
			(Actual figure in mm)			
G. right	1,980	174 (7)	820 (12)	1,013 (10)	1,873 (24)	5,860 (53)
B. right	5,100	274 (7)	2,479 (14)	2,576 (10)	4,658 (25)	15,087 (56)
Gray	2,000	338 (7)	1,489 (14)	1,911 (12)	2,736 (23)	8,474 (56)
P. blue	4,860	618 (7)	2,949 (15)	2,750 (14)	4,737 (27)	15,914 (63)
Sei	3,062	425 (7)	2,116 (14)	2,942 (13)	3,768 (22)	12,313 (56)
Bryde's	3,480	441 (7)	2,125 (13)	3,272 (13)	3,374 (21)	12,692 (54)
Minke	1,520	241 (7)	1,100 (11)	1,951 (12)	2,019 (18)	6,831 (48)
			(% figure)			
G. right	33.79	2.97	13.99	17.29	31.96	100.00
B. right	33.80	1.82	16.43	17.08	30.87	„
Gray	23.60	3.99	17.57	22.55	32.29	„
P. blue	30.54	3.88	18.53	17.28	29.77	„
Sei	24.87	3.45	17.19	23.89	30.60	„
Bryde's	27.42	3.48	16.74	25.78	26.58	„
Minke	22.25	3.53	16.10	28.56	29.56	„

Figures in parentheses show number of vertebrae.

as their proportional length, for seven species of the baleen whales. For the vertebrae the length of each centrum are added, dividing into four regions i. e. cervical, dorsal, lumbar, and caudal. The total length of the vertebrae in this table does not denote, therefore, the total length of the back bone *in situ*, because spaces between vertebrae are neglected.

Fig. 1 shows the proportional length of the skull and each region of vertebrae against the combined length of the skull and vertebrae, comparing each species. As seen in this figure the skull length is greatest proportionally in the Greenland right and black right whales and it occupies 34% or one third of the total length in both species. In the other species only the pygmy blue whale exceeds 30% and the smallest figure is 22% of the minke whale. Thus in the proportional length of the skull there is a big difference by species. For the Greenland and black right whales the huge size of the skull can be explained by the different type of feeding (skimming) than the other species (swallowing or both types combined, Nemoto 1959), but it is thought rather difficult in the other species at least at present to explain the slight difference among them in connection with feeding.

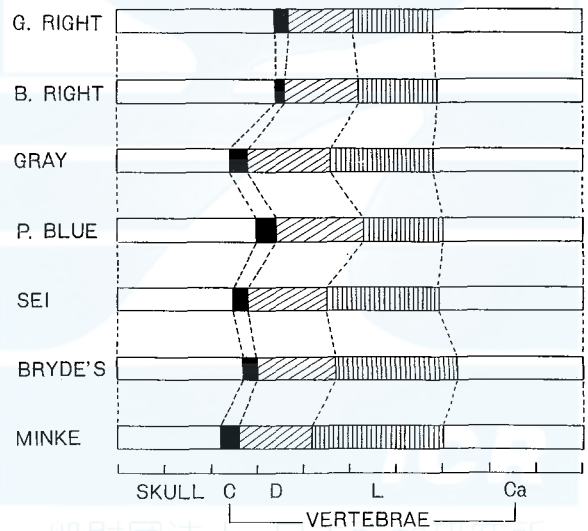

Fig. 1. Proportional length of skull and vertebrae in seven species of baleen whales.

The pygmy blue whale has comparatively large skull than other species except those of Balaenidae, but before going into detail the material for the ordinary blue whale as well as those of the fin and humpback whales are needed.

On the other hand the proportional length of the caudal region of the vertebrae is almost similar in these species, notwithstanding rather big difference in their number (Table 2). The greatest number of the caudal vertebrae is 27 of the pygmy blue whale and the smallest is 18 of the minke, but the proportional length of this region is quite similar, showing 30% in both species. The smallest percentage figure

of this region is 27% of the Bryde's whale, which does not follow long distant migration and living locally. The highest figure is 32% of the Greenland right and gray whales, but both specimens are very young as stated before and there is a possibility of decreasing with growth. In any case it can be concluded that the caudal region occupies about 30% of the combined length of the skull and vertebrae in most of the baleen whales and this length may be required for swimming.

It is also seen from Fig. 1 that the difference in the length of the skull is balanced by the length of the dorsal and lumbar regions of the vertebrae, especially by the latter. The largest number of the lumbar vertebrae is 14 of the pygmy blue whale, but the proportional length of this region of the specimen is 17%, which is the lowest among the balaenopterid whales and lesser than the gray. The proportional length of the dorsal region is roughly proportional to the number of the dorsal vertebrae.

The proportional length of cervical region is smallest in the black right whale, but no remarkable difference in length of this region is noted among the species.

SIZE OF VERTEBRAE

In order to compare the size of each vertebra among the species of the baleen whales I made calculation of the mean length of the centrum using the following formula:

$$\text{Mean length} = \sqrt[3]{axbxc}$$

where a, b and c are the breadth, height and length of the centrum respectively.

The mean length thus calculated can be used as an index of the volume of the centrum. The results of the calculation are shown in Appendix Table 1 for the black right, pygmy blue, sei, Bryde's, and minke whales. The original measurements used in this calculation are given by the authors listed in Table 1.

Then I have calculated the percentage figures of the mean length of each vertebra, using the first lumbar vertebra as a standard. The results are shown in Appendix Table 2. In the table figures for the Greenland right and gray whales are also shown for reference, but in these two species only the length of the centrum was used due to lack of material and hence these figures do not denote the volume of the centra.

Fig. 2 shows the proportional size of each vertebra against the first lumbar in five species of the baleen whales based upon the values shown in Appendix Table 2. As seen in Fig. 2 there is no remarkable difference in the proportional size of vertebra in the cervical and dorsal regions, but quite large difference are present in the posterior portion of the lumbar region and in the anterior portion of the caudal region. The highest value in these regions are those of the minke whale, which follows long distant migration. In this species the lesser number of vertebrae are covered by the well developed vertebrae in these regions.

In comparing the sei and Bryde's whales it is notable that the caudal vertebrae in the anterior portion are much developed in the former than in the latter, due to possibly the difference in extent of the migration between the two species. The sei

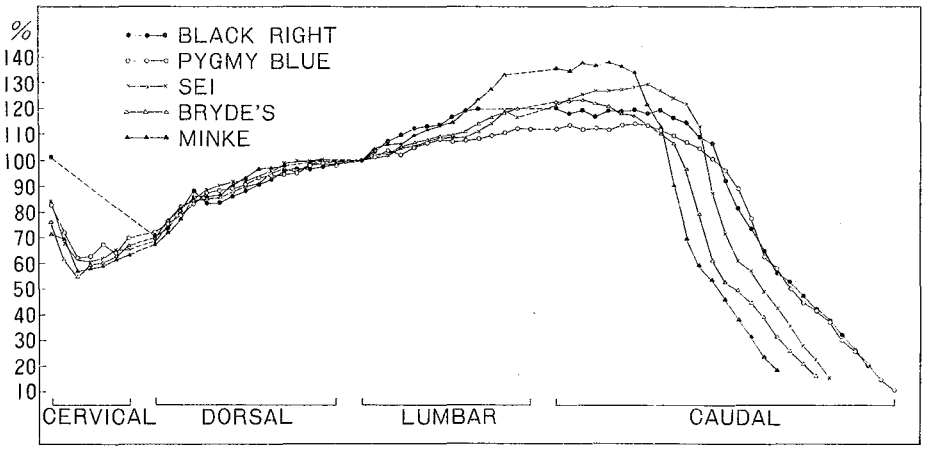

Fig. 2. Comparison of size of vertebra against first lumbar in five species of baleen whales.

whale is migratory, even though extent of its movement is thought lesser than that of the blue and fin whales. In the Antarctic it distribute mostly in the northern part of the whaling ground and in the North Pacific its movement is confined up to the Aleutian chain and very seldomly enters into the Bering Sea, whereas the fin whale penetrates through the Bering Strait into the Arctic basin. But still it has much wider range of migration than the Bryde's whale, which is only a local population. In the offshore waters of Japan the distribution of the Bryde's whale is confined from the Bonin Islands in the south to the east coast of Sanriku in the north and it is seldom to travel beyond 40 degree North Latitude. The highest value of the sei whale is at 7th caudal (128%) and that of the Bryde's whale is at 3rd caudal (124%).

The relation between the black right and pygmy blue whales is also of some interest. In general the curves for the two species show similar tendency, but in

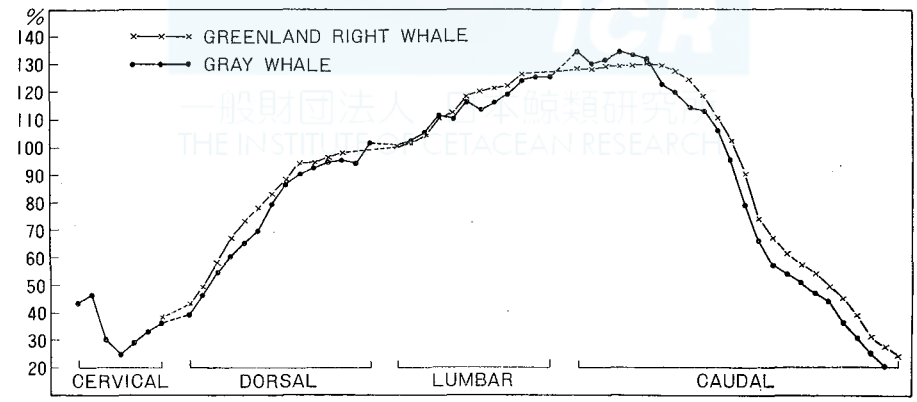

Fig. 3. Percentage length of each vertebra against first lumbar in the Greenland and gray whales.

the black right whale the vertebrae are more developed than the pygmy blue whale in the lumbar region and up to 13th caudal. Both whales are slow swimmer and very little is known of the migration of the pygmy blue whale. It is highly possible, however, that the range of migration is much wider in the black right whale than in the other which is thought to be only a local population.

In conclusion above it can be safely said that in the species which follow long distant migration and in the fast swimmers the vertebrae in the posterior portion of the lumbar and in the anterior portion of the caudal are much developed than the other.

Fig. 3 shows the proportional length of each vertebra of the Greenland right and gray whales. Both curves are similar in general and each corresponding value is smaller in the gray whale than in the Greenland right whale, except those in the caudal region, up to 6th caudal. The Greenland right whale is inhabiting in the Arctic Ocean, whereas the gray whale migrate very long distance between the coast of Mexico and Arctic Ocean, passing through the Bering Strait. It seems rather queer the general agreement of these curves, but since the both specimens are very young and they are presumed below two years, as stated before, and since these curves denote only the lengths of the centra, no definite conclusion may be derived from this figure in relation to movement of whales. Or an explanation may be that that no remarkable difference in the size of vertebrae is present among different species of whales when they are young and the difference in size noted before are developed during the course of growth of the whale body.

REFERENCES

KASUYA, T. and D. W. RICE, 1970. Notes on baleen plates and on arrangement of parasitic barnacles of gray whale. *Sci. Rep. Whales Res. Inst.*, 22: 39–43.

NEMOTO, T., 1959. Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst.*, 14: 149–290.

NISHIWAKI, M. and T. KASUYA, 1970a. Recent record of gray whale in the adjacent waters of Japan and a consideration on its migration. *Sci. Rep. Whales Res. Inst.*, 22: 29–37.

NISHIWAKI, M. and T. KASUYA, 1970b. A Greenland right whale caught at Osaka Bay. *Sci. Rep. Whales Res. Inst.*, 22: 45–62.

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., 1959. Bryde's whales from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, 14: 1–33.

OMURA, H., S. OHSUMI, T. NEMOTO, K. NASU and T. KASUYA, 1969. Black right whales in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 21: 1–78.

OMURA, H., T. ICHIHARA and T. KASUYA, 1970. Osteology of pygmy blue whale with additional information on external and other characteristics. *Sci. Rep. Whales Res. Inst.*, 22: 1–27.

APPENDIX TABLE 1. MEAN LENGTH OF VERTEBRAE OF FIVE SPECIES OF BALEEN WHALES

Mean length = $\sqrt[3]{a \times b \times c}$
where a: breadth; b: height; c: length; of each vertebra in mm.

Vertebral No.	Black right	Pygmy blue	Sei	Bryde's	Minke
C 1		233	165	160	87
2		202	133	129	85
3		173	122	116	70
4	294	175	118	126	71
5		187	121	127	72
6		178	126	133	76
7		196	129	141	78
D 1	205	202	134	147	83
2	214	211	146	157	89
3	231	220	157	167	95
4	253	232	167	177	104
5	241	244	173	179	106
6	243	247	177	180	106
7	250	249	180	185	111
8	257	254	181	188	114
9	265	260	184	192	118
10	272	263	188	198	118
11	276	265	192	200	119
12	279	266	194	201	—
13	281	271	193	206	—
14	283	273	195	—	—
15	—	275	—	—	—
L 1	292	281	197	211	123
2	300	285	199	214	127
3	313	292	201	217	131
4	321	287	206	222	131
5	328	295	207	225	135
6	329	300	211	228	138
7	333	304	214	231	140
8	341	301	215	232	141
9	348	303	215	235	146
10	350	304	219	241	152
11	—	309	225	246	157
12	—	312	235	251	164
13	—	315	230	254	—
14	—	316	—	—	—
Ca 1	352	316	239	259	167
2	345	319	244	260	166
3	349	316	248	261	170
4	343	317	251	258	169
5	350	316	251	256	170
6	348	321	252	251	168
7	349	323	253	248	159
8	345	319	251	241	150

Continued . . .

APPENDIX TABLE 1. Continued.

Vertebral No.	Black right	Pygmy blue	Sei	Bryde's	Minke
Ca 9	350	314	241	233	138
10	341	309	235	225	111
11	336	302	221	204	86
12	319	295	204	167	73
13	312	284	172	129	66
14	270	271	142	111	57
15	239	251	121	105	47
16	215	219	113	95	39
17	189	177	97	83	29
18	164	163	84	67	23
19	154	141	70	55	—
20	138	133	55	44	—
21	123	118	45	34	—
22	109	105	31	—	—
23	93	85	—	—	—
24	77	72	—	—	—
25	60	59	—	—	—
26	—	42	—	—	—
27	—	31	—	—	—

APPENDIX TABLE 2. PERCENTAGE LENGTH OF EACH VERTEBRA AGAINST FIRST LUMBAR

Mean length, shown in Appendix Table 1, are used for comparison, except last two columns in which species only vertebral lengths are available.

Vertebral No.	B. right	P. blue	Sei	Bryde's	Minke	(G. right)	(Gray)
C 1		82.92	83.76	75.83	70.73		42.86
2		71.89	65.51	61.14	69.11		45.71
3		61.57	61.93	54.98	56.91		30.00
4	100.68	62.28	59.90	59.72	57.72	157.30	25.00
5		66.55	61.42	60.19	58.54		28.57
6		63.35	63.96	63.03	61.79		32.86
7		69.75	65.48	66.82	63.41	38.20	36.43
D 1	70.21	71.89	68.02	69.67	67.48	42.70	39.29
2	73.29	75.08	74.11	74.41	72.36	49.44	46.43
3	79.11	78.29	79.70	79.15	77.24	58.43	53.57
4	86.64	82.56	84.77	83.89	84.55	67.42	60.00
5	82.53	86.83	87.82	84.83	86.18	73.03	65.00
6	83.22	87.90	89.85	85.31	86.18	77.53	68.57
7	85.62	88.61	91.37	87.68	90.24	83.15	79.29
8	88.01	90.39	91.88	89.10	92.68	87.64	85.71
9	90.75	92.53	93.40	91.00	95.93	94.38	90.00
10	93.15	93.59	95.43	93.84	95.93	94.38	92.14
11	94.52	94.31	97.46	94.79	96.75	95.51	93.57
12	95.55	94.66	98.48	95.26	—	97.75	95.00
13	96.23	96.44	97.97	97.63	—	—	93.57

Continued . . .

APPENDIX TABLE 2. Continued.

Vertebral No.	B. right	P. blue	Sei	Bryde's	Minke	(G. right)	(Gray)
14	96.92	97.15	98.98	—	—	—	101.43
15	—	97.86	—	—	—	—	—
L 1	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	102.74	101.42	101.02	101.42	103.25	102.25	102.14
3	107.19	103.91	102.03	102.84	106.50	104.49	105.00
4	109.93	102.14	104.57	105.21	106.50	111.24	110.71
5	112.33	104.98	105.08	106.64	109.76	112.36	110.00
6	112.67	106.76	107.11	108.06	112.20	117.98	116.43
7	114.04	108.19	108.63	109.48	113.82	120.22	112.86
8	116.78	107.12	109.14	109.95	114.63	121.35	115.71
9	119.18	107.83	109.14	111.37	118.70	122.47	118.57
10	119.86	108.19	111.17	114.22	123.58	125.84	123.57
11	—	109.96	114.21	116.59	127.64	—	125.00
12	—	111.03	119.29	118.96	133.33	—	125.00
13	—	112.10	116.75	120.38	—	—	—
14	—	112.46	—	—	—	—	—
Ca 1	120.55	112.46	121.32	122.75	135.77	128.09	133.57
2	118.15	113.52	123.86	123.22	134.96	128.09	130.00
3	119.52	112.46	125.89	123.70	138.21	129.21	131.43
4	117.47	112.81	127.41	122.27	137.40	129.21	133.57
5	119.86	112.46	127.41	121.33	138.21	129.21	132.86
6	119.18	114.23	127.92	118.96	136.59	130.34	131.43
7	119.52	114.95	128.43	117.54	129.27	130.34	122.14
8	118.15	113.52	127.41	114.22	121.95	126.97	119.29
9	119.86	111.74	122.34	110.43	112.20	123.60	114.29
10	116.78	109.96	119.29	106.64	90.24	117.98	112.86
11	115.07	107.47	112.18	96.68	69.92	110.11	106.43
12	109.25	104.98	103.55	79.15	59.35	102.25	95.00
13	106.85	101.07	87.31	61.14	53.66	89.89	79.29
14	92.47	96.44	72.08	52.61	46.34	74.16	66.43
15	81.85	89.32	61.42	49.76	38.21	67.42	57.14
16	73.63	77.94	57.36	45.02	31.71	60.67	54.29
17	64.73	62.99	49.24	39.34	23.58	57.30	50.71
18	56.16	58.01	42.64	31.75	18.70	53.93	47.14
19	52.74	50.18	35.53	26.07	—	49.44	44.29
20	47.26	47.33	27.92	20.85	—	44.94	36.43
21	42.12	41.99	22.84	16.11	—	39.33	30.71
22	37.33	37.37	15.74	—	—	31.46	25.00
23	31.85	30.25	—	—	—	26.97	unknown
24	26.37	25.62	—	—	—	23.60	—
25	20.55	21.00	—	—	—	—	—
26	—	14.95	—	—	—	—	—
27	—	11.03	—	—	—	—	—