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Body weights of some species of large whales

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Body weight data for the large species of Cetacea: right, gray, blue, fin, Bryde, sei, humpback and minke whales, have been compiled from various sources, and used to formulate body weight/length relationships. All the cetacean body weights examined can be related to body length in the formulation $W = aL^b$, where W is body weight in tonnes and L is body length in m. Generally, the value of b falls within the range $3{\cdot}0 \pm 0{\cdot}6$ for the species examined. Weight/length formulae have been adjusted to allow for blood and fluid losses during flensing: 6% body weight in baleen whales and 10% body weight in the toothed sperm whale. These adjusted formulae have been used to calculate the biomass of the whale catches in the Antarctic since 1904. Comparisons of weight proportions of body tissues in different species show that right whales are the heaviest whales for a given length and carry the greatest proportion of blubber fat. The baleen whales of the genus *Balaenoptera* (blue, fin, Bryde, sei and minke) carry greater proportions of muscle tissue than the other species.

Introduction

Cetaceans represent a mammalian order which possibly has the greatest variation in size and weight in the entire animal kingdom. Body weights of adult marine Cetacea range from 50 kg for a small dolphin to nearly 200000 kg for a large blue whale.

The methods of weighing whales involve considerable difficulty compared with those employed for dolphins. Size and enormous bulk of the whale carcase present manoevrability problems which are not easily resolved. However, there has been much interest in the weights of whales ever since the advent of full-scale commercial whaling, in connection with product yield. Where possible, a few weighings have been performed and these data have been used to deduce formulae relating weight to linear measurements which may be made simply.

The body length in large whales is measured in a standard way for all species, according to international fishery regulation by the International Whaling Commission. The length is recorded as the distance, taken in a straight line not along the curve of the body, between the tip of the snout and the notch between the tail flukes. Body lengths for different whales are thus directly comparable, and represent the total length as closely as possible. The early formulae produced by Guldberg (1907), Heyerdahl (1932), Laurie (1933) and Zenkovich (1937) gave results which were somewhat speculative.

All authors believed that the whale shape which is essentially streamlined and torpedo-shaped (dorsal and pectoral fins and tail flukes, all necessary for stability and manoevrability, are the only projecting appendages) could be reduced to a simple mathematical model. Guldberg (1907) proposed a model of two cones joined at their bases to describe the whale shape and calculate weight:

$$V = G = \frac{1}{3}\,\frac{\pi}{4}\,D^2L$$

or

$$V = G = \frac{1}{38}\,O^2L$$

where V = body volume, G = body weight, D = diameter of the body at the widest part, L = body length overall i.e. from snout tip to the notch between the tail flukes, O = body circumference at the widest part.

Heyerdahl (1932) made slight adjustments to Guldberg's formula on the basis of a few actual whale weights:

$$V = G = \frac{1}{41}\,O^2L$$

and attempted a special allowance for "fattened" whales:

$$V = G = \frac{1}{44}\,O^2L.$$

Laurie (1933) constructed curves of body weight/overall body length for the blue whale using the formulation of D'Arcy Thompson (1942):

$$W \propto L^3$$

where W = body weight, L = overall body length.

Zenkovich (1937) attempted adjustments for different species:

$$V = L\frac{D^2}{3}$$

for all baleen whales except humpback whales when the formula

$$V = L\frac{D^2}{4} \quad \text{is used.}$$

Schultz (1938), using actual weight data for several species, recognised that there was no absolute cubic relation between weight and length and used a formula of the type:

$$W = a\,L^b$$

which he evaluated for universal application.

$$W = 0{\cdot}0000269\,L^{2{\cdot}789}$$

where W is in kg, L is in cm. This type of formula has been found most useful and is widely used in analysing whale weight data, chiefly because overall body length only is required for weight estimation, although the formula is more generally applied in the form:

$$\log_{10} W = b \log_{10} L + \log_{10} a.$$

Ash (1952) proposed a simplified formula for calculating weights:

$$W = KL - C$$

where K and C are constants. However, this formula is not generally applicable because it actually describes the tangent of the weight/length curve at the point of average length and weight, and hence covers only a limited size range accurately.

Ash (1953) has tried to include a provision for weight increases resulting from fattening during the Antarctic summer feeding season, in weight/length formulae, and has put forward an equation predicting product yield with time spent feeding for humpback whales:

$$W = aL - c + bt$$

where W = weight, L = body length overall, t = time elapsed since 1 January, and a, b and c are constants.

Ash's formulae for humpback whales are not based on direct weighings but on bulk fillings of cookers, and his assumptions on the rate of fattening are therefore unlikely to be as accurate as if direct weighings were available.

The types of formulae mentioned are all based on predictions from linear dimensions, with reference to a few actual whale weights. However, an important point to note, as Ash (1952) mentions, is that weight prediction formulae are intended chiefly for estimating average weight and biomass of a catch rather than for the individual animal.

Whale weighings are usually performed with the co-operation of a whaling factory which possesses adequate equipment to accomplish such feats. The task still remains very difficult, and it is not surprising that all the presently available data on whale weighings in the Appendix, except the very few examples where noted, were obtained by weighing the parts from flensed whales. This method has introduced considerable room for error in the estimation of total body weight, since blood and fluids such as that from the peritoneum, oils and actual tissues may be lost during flensing. Also the weighing of different tissues separately is rarely accurate because bones cannot be completely cleaned of muscle on the flensing plan, and visceral organs are frequently damaged or mislaid.

Gambell (1970), with the co-operation of the Union Whaling Company at Durban, weighed a 13·35 m sperm whale whole and also subsequently in parts. He repeated this operation in 1973 on a 11·50 m sperm whale, and the differences in weight between the two methods, 11 to 12% in the former whale and 14 to 15% in the latter, he attributed to fluid losses of various kinds such as blood and oils. These weighings are the only known reliable records of sperm whales, indeed any large whales, weighed both entire and by parts, although there are a few other weighings of intact whale carcases but not also by parts.

The percentage blood volume has been measured for small species of Cetacea and Pinnipedia which are comparable both from a physiological and ecological standpoint. Cleland (1884) estimated a blood volume of 117 ml/kg body weight in a *Phoca vitulina* pup, using Evan's Blue Dye method. Irving (1939) estimated that the blood volume of *Phoca vitulina*, using vital red dye, was approximately 10% of body volume. However, Wasserman and Mackenzie (1957) found that blood volume was 18% in this species, and Harrison et al. (1968) quote a range of 117–126 ml/kg body weight for blood volume in *Phoca vitulina* pups, but a greater range of 10 to 15% blood volume in the adult. Harrison et al. also give a figure of 15% blood volume in *Halichoerus grypus*, and other estimates of blood volume in seals are given by Scholander (1940) as 10% (by direct bleeding) in *Cystophora cristata*, by Elsner (1964) as 12% (by direct bleeding and saline perfusate) in *Mirounga angustirostris*, and by Bryden and Lim (1969) as 16% in a young *Mirounga leonina* and 20·7% in an adult female of this species.

Direct bleeding has not been considered very satisfactory for determining blood volume, and Scholander (1940), who found that bleeding rabbits yielded only 75% or less of total blood volume, extrapolated his results from seals to Cetacea and calculated blood volumes of 15% for *Phocoena phocoena*, *Hyperoödon rostratus* and *Physeter catodon*, and 10% for *Balaenoptera physalus*, basing his assumptions on considerations of facts known of the anatomy and diving ability of these species. Ridgway (1965) has measured values of 71 ml/kg body weight in *Tursiops truncatus*, 108 ml/kg body weight in *Lagenorhyncus obliquidens*, and 143 ml/kg body weight in *Phocaenoides dalli* using Iodine-131 dilution techniques.

Blood volume is only nearly equivalent to blood weight, because the specific gravity of mammal blood is usually of the order of 1·05 to 1·06, (see Spector, 1956). However, inaccuracies in actual weighings already amount to about ±5% of true owing to cumulative or systematic errors originating from double weighing and loss of parts, and most frequently, the inaccurate setting of weigh bridges and balances. Bjarnason and Lingaas (1954) and Nishiwaki (1950) mention sources of weighing errors. For practical purposes however, volume can be equated with weight for blood. A striking feature of marine mammal blood volumes is that they are high compared with terrestrial mammals (see Harrison and King, 1965), and for example with man where blood volume constitutes 46 ml/kg body weight, (see Spector, 1956).

As we have seen earlier, Gambell found that fluid losses during flensing are of the order of 13% (11 to 15%) for two sperm whales. The difference in body weight before and after the flensing of a minke whale carcase (shown in the Appendix as the only baleen whale weighed whole) is approximately 5% of the total weight. Because of its relatively small size compared with other *Balaenoptera*, the minke whale is possibly subject to less blood loss during flensing than some larger species. Bearing in mind that these weight differences before and after flensing include only a proportion of the total blood and body fluids, Scholander's estimates of 15% blood volume in sperm and 10% in fin whales are probably reasonable when at the most only 75% of blood may drain from a carcase. The estimate of blood loss for sperm whales during flensing is likely to be at least 10%, and for large baleen whales something in the order of at least 6%. This means that the weighings of carcases by parts can only represent about 90% of the true body weight in sperm whales and 94% in baleen whales. These corrections have been applied to the formulae in Table 1.

In Table 1, several formulae describing weight/length relationships in commercial species are given. These formulae were originally calculated by the authors indicated for individual samples where the whales were taken under similar circumstances. These formulae have been adjusted to allow for fluid loss, and because of the uniformity in the samples upon which they are based, they are for practical usage such as in estimating catch biomass, preferable to the formulae shown in Table 2 where whales

Table 1. Published weight/length relationships for large Cetacea, here adjusted for fluid losses. These formulae are most applicable to adults and juveniles, excluding calves. W = weight in tonnes, L = length in feet or metres. Most published formulae were originally for L in English feet. a and b refer to formula $W = aL^b$.

Species		Growth constants			
Common name	Latin name	a, when L in feet	a, when L in metres	b	Reference or derivation
Pacific Right	*Eubalaena glacialis sieboldii*	0·000348	0·013200	3·06	Omura et al. (1969)
Blue	*Balaenoptera musculus*	0·000061	0·002899	3·25	Ash (1952)
Fin	*Balaenoptera physalus*	0·000255	0·007996	2·90	Ash (1952)
Sei	*Balaenoptera borealis*	0·001436	0·025763	2·43	Omura (1950a)
Bryde	*Balaenoptera brydei*	0·000500	0·012965	2·74	Fujino (1955)
Minke	*Balaenoptera acutorostrata*	0·003188	0·049574	2·31	Ohsumi, Masaki & Kawamura (1970)
Humpback	*Megaptera novaeangliae*	0·000495	0·016473	2·95	New calculations, using Ash's (1952) data corrected to tonnes
Sperm	*Physeter catodon*	0·000152	0·006648	3·18	Omura (1950a)

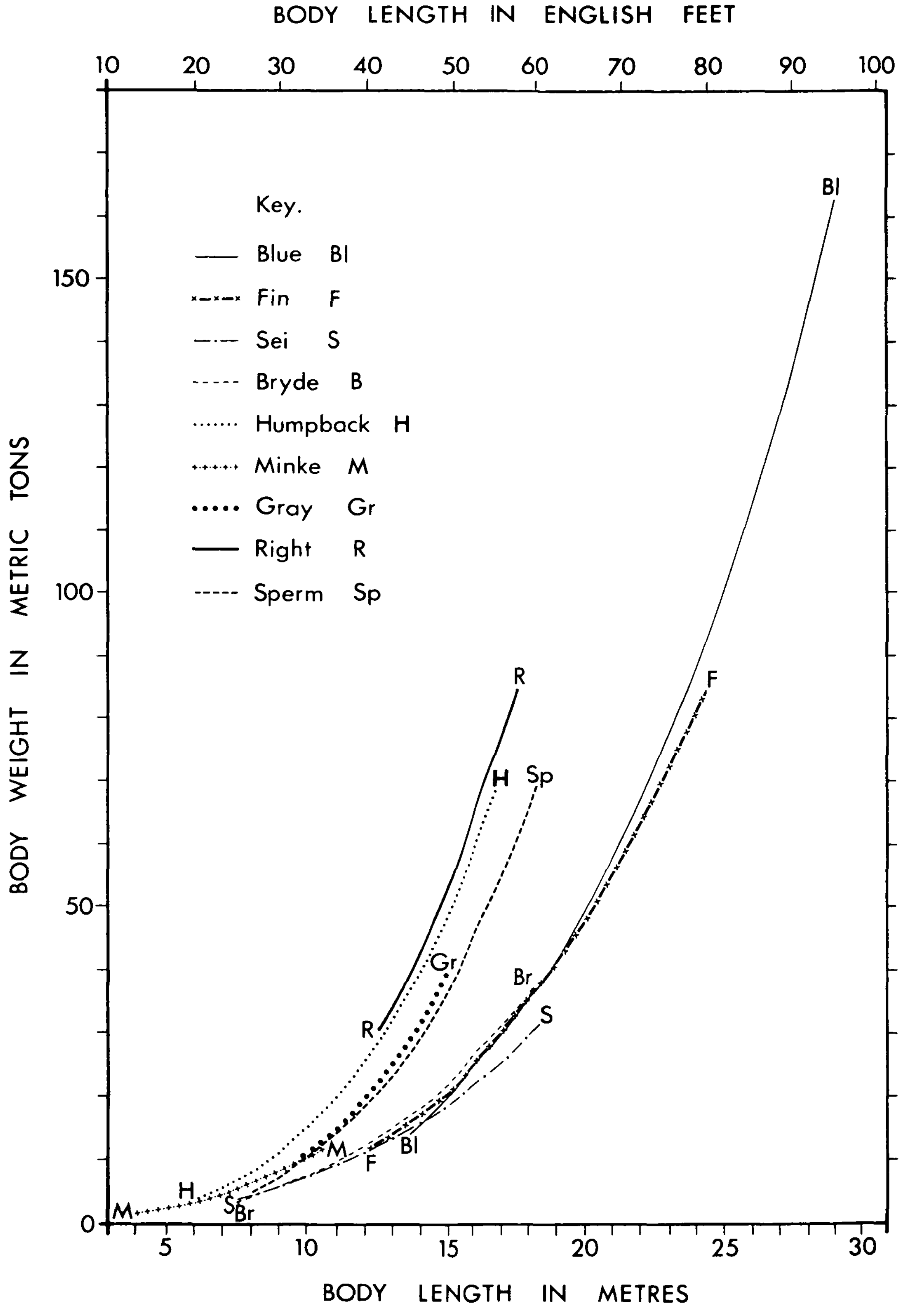

Figure 1. Body weights of large species of Cetacea. Blood and fluid losses have been allowed for as follows: 6% body weight in baleen whales and 10% in sperm whales. All formulae used to predict body weight in tonnes, except that for gray whales where $W = 0{\cdot}0054\,L^{3{\cdot}28}$ (L is in metres), see Table 2, are taken from Table 1.

from various sources have now been combined in deriving weight/length relationships. The ultimate reliability of any results depends much on their subsequent application. The total body weights of commercially exploited whales, based on formulae in Table 1, are shown in Figure 1 from which biomass calculations can easily be made. In Table 2, all available weight data for different species from the world over have been included in calculating weight/length formulae. These formulae have not been corrected for blood loss because they are to be considered as more of academic interest in directly comparing weight/length relationships in different species.

Data, methods and discussion

Comparison of weight/length relationships in some different species of Cetacea

The Appendix summarises the published data available and sources on whale weights for sometime commercially important species. An analysis of the proportions of different tissues in the body by weight for large Cetacea is summarised in Table 3 for several species. The right whale has by far the heaviest proportion of blubber of all species and least proportion of muscle tissue. The sperm whale however has a greater proportion of blubber than the Balaenopteridae. By comparison, the rorquals have a considerably higher proportion of muscle tissue than both the right and sperm whales, and this muscle far exceeds the quantity of blubber in the body. The reverse situation exists in right whales whereas sperm whales appear to carry about equal amounts of each tissue. These variations may be connected with different levels of activity in these species. The rorquals which carry proportionately more muscle than right or sperm whales are the most active species and can swim very fast. Certainly the right whale is one of the slowest whales, as it was the slow swimming speed which caused it to be the preferred species in the early days of whaling before it became over-exploited. The fact that amongst the rorquals the proportion of blubber decreases as the body size of species is re-

Table 2. Formulae for estimating a mean body weight from overall body length for different species of Cetacea using data given in the Appendix. Fluid losses have not been compensated here for animals not weighed whole, but may be allowed for by assuming calculated body weight is 90% total weight in Odontoceti and 94% in Mysticeti. Units used are as follows: L in metres, W in tonnes.

Order	Family	Genus and Species	Origin of data	Sample size	Body weight formula $W = aL^b$ where W = body weight; L = overall body length. Standard errors on b are given where applicable: a	b	Standard deviation for $\log_{10} W$	Comments
Mysticeti	Balaenidae	*Eubalaena glacialis sieboldii*	North Pacific	21	0·0124	3·06		Weight by parts given in Omura et al. (1969)
	Eschrichtidae	*Eschrichtius robustus*	North Pacific	8	0·0051	3·28	0·0860	No information on weighing
	Balaenopteridae	*Balaenoptera musculus*	Antarctic	43	0·0046	3·09 ± 0·08	0·0498	Weight by parts
		Balaenoptera musculus brevicauda	Antarctic	5	0·0004	3·97	0·0322	Weight by parts
		Balaenoptera physalus	Antarctic	34	0·0238	2·53 ± 0·21	0·0332	Weight by parts
			Northern hemisphere	8	0·0015	3·46	0·0295	Weight by parts
		Balaenoptera borealis	Japan	16	0·0242	2·43		Weight by parts given in Omura (1950)
		Balaenoptera brydei	Japan	27	0·0122	2·74		Weight by parts given n Fujino (1955)
		Balaenoptera acutorostrata	Antarctic	22	0·0076	3·23 ± 0.16*	0·0866	Various weighing methods
		Megaptera novaeangliae	Antarctic	17	0·0158	2·95	0·0830	Weights estimated from cooker fillings
Odontoceti	Physeteridae	*Physeter catodon*	Antarctic and Pacific	44	0·0196	2·74 ± 0·18	0·0757	Weight by parts
			Natal	3	0·0029	3·55		Weighed whole

* Small sample < 30.

Table 3. Comparison by weight of the proportions of different body tissues in several species of Cetacea.

Species	Blubber	Muscle	Bone	Viscera
	% of total body weight			
Eubalaena glacialis sieboldii	43	31	13	13
Balaenoptera musculus	27	39	17	12
Balaenoptera physalus	24	45	17	11
Balaenoptera borealis	18	58	12	10
Balaenoptera brydei	23	46	15	10
Balaenoptera acutorostrata	15	62	14	8
Physeter catodon	33	34	10	9

duced, could perhaps be a reflection of interdependent factors such as buoyancy requirements and body mass/body surface area ratios.

Weight proportions of bone and viscera are not as variable between species as are blubber and muscle, and bone in any event is often difficult to weigh exactly owing to the problems of cleaning. The combined blubber and meat weights constitute between 66% and 77% of total body weight in all species.

Regression analyses by the method of least-squares, of all body weight at length data for different cetaceans (Table 2) show that the body weight varies approximately with the cube of the body length. All regression coefficients calculated on sample sizes greater than 10 fall within the range $3{\cdot}0 \pm 0{\cdot}6$. Mean regression coefficients for different families where only sample sizes of at least 10 have been considered show that values are as follows: 3·06 in Balaenidae, 2·84 in Balaenopteridae, 2·74 in Physeteridae. The toothed sperm whale seems to have a lower value than those of the baleen whales. This could be the result of weighings of baleen whales being performed on fattened animals from the polar feeding grounds; the weights of toothed Cetacea being seasonally more stable. However, where standard errors have been given in Table 2, there is a suggestion that this trend may not be significant as there is considerable overlap of values.

Referring to the body weights in the Appendix and the predicted body weights at length shown in Figure 1, the right whale is the heaviest whale for a given length. Of the Balaenopteridae, the heaviest whales are in descending order as follows: humpback, minke, Bryde, and fin, blue and sei whales. Gray whales appear to be heavy for their length, by comparison with the genus Balaenoptera, and together with right and humpback whales exceed the weight at a given length of sperm whales.

Clearly the right whale is a very valuable animal for oil production. Of the rorquals, blue and fin would be expected to yield most oil, although it seems that minke whales would be a valuable source of flesh meat for food.

All these predictions however are for the average whale of each species, and do not allow for the effects of seasonal fattening, full and empty digestive tract, sexual weight differences, pregnancy and lactation, because of the small sample sizes of weights available.

Biomass of catches of whales taken by land stations and pelagic operations in the Antarctic

The Bureau of International Whaling Statistics publishes regularly all the available data on body lengths for the different species taken during each season, together with numbers of whales taken. The catch statistics are also given separately for each geographical region. Using these records one is able to trace the numbers of whales taken each year as far back as 1904. From time to time more original information is retrieved so that the most accurate records are the ones most recently published. However, length data are neither reliable nor available until 1924 for blue and fin whales, and even later for other species. This has meant that one must assume that length statistics for these early years are similar to later ones in the absence of any other evidence.

The following procedure has been adopted for estimating biomass, and certain assumptions have been made.

(1) The length statistics for all years prior to 1924 and some years up to 1940 have been equated with more recent length data owing to the absence of records for these years.

(2) Average lengths of catches have been used in the weight formulae rather than individual lengths to economise on effort and also because individual lengths have not all been recorded, so that a standard method has been used throughout. This method has added slight errors, although insignificant ones, to the biomass estimates because weight increases exponentially with length and hence a mean length of a catch will not give the mean weight of this catch but merely a weight for a particular length. This error is counteracted to some extent if the length frequency distribution is skewed towards the larger lengths.

As an exercise, a random sample of five catches of approximate size 8000–23000 for different species was used to calculate biomass using firstly only the average length of the whole catch in the weight formula multiplied by the catch number: secondly summing each whale weight by substituting individual

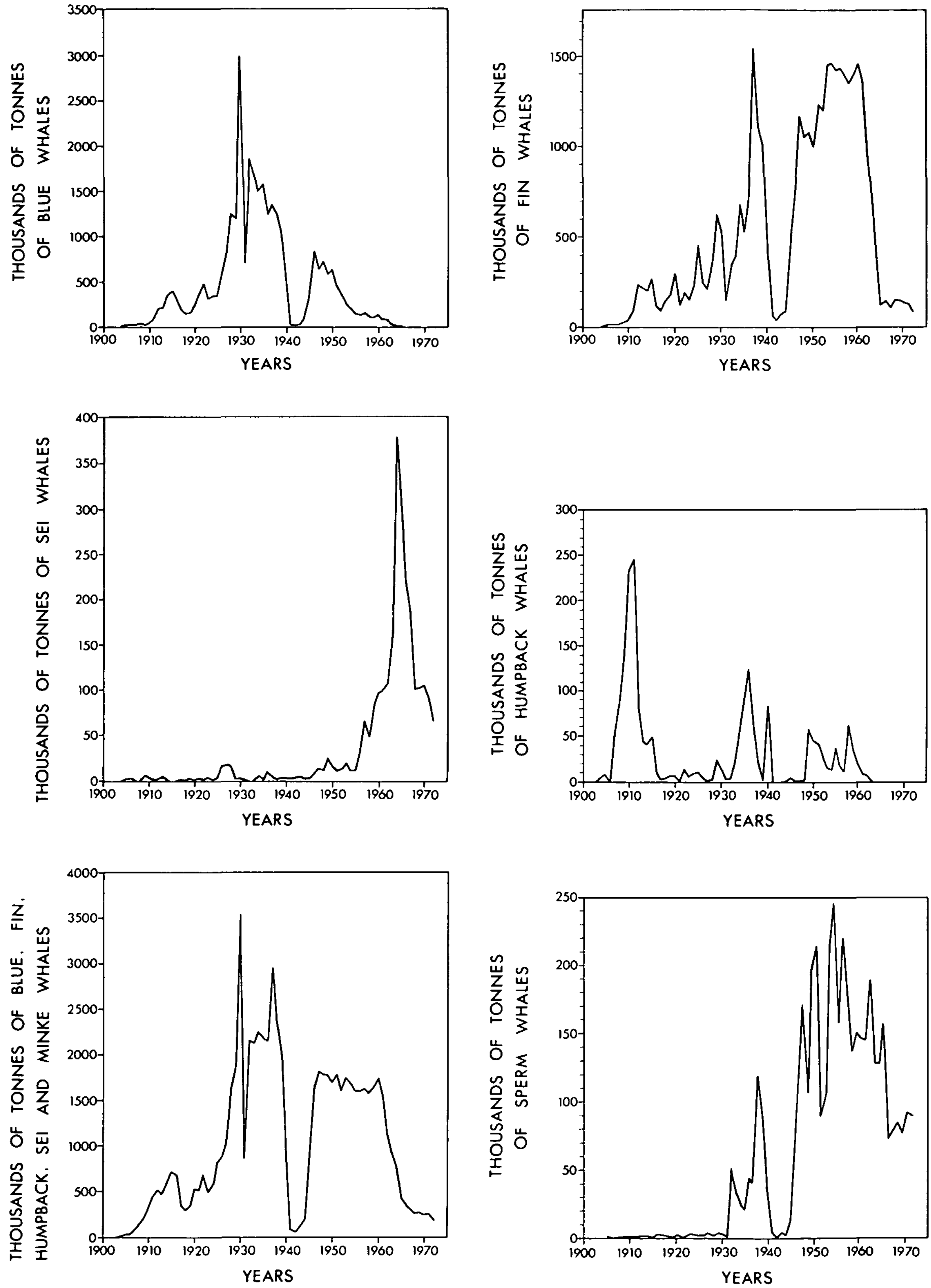

Figure 2. Biomass of whales taken in the Antarctic.

lengths in the weight formula. The percentage differences between the two biomass results are 0·5% to 1·5%, the lower biomass figure consistently being the result using the average length method, as expected. A further analysis applying the formula using the average length method to length distributions of whales for which the true weights are known, for example fin and blue whale data of Nishiwaki (1950), and humpback whale data of Ash (1953), resulted in lower biomass estimates than those using the true weights. The results were approximately within 1·5% of the true weights.

It has been thought therefore, that little would be gained by calculating individual weights of whales in the catches, if the usual error is only of the order of −1·5% of true.

(3) The weight/length formulae in Table 1 have been used to predict biomass, and for practical purposes the graphical illustration of these formulae in Figure 1 has been used. Crisp (1962) proposed a formula for the Antarctic sei whale, $W = 0{\cdot}0287L^{2{\cdot}43}$ (where L is in metres, W in tonnes). This was not based on weighings but was a considered estimate allowing for certain fattening of the whales in this region. If this formula were used in preference to that in Table 1, the catch biomass of sei whales would be raised by about 12%, since an allowance for fluid losses would produce a formula, $W = 0{\cdot}0305L^{2{\cdot}43}$. Until there are several weighings of Antarctic sei whales it will not be possible to see how the weight/length relationship is formulated, and adjustments may be necessary in both a and b in the equation, $W = aL^b$. At present, the catch biomass calculated here using the formula in Table 1 for sei whales can be regarded as a minimum for whales in unfattened condition.

The total estimates of biomass of the Antarctic catches are shown in Figure 2 for blue, fin, humpback and sei whales; also shown is the overall biomass of all rorquals taken, and the biomass of sperm whale catches. These biomass estimates succeed those of Crisp (1962) who calculated tonnages of whales taken in the Antarctic between 1932 and 1959. Crisp used the available weight/length formulae without any corrections for loss of blood and body fluids. The new estimates are also an extension of the biomass calculations by Mackintosh (1970) who illustrated graphically the tonnages of whales taken in the Antarctic between 1921 and 1967. However, Mackintosh's total biomass estimate includes sperm whales whilst the present one does not. The reason for omitting sperm whales is because they are representatives of the Odontoceti and feed on squid whereas the other whales are baleen whales and feed on planktonic krill. This is an important distinction in bioenergetics and ecology. Another important feature of the new biomass estimates is that unlike previous ones an allowance for blood loss has been made.

The estimates cover the entire period during which large scale whaling has taken place, and show clearly that production was at its peak in the 1930's, and has declined since, particularly rapidly since 1960. Figure 2 also illustrates the progressive interest in the smaller species; peak catches of blue whales around 1930–1935; fin whales chiefly around 1950–1960; and sei whales 1960–1970. Meanwhile, there is an increasing interest in the small minke whale which has only been taken in large-scale commercial operations in the Antarctic since 1971; catches in seasons 1971/72 and 1972/73 being approximately 21 700 tonnes and 35 200 tonnes respectively. Sperm whales have also become increasingly important since 1930, and reached a peak of fishing between 1950 and 1965. Humpback whales have been taken spasmodically since 1900, but catches have never reached such high levels as other species. This fact and the general fall-off in commercial whaling are undoubtedly due to the diminishing whale stocks.

The catching of smaller species of whale now being taken requires a conservative approach. Only when very large numbers of these animals are taken will their biomass contribute to a commercially viable fishery, and yet such large catches will diminish their population size more rapidly than will an equivalent reduction in biomass for the larger species. Therefore, a consideration of both numbers and biomass of animals for species taken in a fishery is desirable.

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APPENDIX

Actual weight data for several species of Cetacea, excluding foetal weights. Body length in metres, body weight in tonnes.
* = animal pregnant; c = carcase weighed whole; U = sex unknown.

Species	Locality	Date	Sex	Body length (m)	Body weight (t)	Blubber weight (t)	Meat weight (t)	Bone weight (t)	Viscera weight (t)	References
Eschrichtius	Bering Sea	19 Aug 1936	♀	13·4	*31·47	9·10	6·73	8·92	4·49	Zenkovich (1937)
robustus	California	23 Feb 1959	♀	12·7	16·36					Rice and Wolman (1971)
(Gray)	stock	10 Jan 1961	U	8·5	6·63					Gilmore (1961)
		27 Mar 1962	♂	12·4	16·59					
		28 Mar 1962	♂	9·9	8·88					
		29 Mar 1962	♂	11·7	15·69					Rice and Wolman (1971)
		30 Mar 1962	♂	9·7	8·81					
		14 Dec 1966	♀	13·6	33·85					
Eubalaena	Pacific		♂	15·5		15·80	8·40	15·40		Sleptsov (1955)
glacialis	North		♂	14·7	52·83	18·29	17·37	9·23	6·99	
sieboldii	Pacific		♂	15·1	55·25	23·02	16·54	7·47	7·48	
(Pacific Right)			♂	15·2	48·56	20·47	16·38	4·77	6·04	
			♂	16·1	67·77	27·12	20·90	9·84	8·72	Omura et al. (1969)
			♂	16·4	78·50	33·94	22·53	10·40	10·44	
			♂	17·0	65·76	24·93	21·10	8·90	9·11	
			♂	17·1	67·24	24·76	20·54	9·99	10·39	
			♂	12·4	22·25	10·03	6·62	2·92	2·44	Omura (1958)
			♂	17·1	63·49					Klumov (1962)
			♀	11·7	22·87	8·26	7·99	3·17	3·19	Omura (1958)
			♀	16·3	58·59					
			♀	16·6	63·13					Klumov (1962)
			♀	17·1	63·49					
			♀	17·4	106·50					
			♀	12·6	28·92	10·88	11·39	3·52	2·68	
			♀	14·1	47·56	19·96	12·01	6·93	8·02	Omura et al. (1969)
			♀	15·4	*62·34	26·35	18·20	8·50	8·41	
			♀	16·1	*74·23	29·46	23·64	9·60	10·47	
Balaenoptera	Antarctic	5 May 1924	♂	20·3	48·90	9·12	25·94	9·43		Norsk Hvalfangsttid. 1924 (7)
musculus		24 Dec 1947	♂	25·0	87·64	27·90	29·77	15·38	12·91	
(Blue)		11 Jan 1948	♂	24·7	84·05	24·81	33·84	15·01	8·46	
		14 Jan 1948	♂	23·2	63·06	16·56	25·88	12·60	6·17	
		15 Jan 1948	♂	22·3	56·48	15·43	22·38	10·83	6·07	
		16 Jan 1948	♂	22·8	68·97	19·02	28·33	12·75	7·37	Nishiwaki (1950)
		21 Jan 1948	♂	22·6	77·42	22·00	34·93	11·10	7·74	
		22 Jan 1948	♂	25·3	107·80	27·89	39·84	19·61	11·57	
		15 Feb 1948	♂	23·5	97·63	28·70	41·61	14·64	10·74	
		20 Feb 1948	♂	22·8	86·27	22·66	30·73	16·73	10·85	
		25 Feb 1948	♂	24·4	85·35	23·31	36·47	14·87	8·71	

Species	Locality	Date	Sex	Body length (m)	Body weight (t)	Blubber weight (t)	Meat weight (t)	Bone weight (t)	Viscera weight (t)	References
Balaenoptera musculus (Blue)	Antarctic	5 Mar 1948	♂	25·3	99·73	26,07	35·89	16·64	11·82	Nishiwaki (1950)
		26 Dec 1948	♂	24·7	76·91	19·92	27·45	16·69	9·14	
		1951	♂	25·3	109·93	28·09	44·36	20·55	13·80	Ohno and Fujino (1952)
		1951	♂	23·8	79·25	27·58	26·72	12·34	9·04	
		17 Mar 1947	♀	28·7	140·00					Voronin (1948) in Tomilin (1967)
		20 Mar 1947	♀	27·6	190·00	30·00	66·00	26·00		
			♀	27·1	136·40	31·90	61·43	18·49		Winston (1950) in Tomilin (1967)
		29 Dec 1947	♀	25·3	*110·21	35·87	39·29	17·16	15·39	Nishiwaki (1950)
		30 Dec 1947	♀	25·3	*96·49	22·62	34·14	19·91	13·66	
		2 Jan 1948	♀	24·1	76·28	18·44	29·50	14·45	10·42	
		7 Jan 1948	♀	25·3	*94·23	27·55	37·01	16·98	10·30	
		8 Jan 1948	♀	21·3	56·71	16·11	22·91	10·79	5·55	
		9 Jan 1948	♀	23·5	70·06	16·71	27·15	13·61	8·20	
		12 Jan 1948	♀	23·8	68·93	22·69	24·83	11·98	7·94	
		21 Jan 1948	♀	23·2	77·63	20·68	34·04	11·93	9·49	
		21 Jan 1948	♀	25·3	93·50	22·03	31·61	20·08	12·68	
		27 Jan 1948	♀	27·2	127·54	32·36	61·51	17·54	13·94	
		2 Feb 1948	♀	22·6	55·33	15·58	22·67	10·21	5·64	
		7 Feb 1948	♀	23·2	77·43	19·70	30·06	13·30	10·03	
		14 Feb 1948	♀	26·3	108·62	31·24	46·41	16·26	12·60	
		20 Feb 1948	♀	22·3	62·33	15·75	25·50	11·26	7·03	
		21 Feb 1948	♀	23·5	82·29	20·33	35·80	13·67	8·70	
		23 Feb 1948	♀	26·8	113·75	31·28	49·64	17·31	13·18	
		23 Feb 1948	♀	23·2	84·28	20·27	33·96	13·83	9·95	
		3 Mar 1948	♀	25·0	94·96	26·31	33·52	16·67	12·82	
		7 Mar 1948	♀	24·7	95·43	25·53	38·85	15·80	8·79	
		2 Mar 1949	♀	25·0	99·71	27·20	34·00	16·24	13·12	
		7 Nov 1926	♀	27·2	*122·00	25·65	56·44	22·28	8·48	Laurie (1933)
			U	16·0	23·00					Krogh (1934)
			U	7·0	2·00					
			U	29·5	163·00					Laurie (1933)
	Newfoundland,	1903	U	23·7	63·00					Andrews (1916)
	Canada	1941	U		58·06					Crile (1941)
Balaenoptera musculus brevicauda (Pigmy Blue)	Antarctic	25 Dec 1966	♂	18·6	42·99	13·33	15·50	6·40	6·56	Omura et al. (1970)
		13 Jan 1967	♂	16·0	24·74	6·30	10·69	3·75	3·50	
		17 Jan 1967	♂	20·3	56·89	17·95	21·36	7·91	8·67	
		12 Mar 1970	♂	18·9	42·24	12·18	17·63	5·85	6·10	Whales Research Inst., Tokyo
		9 Mar 1970	♀	21·8	*69·01	20·87	28·01	8·58	10·88	
Balaenoptera physalus (Fin)	Commander Is.	12 Jun 1936	♂	18·9	34·00	2·81	11·29	11·74		Zenkovich (1937)
	Far East	31 May 1941	♂	18·5	36·90	3·73	13·80	11·00	2·77	Zenkovich (1952)
	Iceland	6 Aug 1953	♂	15·9	21·17	2·94	8·50	6·51	2·44	Bjarnason & Lingaas (1954)
		7 Sep 1953	♂	18·9	41·80	5·77	17·17	12·48	4·95	

Species	Locality	Date	Sex	Body length (m)	Body weight (t)	Blubber weight (t)	Meat weight (t)	Bone weight (t)	Viscera weight (t)	References
Balaenoptera physalus (Fin)	Antarctic	30 Dec 1947	♂	19·5	40·30	9·27	17·89	7·90	4·41	Nishiwaki (1950)
		30 Dec 1947	♂	20·4	45·24	10·34	20·75	8·94	4·40	
		7 Jan 1948	♂	19·2	48·09	11·09	22·39	8·79	4·23	
		8 Jan 1948	♂	20·2	40·21	9·57	19·50	6·27	3·96	
		18 Jan 1948	♂	19·5	41·65	10·59	19·11	7·08	3·78	
		6 Feb 1948	♂	21·1	47·58	10·78	21·96	7·88	4·54	
		19 Dec 1948	♂	19·2	40·39	9·67	19·67	7·00	3·53	
		10 Jan 1949	♂	20·4	45·61	10·46	21·61	8·40	4·54	
		21 Jan 1949	♂	20·4	49·36	12·38	22·92	7·69	5·90	
		14 Mar 1949	♂	19·9	48·37	10·70	18·31	8·03	5·32	
		1951	♂	20·4	48·33	11·32	21·81	8·27	5·75	Ohno & Fujino (1952)
			♂	20·4	45·81	11·41	20·78	7·62	4·68	
	Korf Bay	13 Aug 1933	♀	20·8	*53·80	7·75	23·70	9·65	2·95	Zenkovich (1937)
	Natal'ya Bay	24 Aug 1933	♀	19·9	48·60	6·33	22·51	8·49	2·79	
	Far East	7 Aug 1941	♀	19·8	*48·07	6·22	20·48	11·01	3·05	Zenkovich (1952)
	California	1941	♀	21·7	59·39	11·60		8·91	3·48	Crile (1941)
	Antarctic	3 Jan 1948	♀	21·1	51·67	10·54	25·36	8·34	5·58	Nishiwaki (1950)
		11 Jan 1948	♀	22·6	64·26	15·60	29·93	10·49	6·97	
		11 Jan 1948	♀	22·9	57·60	13·78	25·22	11·42	6·21	
		13 Jan 1948	♀	22·7	*69·54	18·56	31·17	10·20	7·98	
		17 Jan 1948	♀	21·9	*60·72	14·19	29·09	9·87	6·40	
		29 Jan 1948	♀	21·7	*57·68	14·75	28·30	7·82	5·69	
		5 Feb 1948	♀	21·7	*58·51	15·18	27·02	8·96	6·06	
		12 Feb 1948	♀	20·7	47·37	10·03	21·18	9·07	5·16	
		2 Mar 1948	♀	20·7	48·50	9·97	20·44	9·23	5·17	
		7 Mar 1948	♀	20·7	49·70	13·70	26·65	7·45	5·89	
		17 Dec 1948	♀	20·7	*49·39	13·34	22·12	8·01	5·12	
		18 Dec 1948	♀	22·3	57·13	15·86	24·29	10·01	6·17	
		27 Dec 1948	♀	18·6	37·37	8·27	18·39	5·91	3·65	
		28 Dec 1948	♀	21·7	*53·46	11·32	24·02	9·51	5·95	
		30 Dec 1948	♀	22·3	58·53	13·34	28·37	10·68	5·36	
		6 Jan 1949	♀	22·6	*58·22	18·25	25·42	8·91	5·23	
		25 Feb 1949	♀	23·2	57·49	13·32	24·09	9·13	5·91	
		26 Feb 1949	♀	21·4	60·33	12·39	26·32	9·80	7·21	
		26 Feb 1949	♀	21·7	53·09	12·95	25·24	8·67	5·52	
		1951	♀	20·4	54·77	10·60	27·23	9·10	6·34	Ohno & Fujino (1952)
			♀	17·4	34·35	6·95	17·63	5·17	3·86	
			♀	20·7	49·58	12·37	21·71	7·83	6·24	
Balaenoptera borealis (Sei)	Japan	3 Aug 1949	♂	11·6	8·53	1·27	5·13	1·27	0·70	Omura (1950)
		7 Aug 1949	♂	11·9	10·25	1·68	6·16	1·33	0·92	
		10 Aug 1949	♂	12·5	11·38	1·96	6·46	1·64	1·13	
		14 Oct 1949	♂	12·5	11·28	2·42	6·06	1·57	1·07	
		2 Jun 1968	♂	9·1	5·82	1·68	2·51	0·80		Whales Research Inst., Tokyo

Species	Locality	Date	Sex	Body length (m)	Body weight (t)	Blubber weight (t)	Meat weight (t)	Bone weight (t)	Viscera weight (t)	References
Balaenoptera	Antarctic		♂	13·6	16·08	2·00	2·00			Tomilin (1967)
borealis	Japan	24 Jul 1949	♀	14·7	15·56	3·15	8·96	1·74	1·39	
(Sei)		16 Aug 1949	♀	11·6	8·58	1·70	4·72	1·21	0·84	
		16 Aug 1949	♀	13·5	13·32	2·95	7·14	1·67	1·38	
		24 Aug 1949	♀	11·9	9·90	1·67	6·06	1·20	0·81	
		27 Aug 1949	♀	11·6	10·61	1·83	6·06	1·35	1·21	
		14 Sep 1949	♀	13·8	13·80	2·04	8·13	1·71	1·70	Omura (1950)
		19 Sep 1949	♀	14·3	15·76	2·81	9·20	1·92	1·54	
		20 Sep 1949	♀	12·8	12·94	2·19	7·71	1·59	1·24	
		27 Sep 1949	♀	11·6	8·89	1·74	4·93	1·40	0·71	
		4 Oct 1949	♀	14·3	16·36	2·53	10·34	1·90	1·39	
		5 Oct 1949	♀	13·5	12·34	2·06	7·22	1·62	1·20	
		9 Oct 1949	♀	13·1	12·22	1·99	7·05	1·59	1·38	
	Iceland	24 Aug 1953	♀	14·7	21·62	3·61	9·05	6·03	2·23	Bjarnason & Lingaas (1954)
	Natal	1 Sep 1966	♀	16·4	*37·75	8·02	17·88	7·46	2·75	Union Whaling Co. Ltd. Durban
	Unknown		U	14·3	16·00					Tomilin (1967)
Balaenoptera	Japan	13 Apr 1948	♂	12·8	11·98	3·10	5·82	1·72	0·86	
brydei		15 Apr 1948	♂	12·8	11·77	2·93	5·77	1·72	0·91	Omura (1950)
(Bryde)		15 Apr 1948	♂	12·8	13·87	3·51	6·97	1·90	0·90	
		28 May 1950	♂	12·8	13·46	2·74	6·54	2·26	1·29	
		29 May 1950	♂	12·5	11·75	2·63	5·57	1·87	1·32	
		1 Jun 1950	♂	12·8	13·76	2·90	6·35	2·24	1·55	
		8 Jun 1950	♂	12·2	11·49	2·34	5·57	1·84	0·99	Fujino (1955)
		8 Jun 1950	♂	12·5	11·64	2·34	5·78	1·86	1·09	
		9 Jun 1950	♂	12·5	11·93	2·55	5·91	1·84	1·06	
		9 Jun 1950	♂	12·5	13·61	3·08	6·39	2·23	1·26	
		12 Apr 1948	♀	11·3	8·39	2·04	4·04	1·14	0·54	
		14 Apr 1948	♀	13·1	13·91	3·67	6·94	1·85	1·25	Omura (1950)
		16 Apr 1948	♀	13·1	15·43	3·89	7·70	1·85	1·39	
		16 Apr 1948	♀	12·5	14·12	3·62	7·24	1·92	0·94	
		15 May 1950	♀	12·2	13·78	2·78	6·83	2·52	1·19	
		16 May 1950	♀	12·8	13·91	2·92	7·07	2·13	1·24	
		16 May 1950	♀	13·5	12·55	2·19	6·36	2·21	1·27	
		22 May 1950	♀	12·8	12·46	2·97	5·53	1·98	1·42	
		23 May 1950	♀	12·8	11·89	2·71	5·76	1·96	1·20	
		24 May 1950	♀	13·1	12·79	3·13	5·65	2·02	1·59	
		26 May 1950	♀	12·5	11·32	2·72	5·12	1·83	1·22	Fujino (1955)
		27 May 1950	♀	12·2	9·99	2·54	3·73	1·86	1·41	
		30 May 1950	♀	13·8	16·15	3·60	7·07	2·69	2·10	
		31 May 1950	♀	13·8	15·96	3·29	7·51	2·57	1·78	
		2 Jun 1950	♀	12·8	14·85	3·24	6·98	2·37	1·63	
		4 Jun 1950	♀	12·8	12·78	2·95	5·27	2·19	1·72	
		5 Jun 1950	♀	13·5	15·47	3·25	7·35	2·28	1·81	

Species	Locality	Date	Sex	Body length (m)	Body weight (t)	Blubber weight (t)	Meat weight (t)	Bone weight (t)	Viscera weight (t)	
Balaenoptera acutorostrata (Minke)	Antarctic		♂	7·3	6·20					
			♂	8·2	6·78					
			♂	8·3	7·65	1·50				Arsen'ev (1961)
			♂	8·4	7·90					
			♂	8·4	8·60					
			♂	8·4	8·80					
			♂	6·9	6·07					Tomilin (1967)
		1968	♂	7·1	4·17	0·67	2·56	0·63	0·28	
		1968	♂	7·5	5·39	0·80	3·29	0·92	0·34	
		1968	♂	7·8	5·01	1·73	2·97	0·73	0·55	Ohsumi et al. (1970)
		1968	♂	8·0	5·26	0·78	3·22	0·84	0·40	
		1968	♂	8·2	6·56	0·92	4·31	0·80	0·49	
			♀	8·3	7·30					
			♀	8·4	7·00					Arsen'ev (1961)
			♀	8·6	8·90					
			♀	8·7	5·00	0·40	2·40			Tomilin (1967)
			♀	9·3	7·96	1·27	5·08	0·94	0·55	Ohsumi et al. (1970)
	Washington		♀	3·9	0·55					Scheffer & Slipp (1948)
	Unknown		♀	8·3	7·65	1·50				Zenkovich (1955)
			U	4·9	1·27					British Museum, London
			U	3·2	0·30					Fry (1935)
	Antarctic		U	7·9	4·85					Sergeant (1969)
		18 Dec 1958	U	11·1	c 5·33	1·22	2·44	1·12	0·30	Institute of Oceanographic Sciences, London
Megaptera novaeangliae (Humpback)	Bering Sea	5 Oct 1935	♂	12·9	27·71	2·85	5·79	11·79	2·77	Zenkovich (1937) after Boev (1935)
		9 Sep 1933	♀	13·9	32·37	5·32	9·96	10·02	3·63	Zenkovich (1934)
	Puget Sound	9 Sep 1933	♀	15·0	35·00					Bailey (1936) in Tomilin (1967)
	California		♀	13·4	39·92					
			♀	13·8	40·82					Quiring (1943)
			♀	12·5	37·20					
	Antarctic	1951	♀	13·4	24·82	5·82	9·95	3·77	3·71	Ohno & Fujino (1952)
		Other body weights estimated from cooker fillings are available for 17 animals, Ash (1953)								
Physeter catodon (Sperm)	Japan	21 Apr 1948	♂	14·1	28·92	9·87	10·11	2·75	1·76	
		21 Apr 1948	♂	16·5	41·73	13·94	15·56	3·55	2·27	
		24 Apr 1948	♂	14·3	28·16	9·37	9·73	2·93	1·50	
		23 Apr 1949	♂	15·9	37·71	11·85	11·86	3·14	2·96	
		11 Aug 1949	♂	11·6	14·28	4·21	5·20	1·35	0·99	Omura (1950)
		22 Aug 1949	♂	10·1	9·85	3·03	3·48	1·09	1·18	
		23 Aug 1949	♂	10·7	11·93	4·12	3·61	1·20	1·18	
		4 Sep 1949	♂	11·9	16·11	5·65	4·87	1·47	1·64	
		13 Sep 1949	♂	14·9	32·23	10·43	9·72	3·28	2·84	

Species	Locality	Date	Sex	Body length (m)	Body weight (t)	Blubber weight (t)	Meat weight (t)	Bone weight (t)	Viscera weight (t)	References
Physeter catodon (Sperm)	Japan	26 Sep 1949	♂	11·9	16·81	5·68	5·05	1·48	1·55	Omura (1950)
		14 Oct 1949	♂	13·5	23·90	7·61	7·96	2·28	2·29	
	Iceland	12 Aug 1953	♂	15·3	35·71	9·55	6·65	4·65	2·77	Bjarnason & Lingaas (1954)
	Bering Sea	26 Jun 1936	♂	13·5	22·67	4·96	5·64	5·87	1·28	Zenkovich (1937)
		28 Jun 1936	♂	18·0	53·37	12·66	7·68	14·01	2·20	
	Canada	1941	♂	13·1	31·21					Crile (1941)
	Natal	8 Sep 1969	♂	13·4	c 31·50	13·25	7·97	5·18	4·64	Gambell (1970)
		16 Sep 1970	♀	10·0	c 11·38					Union Whaling Co. Ltd. Durban
		24 Aug 1966	♀	11·0	23·99					
	Japan	22 Aug 1949	♀	11·0	11·96	3·97	3·88	1·20	1·50	Omura (1950)
		19 Sep 1949	♀	11·6	13·84	4·69	4·21	1·43	2·02	
	Natal	12 Mar 1973	♀	11·5	c 15·26	3·48	2·15	3·08	1·28	Gambell (1973, unpublished)
	Bering Sea	1934	U	12·4	16·14	5·00				Tomilin (1967)
		1934	U	13·6	25·00	6·00				
		1934	U	13·8	20·62	6·00				
		1934	U	14·6	26·05	6·50				
		1934	U	16·4	30·84	7·00				
		1934	U	16·8	32·00	8·00				
		1934	U	17·0	38·60	11·10				
		1934	U	17·2	40·26	10·00				
		1934	U	18·1	57·10	11·00				
		1934	U	18·6	38·52	10·00				
	Antarctic	1950/1951	U	13·7	26·25	7·65	4·66	4·08	1·87	Ohno & Fujino (1952)
		1950/1951	U	14·0	31·67	11·62	7·16	4·49	2·06	
		1950/1951	U	14·0	29·95	10·93	7·84	3·65	1·95	
		1950/1951	U	14·6	39·08	11·91	8·36	5·73	2·52	
		1950/1951	U	14·6	34·39	11·55	8·28	4·72	2·42	
		1950/1951	U	14·6	32·38	10·88	7·14	4·52	2·27	
		1950/1951	U	14·9	38·94	11·00	9·39	5·97	2·40	
		1950/1951	U	14·9	34·47	11·41	7·51	4·47	2·17	
		1950/1951	U	14·9	36·59	11·49	9·18	4·63	2·59	
		1950/1951	U	15·5	41·37	13·04	10·45	5·64	2·07	
		1950/1951	U	15·5	43·01	14·21	9·84	5·95	2·50	
		1950/1951	U	15·5	37·01	12·19	7·59	5·29	2·04	
		1950/1951	U	15·8	39·93	11·00	9·97	5·59	2·28	
		1950/1951	U	16·2	46·85	14·56	9·40	6·78	2·69	
		1950/1951	U	16·5	51·70	15·00	11·95	7·93	2·88	
		1950/1951	U	16·5	42·79	13·13	9·26	6·60	2·53	