Title: A summary of intraspecific size variation for large mysticetes

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Abstract

Following existing work on odontocetes, an extensive survey of literature was conducted to summarize the growth and body mass of nine mysticete species along with analyses of adult size distributions using data from the International Whaling Commission catch database. Relationships uncovered between adult length parameters in mysticetes are combined with results previously obtained for odontocetes. On average, the mean adult length was 4% below the asymptotic size and its relative variation appeared to be very similar across most species (CV=4-5%), though is notably higher in species with more prolonged growth throughout adulthood (CV=6-8%). Total body mass relationships between mysticete species appear to align with feeding strategies, as generalists and skim-feeders are notably heavier than lunge-feeding specialists.

Key words: Baleen whales, Mysticetes, Cetaceans, Body size, Body mass, Intraspecific variation.

1| Introduction

Knowledge on adult size variation in cetaceans can have various applications in the research on cetacean ecology (Pershing et al., 2010), conservation (Christiansen et al., 2020), stock divisions (Best, 1977; Ichihara, 1966; Pastene et al., 2020), and evolution (Bianucci et al., 2019; Bisconti et al., 2021). Due to the broader focus across multiple taxa, one review was only able to examine the literature and commercial data for *Balaenoptera musculus* (McClain et al., 2015). Since then, independent advances were made for other species (Agbayani et al., 2020; Christiansen et al., 2022; Fortune et al., 2021; George et al., 2021; Russell et al., 2023), warranting a deeper review of existing patterns in adult size variation and body mass relationships.

A comprehensive effort was placed into reviewing the adult variation in total body length (TBL) and body mass relationships of large cetaceans, beginning with odontocetes (McClure, 2024). However, the limited number of sampled species prevented strong conclusions. The previous analysis will now be extended towards nine mysticete species spanning five genera. The mysticetes selected include all extant members of the Balaenidae family, *Eschrichtius robustus* (Lilljeborg, 1861), *Megaptera novaeangliae* (Borowski, 1781), and the *Balaenoptera* species ranging in size from *B. edeni* (Anderson, 1878) to *B. musculus* (Linneaus, 1758).

In general, large baleen whales are weaned within one year, sexually mature after 5-10 years, and physically mature after 25-40 years (Agbayani et al., 2020; Aguilar & Lockyer, 1987; Bando, 2021; Best, 2011; Best & Lockyer, 2002; Branch, 2008; Chittleborough, 1965; Fortune et al., 2021). In *Balaena mysticetus* (Linneaus, 1758), sexual maturity occurs after 25 years and

physical growth progresses much further into senescence (George et al., 1999; Tarpley et al., 2021). As done in the previous analysis (McClure, 2024), the correlation between the interval from sexual to physical maturity and the coefficients of variation (CV) in mean adult size will be examined for each species.

An unprecedented review of existing literature was conducted along with an analysis of length distributions within the IWC catch database. Analyses on body mass relationships, largest reliable sizes, and postnatal growth are also provided. The data presented in this review will assist future ecological, anatomical, energetic, and phylogenetic research that benefits from incorporating intraspecific information about TBL and body mass.

2| Methods

The nine mysticete species under review are summarized in Table 1. Literature was comprehensively surveyed for morphometric data and growth parameters using the exact standards described in the previous review for odontocetes (McClure, 2024). Data on the mean TBL at birth (L_b), weaning (L_w), sexual maturity (L_{sm}), and physical maturity (L_∞) are summarized here. In total, 332 sources from literature (71 books, 26 conference papers, 224 published articles, 8 technical reports/research documents, 2 theses, and 1 media article) were surveyed and 125 were selected after filtering.

Most of the published mass data for large mysticetes were the sums of individual pieces weighed on platform scales or bulk fillings of pressure cookers (Lockyer, 1976). Blood and other body fluids are lost in this process, typically estimated to compose 6-7% of the total body mass (Laurie, 1933; Moore et al., 2004). The canonical allometric formula (Equations 1 & 2) and the Rice-Wolman (RW) model (Equation 3) are reported for mass relationships (George, 2009; Rice & Wolman, 1971; Schultz, 1938). Formulas, data, references, and code are provided in Supplementary Files 1-4, respectively.

$$\log(\mathrm{Mass}) = \mathrm{b} \times \log\ (\mathrm{TBL}) + \log(\mathrm{a})\ , (1)$$

$$\mathrm{Mass} = \mathrm{a} \times (\mathrm{TBL})^{\mathrm{b}}, (2)$$

$$\mathrm{Mass} = \mathrm{a} \times (\mathrm{TBL})^{\mathrm{b1}} \times (\mathrm{Girth})^{\mathrm{b2}}, (3)$$

As in the analysis for odontocetes (McClure, 2024), the mean adult TBL (L_{mean}) and standard deviation (SD) of females were primarily estimated using direct samples of individuals recorded as sexually mature in the commercial data. Corresponding parameters for males were estimated by dissecting length frequencies of mature individuals from normal probability plots (Harding, 1949). To enforce objectivity and consistency, published estimates for the L_{sm} were used as starting values for the point of inflection. Preliminary comparisons for select female catches validated the congruency between the two methods. Therefore, the graphical analysis was

applied to certain female catches where the difference in sample size deemed it preferrable. Regional differences in the L_{mean} values were examined using two-sample *t*-tests (Zar, 2010).

The analyses for rorqual species within in the IWC catch database are restricted to expeditions from after the introduction of minimum length regulations in 1937, corresponding to the ‘’Late period’’ as described in previous work on *B. musculus* (Branch et al., 2007). This convention helps minimize data quality issues within early whaling data such as non-standard measuring techniques, visual estimation, and rounding to 5-ft intervals (Branch et al., 2007; Donovan, 2000). While the intentional ‘stretching’ of whales below the minimum legal size is known to afflict much of the data reported prior to the IOS (Best, 1989), these size restrictions had minimal overlap with the distributions of mature individuals.

The current review distinguishes the three species within *Eubalaena* (Rosenbaum et al., 2000): *E. glacialis* in the North Atlantic (Müller, 1776), *E. japonica* in the North Pacific (Lacépède, 1818) and *E. australis* in the Southern Hemisphere (Desmoulins, 1822). Due to limited samples across both modern catches and necropsies, the adult size for *E. glacilias* was not as deeply examined. The L_{mean} for *E. australis* and *B. mysticetus* were respectively calculated from the Soviet commercial catches (Figure S1) and North Pacific subsistence harvests recorded in the IWC catch database (Figure S2). The L_{mean} for *E. japonica* (Table 2 & Figure S1) were sourced from sexed individuals from literature (Ivashchenko et al., 2017; Ivashchenko & Clapham, 2012; Klumov, 1962; Omura et al., 1969; Pike & MacAskie, 1969; Zenkovich, 1954). All non-

examined specimens ≥ 15 m were assumed to be sexually mature. Midpoints were used for lengths binned to 50 cm intervals.

All stocks within the *B. edeni* complex are treated as one species as the precise taxonomy has yet to be resolved (Constantine et al., 2018; Junge, 1950). Due to low sample sizes, *B. edeni* catches from the South Pacific, Southern land stations, and Indian Ocean were excluded from analyses. Distinct subspecies corresponding to the Northern and Southern Hemispheres are recognized for nearly all other rorqual species (Jackson et al., 2014; Rice, 1998; Rosel & Wilcox, 2014). Throughout lower latitudes, the southern populations of *B. musculus* are delineated into *B. m. brevicauda* (Ichihara, 1966), *B. m. indica* (Blyth, 1859), and another proposed subspecies in Southeast (SE) Pacific (Attard et al., 2024; Pastene et al., 2020). Each are distinct in size from *B. m. intermedia* (Burmeister, 1871), the primary subspecies of the Antarctic.

Since mixture within catches would confound regional comparisons, the L_{mean} values for *B. musculus* in the Southern Hemisphere is summarized in accordance with subspecies rather than ocean basin. Parameters for mature females from the SE Pacific and the Antarctic were obtained directly from a previous analysis (Branch et al., 2007). For the graphical analysis of Antarctic males, whales caught below 60°S were isolated to minimize overlap with other subspecies. Analyses for *B. m. brevicauda* were restricted to data from Soviet fleets that ignored the 21.3 m minimum length restriction. Due to known morphological similarities (Branch & Mikhalev, 2008), *B. m. indica* is synonymized with *B. m. brevicauda* in this review.

Since the length distributions for mature mysticetes are approximately normal (Branch et al., 2007; Ohsumi et al., 1958), the expected upper bound for the maximum value within a normally-distributed sample of *n* (Equation 4) is used as an approximation to compare against potentially unreliable maximum values within the whaling data (Kamath, 2015). For a given species/subspecies, *n* is the total number of whales in the entire IWC catch database that were greater than or equal to the L_{sm} and rounded to the nearest thousand (Y = deviation from mean TBL).

$$\mathbf{E}\,[Y] \leq \sigma \text{ x } \sqrt{2\ \log n}\,, (4)$$

Since natural variation may enable the occurrence of unexpected outliers, reliable estimates for the L_{max} will also be determined using a combination of the verified measurements in literature and the largest sizes recorded across different expeditions of the total catches within the commercial data. This helps to account for the possible influence of biases in measuring technique.

3| Review of size distributions and mass relationships

Table 1: Summary of adult body length and mass for nine mysticete species.

Species	Common Name	Mean adult length and mass (M/F)[a,b]	*n*	Maximum adult length and mass[b]

Eubalaena australis	Southern Right Whale	14.3 m / 14.8 m 46.7 t / 52.0 t	1,341[c] / 551	17.4 m 85.9 t
Eubalaena japonica	North Pacific Right Whale	16.0 m / 16.8 m 66.2 t / 77.1 t	71 / 40	19.7 m 126.4 t
Balaena mysticetus	Bowhead Whale	14.4 m / 15.4 m 47.7 t / 58.8 t	200[c] / 234[c]	20.5 m 172.0 t
Eschrichtius robustus	Gray Whale	12.0 m / 12.6 m 19.1 t / 21.9 t	792[c] / 773[c]	15.2 m 39.3 t
Megaptera novaeangliae	Humpback Whale	12.4 m / 13.3 m 27.7 t / 34.1 t	31,324[c] / 7,237	18.0 m 83.7 t
Balaenoptera edeni	Bryde's Whale	12.6 m / 13.1 m 14.1 t / 15.7 t	6,594[c] / 2,177	16.3 m 28.6 t
Balaenoptera borealis	Sei Whale	14.4 m / 15.4 m 23.1 t / 28.6 t	85,055[c] / 39,843	20.1 m 66.5 t
Balaenoptera physalus	Fin Whale	20.1 m / 21.7 m 51.9 t / 63.0 t	204,370[c] / 99,863	27.2 m 112.1 t
Balaenoptera musculus	Blue Whale	23.6 m / 25.1 m 84.4 t / 103.3 t	34,129[c] / 12,616	31.1 m 209.0 t

a. See text and subsequent tables as some mean lengths are weighted averages for populations with significant size differences.
b. Body masses are estimated from either linear regression or largest oil yields.
c. Approximate sample size from component curves

Balaenidae

Despite similarity in size between *E. glacilias* and *E. australis* up to sexual maturity (Christiansen et al., 2022; Fortune et al., 2021), mature females are known to be significantly larger and in better body condition in the North Atlantic due to environmental stressors (Christiansen et al., 2020; Stewart et al., 2021). Aside from *E. japonica* being significantly larger, differences in external morphology between the three species are minimal (Fortune et al., 2021; Omura et al., 1969). Table 2 shows that the L_{mean} for *E. australis* exceeded the photogrammetric estimates for the L_{∞} (Christiansen et al., 2022). This appears to reflect previous concerns regarding the compatibility between photogrammetric and commercial data for this species (Tormosov et al., 1998). This is addressed in greater detail in the discussion.

E. glacialis is sometimes cited to reach a maximum TBL of 17.8-18 m (Cummings, 1985; Huang et al., 2009), but these measurements were either unstandardized or taken from *E. japonica* when the two species were still synonymized (Omura, 1958; Thompson, 1928). The largest reliable measurement in literature for *E. glacialis* was a 16.5 m female captured near Long Island, New York (Andrews, 1908). The Soviet data for *E. australis* reported males reaching 17.2 m, and the infraction records for other nations reported a female measuring 17.4 m. The largest reliable measurements for *E. japonica* appear to be a binned length of 18.1-18.5 m for a male and 19.5-19.8 m for a female (Ivashchenko & Clapham, 2012).

Table 2: Growth parameters for Balaenidae

Species	L_b (m)	L_w (m)	L_{sm} (m) M/F	L_{mean} ± SD (m) M/F	L_∞ (m) M/F	L_{max} (m) M/F	Reference
E. japonica	—	11	14.5[a]	16.0 ± 0.86 / 16.8 ± 1.13	16.5[a] / 17.5[a]	18.3[a] / 19.7[a]	Ivashchenko & Clapham, 2012; Klumov, 1962; Omura et al., 1969; Current study
E. australis	4.7	9.5	12.6[b] / 13.1	14.3 ± 0.78[c] / 14.8 ± 0.98[c]	13.7[b]/ 14.3	17.2 / 17.4	Christiansen et al., 2022; Current study
B. mysticetus	4.3	8.5	12.7[a] / 13.4	14.4 ± 1.20 / 15.4 ± 1.26[d]	15.5[a] / 16.5[a]	19.2[e] / 20.5[e]	George et al., 1999; Lubetkin et al., 2012; Tarpley et al., 2021; Current study

a. Midpoint of binned value or estimated range in literature.
b. Estimated by adjusting for 4% difference between males and females
c. Whaling data may not be directly comparable to L_∞ values from photogrammetry surveys.
d. Estimated from graphical analysis of total female catch.
e. Estimates from Equation 4.

For *B. mysticetus*, the largest female and male within the analyzed harvest data were 19.2 m and 17.8 m, respectively. The minimum estimate for the historical population size of the North Pacific population of *B. mysticetus* is around 13,000 (Woodby & Botkin, 1993). If it's assumed that mature females composed 25% of this value, Equation 4 predicts the female L_{max} to be 20.5 m. Given the selection against larger individuals in subsistence harvests and the high variability of continued growth in *B. mysticetus*, Equation 4's prediction is likely the best L_{max} value for this species.

Postnatal and near-term fetal weights have been published for *E. japonica* (n= 18), *E. glacialis* (n=13), *E australis* (n=3), and *B. mysticetus* (n=7) from necropsies and whaling (Best, 2008; Fortune et al., 2021; George, 2009; Klumov, 1962; Omura et al., 1969). The heaviest record for *E. japonica* was a 17.4 m lactating female that weighed 106.5 tonnes after flensing or 113.3 tonnes after a 6 % fluid correction (Klumov, 1962). The heaviest RW body mass estimate for *B. mysticetus* was 101 tonnes for a 16.5 m female (George et al., 2021).

The RW1 body mass model published for *B. mysticetus* (George, 2009) accurately predicted the masses for the non-pregnant *E. japonica* specimens (r^2= 0.969; n=6), excluding three outliers with known errors in girth measurements (Christiansen et al., 2019). AIC model selection preferred a linear model (Equation 1) that pooled the mass data for the two genera (AICc = -65.98, weight = 0.74). Mass data and external measurements for each species were pooled into Equations 1-3 as composite models for the Balaenidae family (Table S1, Figures 1 & S3). As explicitly noted by the original author (Klumov, 1962), corrections on the order of 8-11 tonnes were necessary for three whales that were missing components for the skulls and viscera. This went unmentioned when the data was republished in the more widely-cited review (Omura et al., 1969). Consequently, these underestimated weights remained uncorrected in subsequent literature (Fortune et al., 2021; Lockyer, 1976).

Figure 1A compares the composite balaenid model (Equation 2) to photogrammetric mass models for *E. australis* and *B. mysticetus* (Christiansen et al., 2022, 2024). A balaenid would weigh 54.2 tonnes (80% PI 42.6-69.4 tonnes) at 15 m and 143.0 tonnes (80% PI 111.1-184.2

tonnes) at 20.5 m. Oil yield to body mass conversions for *B. mysticetus* (George et al., 2007, 2021) suggest that individuals yielding 337-375 barrels (37.0-40.9 tonnes) of oil (Fairburn, 1955; Pease, 1918; Williams, 1904) would have weighed 154-172 tonnes intact. These figures fall well within the expected body mass for a 20.5 m balaenid.

Eschrichtiidae

For *E. robustus*, the graphical analysis of the total catches was employed for both sexes (Table 3 & Figure S4). The largest canonically cited individuals are a 14.62 m male and a 15.54 m unsexed specimen (Cope, 1868), though the reliability of these measurements are questionable (Andrews, 1914). A 14.3 m male and 15 m female were verified by researchers aboard the *Aleut* (Zenkovich, 1934, 1937). The commercial dataset reports 10 males exceeding 14.3 m and 4 females exceeding 15 m. The largest individual was an 18.3 m male caught in 1928, which is likely not reliable as there are no records of females exceeding 15.2 m. When accounting for sexual dimorphism, the largest reliably recorded males in the commercial data appear to be 14.5 m.

Table 3: Growth parameters for *E. robustus*

Length	Males	Females	Reference
L_b (m)	4.6	4.7	Agbayani et al., 2020
L_w (m)	8.3	8.4	Agbayani et al., 2020
L_{sm}(m)	11.1	11.6	Agbayani et al., 2020

L_{mean} ± SD	12.0 ± 0.63	12.5 ± 0.68	Current study
L_{∞} (m)	12.6	13.1	Agbayani et al., 2020
L_{max} (m)	14.5	15.2	Current study

In total, 36 weights for *E. robustus* collected from whaling, strandings, and captive specimens have been published (Agbayani et al., 2020; Sumich et al., 2013). The heaviest was a 13.55 m pregnant female that weighed 33.85 tonnes after flensing (Rice & Wolman, 1971). The various published models for this species are provided in Table S2 (Agbayani et al., 2020; Christiansen et al., 2021; Lockyer, 1976; Sumich, 1986; Sumich et al., 2013). For the RW curves in Figure 1B, girths are fixed to the observed values of 50% of the TBL for the lean condition, 60% for the standard fattened condition, and 70% for the pregnant fattened condition (Sumich, 1986).

Figure 1B shows that the mass relationship published alongside a recent growth curve (Agbayani et al., 2020) precisely aligned with both the RW curve for the lean condition and a volume model for a predominantly emaciated sample of whales (Christiansen et al., 2021). This supports concerns by the authors (Agbayani et al., 2020) that the sample for this model appears too limited to represent the normal condition. When setting the RW model at the normal body condition (girth = 55% TBL), *E. robustus* would weigh 19.1 tonnes at 12 m while a pregnant female would weigh 39.3 tonnes at 15.2 m.

Balaenopteridae

Growth parameters along with corresponding L_{mean} values are provided in Table 4. Due to congruity in existing L_{sm} and L_{∞} estimates, all *M. novaeangliae* populations and certain subspecies within *Balaenoptera* were pooled together in Table 4 and supplementary plots (Figures S5-S17).

Table 4: Growth parameters for Balaenopteridae

Species	**L_b (m)**	**L_w (m)**	**L_{sm} (m)** M/F	**L_{mean} ± SD (m)[a]** M/F	**L_{∞} (m)** M/F	**L_{max} (m)** M/F	**Reference**
M. novaeangliae	4.3	9.1	11.2 / 11.9	12.4 ± 0.86 / 13.3 ± 0.91	13.1 / 13.7	17.0[b] / 18.0[b]	Chittleborough, 1965; Nishiwaki, 1959, 1960; Current Study
***B. edeni* (North Pacific)**	4	7.1[c]	11.4 / 11.8	12.5 ± 0.56 / 13.0 ± 0.55	12.7 / 13.3	14.8 / 15.5	Bando, 2021; Lockyer, 1984; Current Study
B. b. borealis	4.3	9[c]	12.7 / 13.3	13.7 ± 0.61 / 14.5 ± 0.69	14.1 / 15.2	17.5[b] / 18.6	Bando, 2020; Best & Lockyer, 2002; Lockyer, 1984; Current Study
B. b. schlegelii	4.3	8[c]	13.8 / 14.1	14.7 ± 0.62 / 15.6 ± 0.74	15.5[d]/ 16.5[d]	19.0[b] /20.1	Best & Lockyer, 2002; Lockyer, 1977, 1984 Current Study
B. p. physalus / velifera	6.4	11.3	17.4 / 18.5	18.4 ± 0.90 / 19.7 ± 1.00	19.2 / 20.7	23.6 / 25.3	Aguilar et al., 1988; Ohsumi et al., 1958; Current Study
B. p. quoyi	6-6.5	12	19.2 / 20.0	20.4 ± 0.86 / 21.9 ± 1.06	21.0 / 22.3	25.0 / 27.2	Mackintosh, 1942; Mackintosh & Wheeler, 1929; Current Study
B. m. musculus	—	—	20.5 / 21.5	22.8 ± 1.02 / 24.0 ± 1.17	23.4 / 24.8	26.8 / 28.0	Pike & McAskie, 1969; Ohsumi, 1979; Current Study
B. m. intermedia	7	16	22.6 / 23.4	24.0 ± 1.11 / 25.7 ± 1.24[e]	25.0 / 26.2	29.9 / 31.1	Branch & Mikhalev, 2008; Lockyer, 1981;

							Mackintosh & Wheeler, 1929; Current study
B. m. brevicauda	5.6	13.5	18.3 / 19.2	20.0 ± 0.92 / 20.9 ± 1.04	21.1 / 21.9	23.8 / 24.4	Branch, 2008; Ichihara, 1966; Mikhalev, 2019; Current study

a. Reflects pooled averages for species/group. Sample sizes reported in Table 10.
b. Estimated parameter.
c. Data insufficient or extrapolation.
d. These values correspond to whales captured off South Georgia. Sei whales captured off Donkergat and Durban were known to physically mature at around 15.8 m and 14.8 m for females and males, respectively.
e. Weighted mean and SD of model estimates for pelagic data (1937-1973).

For *M. novaeangliae*, adults from the South Atlantic, North Atlantic, and Southern Hemisphere land stations were significantly larger (*t*-test, $p < 0.05$) than all other regions (Table 5). Equation 4 predicted L_{max} values of 17.5 m (n = 34,000) for females and 16.4 m (n = 44,000) for males. Since 1937, 17 males and 13 females were reported to measure 17 m or greater. The largest female was reportedly 19.5 m, while the next 13 were 18.3 m or lower.

The largest record amongst precisely calibrated photogrammetry measurements was a 16.8 m individual observed repeatedly in the Arabian Sea (F. Christiansen, personal communication, 2023). The mounted skeleton displayed at the Nha Trang Institute of Oceanography in Vietnam appears to be the largest in the world, officially measuring 18 m (Redman, 2019). When comparing this to the values from the commercial data and Equation 4's predictions, the L_{max} for *M. novaeangliae* can be estimated to be 18 m for females and 17 m for males.

Table 5: Regional comparison of L_{mean} for *M. novaeangliae*.

	L_{mean} ± SD (m)

Region	Males	Females
North Pacific	12.4 ± 0.93 (2,594)	13.2 ± 0.97 (465)
North Atlantic	12.9 ±1.16 (113)	13.7 ± 0.90 (35)
South Pacific	12.4 ± 0.70 (6,008)	13.3 ± 0.74 (433)
South Atlantic	13.1 ± 1.00 (1,805)	14.4 ± 0.93 (62)
Indian Ocean	12.2 ± 0.79 (8,756)	13.3 ± 0.80 (632)
S. Hemisphere Land Stations	12.8 ± 0.78 (178)	13.8 ± 0.91 (61)
S. Hemisphere Pelagic	12.4 ± 0.78 (5,781)	13.2 ± 0.87 (3,455)
S. Hemisphere Pelagic (Soviet)	12.4 ± 1.00 (4,740)	13.3 ± 0.96 (2,097)

For *B. edeni*, the length distributions of mature females in the South Atlantic and Southern pelagic catches were polymodal (Figures S6 & S7), consistent with observations of distinct morphs (Best, 1977; Ohsumi, 1980). These distributions were excluded from *t*-test comparisons. The South Atlantic data contains a peak around 15.5 m and a maximum TBL of 18 m (Figure S6), indicating that nearly 20% of the sample were misidentified catches of *B. borealis* (Figure S7). Outliers of this type comprised only a small percentage of the total male catches for the South Atlantic (< 2.0 %) and North Pacific (< 0.02%). Otherwise, no obvious mixtures of different morphs or species were detected in other regions (Figures S8 & S9).

Adults from the North Pacific were significantly smaller ($p < 0.05$) than those from the Southern Hemisphere (Table 6). Due to rampant misidentification with other rorquals, caution should be taken with commercial records of individuals exceeding 15.5 m, a length typically not exceeded

in verified records (Best, 1977; Ohsumi, 1980). The largest specimen that can be tentatively assigned to *B. edeni* was a 16.3 m female captured off of Western Australia in 1963 (Best, 1977). A corresponding record of a 15.9 m male within the Soviet catch data from the Gulf of Aden seemed particularly convincing, as both the whaling data and lack of confirmed sightings in literature suggests that sei whales are infrequent or wholly absent in the Arabian Sea region.

Table 6: Regional comparison of L_{mean} for *B. edeni*.

Region	L_{mean} ± SD (m) (n) Males	Females
North Pacific	12.5 ± 0.55 (5,366)	13.0 ± 0.55 (1,724)
South Atlantic	13.2 ± 0.87[a] (629)	13.7 ± 0.60 [a,b] (121)
S. Hemisphere Pelagic	13.0 ± 0.58 (222)	13.6 ± 0.67[b] (83)
S. Hemisphere Pelagic (Soviet)	13.1 ± 0.56 (377)	13.6 ± 0.65 (249)

a. *B. borealis* mixture detected within total sample. Reported mean and sample size calculated from isolated components for *B.edeni*.
b. Mixture of two morphs

The L_{mean} values for *B. borealis* in the Indian Ocean and South Atlantic were significantly lower (t-test, $p < 0.05$) than those from Southern land station and pelagic catches (Table 7). Adults from the South Pacific were even smaller, falling within the size range of adults from the Northern Hemisphere. The graphically estimated parameters reported in Table 7 were consistent with the limited sample of mature females (mean = 14.1 m; SD = 0.76 m; median & mode=14.3

m; n = 26). The data from the South Pacific was not used to calculate the L_{mean} for southern sei whales in Table 4.

The largest female within the total catches for *B. borealis* in the Northern Hemisphere was an 18.6 m individual captured off the North Pacific. The next 13 measured between 17-18 m. The largest in the Southern Hemisphere were two 20.1 m individuals captured at South Georgia in 1949 and 1960. The next 15 largest measured between 18.3 m-19.6 m. These do not readily appear to be misidentified records for *B. physalus* when adding some allowance to the Equation 4 predictions of 17.6 m (n = 18,000) for northern females and 19.1 m (n = 67,000) for southern females. There are questionable records of males exceeding the maximum reported female size. The L_{max} for males reported in Table 4 were therefore downsized from the largest females using the ratio of sexual dimorphism of their respective L_{∞} values.

Table 7: Regional comparison of L_{mean} for *B. borealis.*

	L_{mean} ± SD (m)	
Region	**Males**	**Females**
North Pacific	13.7 ± 0.61 (18,588)	14.6 ± 0.68 (6,850)
North Atlantic	13.3 ± 0.65 (1,783)	14.2 ± 0.65 (315)
South Pacific	13.6 ± 0.90 (284)	14.4 ± 0.80[a] (362)
South Atlantic	14.6 ± 0.90 (3,892)	15.0 ± 0.85 (1,145)
Indian Ocean	14.0 ± 0.68 (1,212)	15.0 ± 0.94 (102)
S. Hemisphere Land Stations	14.9 ± 0.55 (4,825)	15.8 ± 0.68 (2,692)

S. Hemisphere Pelagic	14.6 ± 0.59 (42,127)	15.6 ± 0.73 (20,330)
S. Hemisphere Pelagic (Soviet)	14.8 ± 0.65 (13,393)	15.6 ± 0.76 (8,407)

a. Estimated from graphical analysis of total female catch

Despite possessing similar means (Table 8), the female length distributions for *B. physalus* in the South Atlantic and Indian Ocean land stations were strongly negatively skewed (Figure S13). They were thus excluded from *t*-test comparisons. While the distributions for the rest of the Southern Hemisphere were approximately normal, outliers as small as 14.3-16 m were detected across the Chilean, Soviet, and British catches. Apart from comparisons between the South Pacific and Soviet Pelagic female catches, all regional differences in mean length ≥ 0.1 m were statistically significant (*t*-test, $p < 0.05$).

The Equation 4 predictions for northern and southern females were respectively 24.2 m (n = 29,000) and 27.2 m (n = 220,000). The largest females from the North Pacific and Atlantic respectively measured 25 and 25.3 m. The Soviet data from the Antarctic records one female reaching 27.2 m, consistent with Equation 4's prediction. The largest male from the North Pacific measured 23.6 m, congruent with a stranding record of another male with an approximate length of 22-24 m (Zhu et al., 2018; "中国最大长须鲸骨骼标本来了 [China's largest fin whale skeleton specimen arrives]," 2021). A southern male reported to measure 25 m lies close to the Equation 4 prediction (24.7 m; n = 240,000), whereas two larger individuals were liable to have been misidentified females.

Table 8: Regional comparison of L_{mean} for *B. physalus*.

	L_{mean} ± SD (m)	
Region	**Males**	**Females**
North Pacific	18.4 ± 0.89 (16,619)	19.7 ± 0.94 (4,877)
North Atlantic	18.2 ± 1.01 (12,593)	19.6 ± 1.10 (2,446)
South Pacific	20.1 ± 0.78 (142)	21.3 ± 1.00[a] (94)
South Atlantic	19.9 ± 1.19 (666)	21.3 ± 2.07[b] (35)
Indian Ocean	19.9 ± 0.99 (3,169)	21.8 ± 1.47[b] (73)
S. Hemisphere Land Stations	19.9 ± 0.91 (14,564)	21.7 ± 1.14 (3,892)
S. Hemisphere Pelagic	20.4 ± 0.82 (173,095)	21.9 ± 1.05 (85,403)
S. Hemisphere Pelagic (Soviet)	20.1 ± 1.00 (4,828)	21.5 ± 1.19 (3,214)

a. Estimated from graphical analysis of total female catch
b. Negatively skewed.

The SE Pacific subspecies of *B. musculus* was very comparable in size to the northern subspecies (Table 9), though a significant difference was detected between the SE Pacific and North Pacific (*t*-test, $p < 0.05$). The largest whales reliably identified as *B. m. brevicauda* appear to have been around 24.2-24.5 m (Omura, 1984; Pastene et al., 2020). The largest individual in the Northern Hemisphere dataset was a 28.0 m female from the North Atlantic, a size substantiated by mounted skeletons and photogrammetry studies on the northern subspecies (Gorter, 2010; Ortega-Ortiz et al., 2022).

While the literature (Risting, 1922, 1928) and commercial data from early Norwegian expeditions report that *B. m. intermedia* reached 32-35 m, contemporary expeditions by other nations only reported TBLs up to 31.1 m. The maximum sizes within Norwegian catch statistics fell in line with other nations after 1931, hinting that at least most of these exceptional records were artefacts from measuring procedures. The greatest TBL for *B. m. intermedia* to be directly measured by a scientist was 29.9 m (Rice, 1978). Since 1937, the commercial data reports six females ≥ 30.5 m, the largest was taken in 1948 and measured 31.1 m. This size falls well within Equation 4's prediction of 31.6 m when conservatively estimating that only 50% of all captured females in the IWC catch database were mature (n = 77,956).

Table 9: Regional comparison of L_{mean} for *B. musculus*.

	L_{mean} ± SD (m)	
Region	**Males**	**Females**
North Pacific	22.8 ± 0.98 (1,054)	24.1 ± 1.05 (183)
North Atlantic	22.2 ± 1.03 (202)	23.4 ± 1.45 (44)
Antarctic	24.0 ± 1.11 (28,865)	25.7 ± 1.24[a] (10,809)
Pygmy	20.0 ± 0.92 (3,199)	20.9 ± 1.04 (1,509)
SE Pacific	22.1 ± 1.13[b] (809)	23.5 ± 1.20[b] (71)

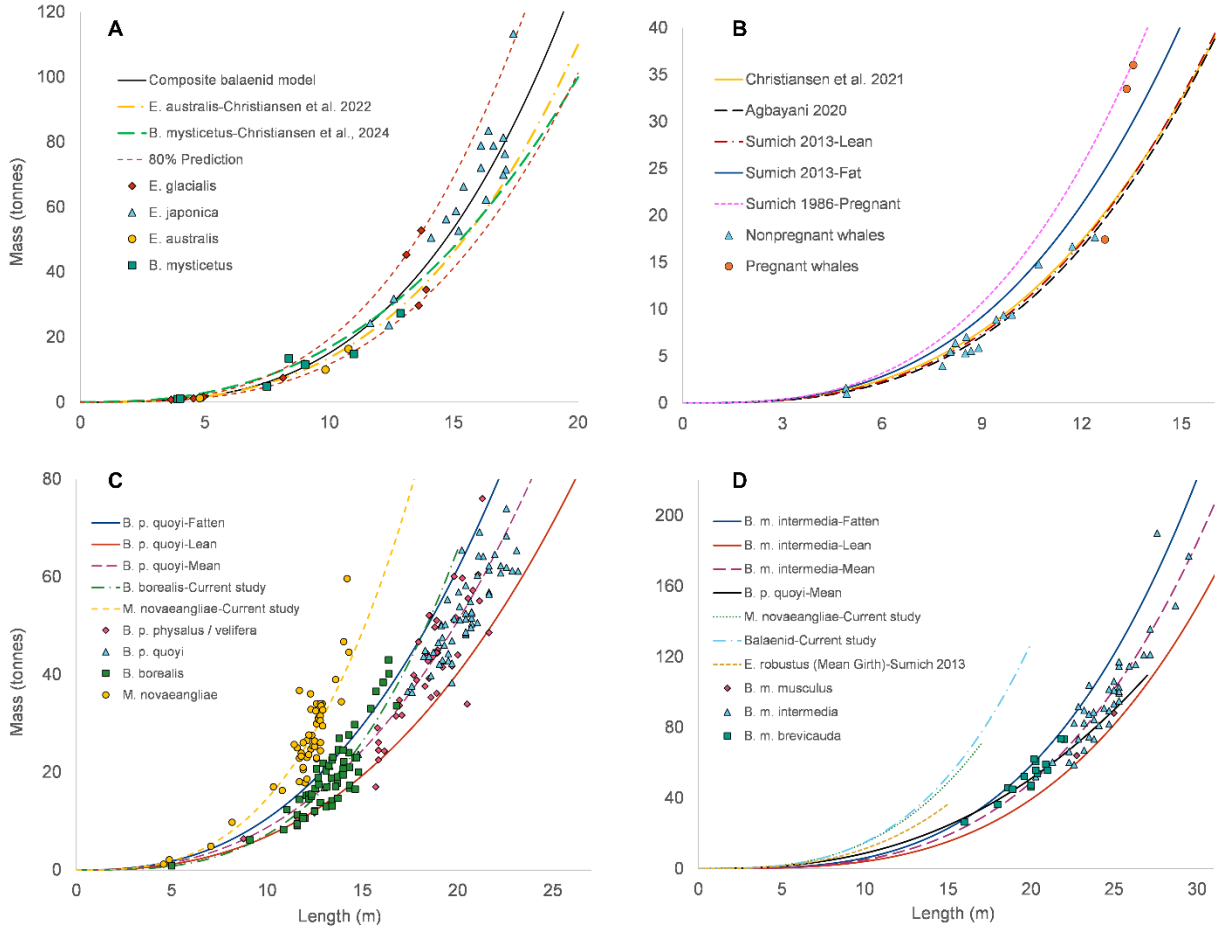
a. Weighted average of mean and SD of Pelagic catch below 60°S (1937-1973) from Branch et al., 2007.

b. Includes data taken since 1931.

The heaviest piecemeal masses reported in communications and previous literature were 56.1 tonnes for *M. novaeangliae* (Best, 2008) , 24.9 tonnes for *B. edeni* (Tamura et al., 2016), and 40.45 tonnes for *B. borealis* (Y. Ivashchenko, personal communication, 2023). The heaviest weight recorded for *B. physalus* was a 21.3 m North Atlantic female that weighed 69.3 tonnes (Víkingsson et al., 1988), with corrections for the missing tongue and body fluids amounting to 76.4 tonnes. The heaviest record for *B. musculus* was a 27.6 m pregnant female reported to weigh 190 tonnes (Voronin, 1948). This individual's maximum blubber thickness of 42 cm substantiates that this individual was of exceptional condition, as this measurement rarely approaches 40 cm (Slijper, 1948). A record of 196 long tons / 199 tonnes reported in some literature (Carwardine, 1995; McClain et al., 2015), appears to be a conversion error for a total mass of 178 tonnes /196 short tons (Scheffer, 1974).

Along with existing formulas (Table S8), individual weights for *M. novaeangliae* (n = 50), *B. borealis* (n = 60), *B. physalus* (n =106) and *B. musculus* (n = 56) were compiled for this review. Fluid-corrected body mass data and corresponding curves for Balaenopteridae are compared in Figures 1C & D. The dataset for *M. novaeangliae* and *B. borealis* were larger than those available to previous authors (Lockyer, 1976; Mikhalev, 2019) and all data were compiled into mass models for their respective species (Table S3, Figures 1, S18 & S19). While AIC model selection strongly preferred separate regional models for *B. borealis* (AICc=-145.32, weight = 1), summary statistics on adult body weight from unpublished JARPNII survey data (Tamura et al., 2016) strongly hint that previously observed regional differences in weight were due to temporal sampling bias (Víkingsson et al., 1988).

Figure 1: Body mass relationships for large mysticetes



Legend: Fluid-corrected body mass data for Balaenidae (A), *E. robustus* (B), *M. novaeangliae*/*B. physalus*/*B. borealis* (C), and *B. musculus* (D).

Skeletal mass regressions for *B. musculus* ($r^2 = 0.910$, $n = 43$) and *B. physalus* ($r^2 = 0.856$, $n = 40$) were coupled with published soft tissue ratios (Lockyer, 1981) to produce mass models corresponding to the extremes in body conditions (Figures 1, S20, & S21). The ratios for *B. physalus* were updated with additional data (Mogoe et al., 2014). To account for the observed discrepancy in the visceral weight (Omura et al., 1970), adjustments in the visceral components

were calculated and refitted into a mass model for *B. m. brevicauda* (Table S3). Figure 1 shows that all *Balaenoptera* species are considerably lighter than balaenids, *E. robustus*, and *M. novaeangliae* at equal lengths. With a 6% correction, the regression models predict *B. m. brevicauda* weighing 96.7 tonnes (77.6-115.8 tonnes) at 24.4 m, *B. m. intermedia* weighing 130.7 tonnes (105.0-156.4 tonnes) at 27 m, and 207.8 tonnes (167.0-248.7 tonnes) at 31.1 m.

While mass data for *B. musculus* is sparse for individuals exceeding 28 m, whalers generally observed that exceptionally long females produced only slightly more oil than fattened individuals between 24-27.4 m (Walsh, 2010). The record yield was 354 barrels / 56.64 tonnes from a 30.8 m pregnant female while 305 barrels / 48.8 tonnes was extracted from a 27.7 m individual (Tønnessen & Johnsen, 1982). It may be that 27-28 m is the maximum TBL for optimal weight gain and larger whales cannot become especially fat. Oil yields from blubber, meat, and bones compose up to 29% of the total piecemeal mass of a fattened individual (Lockyer, 1981). This predicts an intact body mass of at least 209 tonnes for a whale that produced 56.64 tonnes of oil.

Relationships between length parameters

The following analyses combined the parameters reported in both the present review and previous work on odontocetes (McClure, 2024). The relationship between L_b, L_w, and maternal size were previously investigated using interchangeable use of the female L_∞ and L_{max} (Huang et al., 2009). This was re-examined using more precise estimates of the female L_∞ and observed

values of L_b (n = 13) and L_w (n = 12). On average, L_b equaled 33.6% of L_∞ and was significantly larger in odontocetes (mean = 41.9%, n = 4) than in mysticetes (mean = 29.8%, n = 9, Welch's two-sample *t*-test: $p < 0.05$). The L_w averaged 63.5 % of L_∞ and the difference between odontocetes (mean = 73.1%, n = 3) and mysticetes (mean =60.3%, n = 9) was not significant (Welch's two-sample *t*-test, $p > 0.05$).

Table 10: Relationships between L_{sm}, L_{mean} , and L_∞ in large mysticetes.

Species	**L_{sm}/L_{mean} (%) M/F**	**L_{sm}/L_∞ (%) M/F**	**L_{mean}/L_∞ (%) M/F**	**CV (%) M/F**	***N* M/F**
E. japonica	90.6 / 86.3	87.9 / 82.9	97.0 / 96.0	5.40 / 6.74	71 / 40
B. mysticetus	88.2 / 87.0	81.9 / 81.2	92.9 / 93.3	8.33 / 8.18	200[a] / 234[a]
E. robustus	92.5 / 92.8	88.1 / 88.5	95.2 / 95.4	5.25 / 5.44	792[a] / 773[a]
M. novaeangliae	90.3 / 89.5	85.5 / 86.9	94.7 / 97.1	6.94 / 6.84	31,324[a] / 7,237
B. edeni (North Pacific)	91.2 / 90.8	89. 9 / 88.7	98.4 / 97.7	4.48 / 4.23	5,047[a] / 1,724
B. borealis					
North	92.7 / 91.7	90.1 / 87.5	97.2 / 95.4	4.45 / 4.76	20,016[a] / 7,165
South	93.9 / 90.4	89.0 / 86.0	94.8 / 95.1	4.22 / 4.74	65,039[a] / 32,678
B. physalus					
North	94.1 / 93.9	90.6 / 89.4	96.4 / 95.2	4.86 / 5.08	26,009[a] / 7,323
South	94.1 / 91.3	91.4 / 89.7	97.1 / 98.2	4.22 / 4.84	178,361[a] / 92,631
B. musculus					
North	90.9 / 90.2	88.6 / 87.3	97.4 / 96.8	4.47 / 4.88	1,147[a] / 227
Antarctic	94.2 / 91.4	90.4 / 89.7	96.0 / 98.1	4.63 / 4.82	28,865[a] / 10,809
Pygmy	91.5 / 91.9	86.7 / 87.7	94.8 /95.4	4.60 / 4.98	3,199[a] / 1,509

a. Estimate from component curve.

Being parameters for adult size, the relationships between L_{mean}, L_{sm}, and L_{∞} are compared in species and subspecies for which all three were known (Table 10). *E. australis* was omitted due to issues with the compatibility of the L_{∞} estimates from photogrammetry data. On average, the L_{sm}/L_{mean}, L_{sm}/L_{∞}, and L_{mean}/L_{∞} ratios equaled 87.4%, 90.9%, and 96.0%, respectively. None of these values were significantly different between odontocetes and mysticetes (Welch's two-sample *t*-test, $p < 0.05$). After removing species where < 200 mature individuals were sampled, the species with the highest CV values were *B. mysticetus*, *P. macrocephalus*, and *M. novaeangliae*. As would be expected, the correlation against CV was statistically significant for all three ratios: L_{sm}/L_{mean} ($F_{1,24}$=23.1, $p < 0.001$), L_{mean}/L_{∞} ($F_{1,24}$= 43.1, $p < 0.001$), and L_{mean}/L_{∞} ($F_{1,24}$= 16.4, $p < 0.001$).

4| Discussion

The discrepancy between commercial data and photogrammetry measurements for *E. australis* mirrored previous observations for both this species (Tormosov et al., 1998) and *B. mysticetus* (George et al., 2004), where hauled whales appeared to be systematically longer. This phenomenon is replicated to neither the same degree nor consistency in more streamlined species that overlap in mass (Bierlich et al., 2023; Miller et al., 2013; Ortega-Ortiz et al., 2022; Russell et al., 2023, 2024). Rather than the tissue itself stretching from the force, the discrepancy appears to be due to Balaenids experiencing a greater post-mortem deviation from their natural posture while lying upon a flat surface.

It is notable that the photogrammetric volume models for *B. musculus*, *M. novaeangliae*, *E. robustus*, *P. macrocephalus* were able to match the mass models derived from direct weighings with body density estimates nearer to that of seawater (Christiansen et al., 2021; Glarou et al., 2022; Napoli et al., 2024; Russell et al., 2023, 2024). By contrast, photogrammetric models for balaenids predicted notably lower body density estimates (Christiansen et al., 2024; Glarou et al., 2022). As the true body mass and volume would remain constant as the posture changes, the volume of landed whales might be overestimated by models designed for photographed whales. This may introduce downward bias when calculating the average body density of landed whales by their estimated volume (Christiansen et al., 2019, 2024). Since the compatibility between commercial and photogrammetry data implies that other species exhibit a straighter natural posture, measurements for balaenids taken along a flat surface may be more compatible for interspecies comparisons.

In general, the regional differences in L_{mean} for *Balaenoptera* species were consistent with previous research that uncovered either inherent differences in asymptotic size (Best, 1977; Best & Lockyer, 2002; Lockyer, 1977; Ohsumi, 1980) or variation in growth rate (Lockyer, 1981; Mogoe et al., 2014; Panfilov, 1978). However, differences were also detected for populations that were considered synonymous in size, such as the northern populations of *B. physalus* (Aguilar et al., 1988; Aguilar & Lockyer, 1987) and certain populations within *M. novaeangliae* (Chittleborough, 1965; Stevick, 1999). It may be, as previously concluded for *P. macrocephalus* (McClure, 2024), that these differences are confounded by age composition or catch selectivity,

negating a true morphological difference. There may also be evidence of density-dependent growth, as the highest L_{mean} values reported for *M. novaeangliae* belonged to the smallest catches.

Across the Southern Hemisphere dataset for *B. physalus*, several expeditions reported mature females as small as 14.3-16 m. This is notable as the smallest mature females reported in biological studies typically measured 18.5-18.6 m (Kakuwa et al., 1953; Mackintosh, 1942; Ohno & Fujino, 1952). While unusually small mature females would align with the observations made for a proposed pygmy subspecies (Clarke, 2004), clerical errors or species misidentification must also be considered.

For *B. musculus*, the SE Pacific catch was most similar in mean size to the northern subspecies, in agreement with the results of genetic clustering with the ENP stock (Attard et al., 2024). The size difference from the pooled North Pacific catch data aligns with previous findings in separating the ENP and WNP populations (Monnahan et al., 2014). The South Pacific catch for *B. borealis* mirrors this trend in body size without any obvious signs of species misidentification with *B. edeni*. While biological studies do not seem to be available, the calls recorded from *B. borealis* near Chile were unique from all other regions (Español-Jiménez et al., 2019). This would support that the SE Pacific stock for *B. borealis* may be a discrete population from the rest known in the Southern Hemisphere.

Interspecific differences in body mass were notably grouped by feeding strategy: lunge-feeding *Balaenoptera* were the lightest and the skim-feeding balaenids were the heaviest by a substantial margin, as previously acknowledged (George, 2009; Lockyer, 1976). Intermediate of the two groups were *E. robustus* and *M. novaeangliae*, generalists that employ a combination of different feeding mechanisms (Croll et al., 2018; Nerini, 1984). Given the high cost of lunge-feeding (Potvin et al., 2012), it is likely that the different mass relationships and overall morphology of these species reflect the combination of feeding energetics and prey availability. Due to limited sampling, weight variation remains understudied for certain stocks, such as those in the North Atlantic for most species. This may be resolved as the methodology of photogrammetric body mass estimates continues to advance (Christiansen et al., 2022; Russell et al., 2023). These techniques also offer the advantage of performing longitudinal comparisons for the same individuals.

Analyses of early growth parameters re-affirms the convergence in relative size at weaning while birth size in odontocetes was found to be relatively greater than that of mysticetes. This is consistent with odontocete gestation generally lasting about 50% longer (Best et al., 1984; Kasuya, 1977; Lockyer, 1984; Olesiuk et al., 2005). As capital breeders, mysticetes accumulate energy stores that foster considerably faster growth during lactation than the continuous reserves of odontocetes (Irvine et al., 2017; Oftedal, 1997). Odontocetes producing proportionally larger neonates through longer gestations may serve to compensate for the slower postnatal growth towards weaning size. This could be an important factor to explore in future research on the adaptational divergence in cetacean reproduction.

Without direct data from biological examinations or photogrammetric surveys, size parameters for certain cetacean species are estimated using other species as analogs (Huang et al., 2009; Pastene et al., 2020). In general, the L_{mean} for large cetaceans was ~4% lower than the L_{∞}, and the CVs were about 4-5% in most species. *P. macrocephalus*, *M. novaeangliae*, and *B. mysticetus* having the highest variability in adult size (6-8%) is consistent with previous research indicating more prolonged growth after sexual maturity and very low frequencies of physically mature individuals (Chittleborough, 1955b, 1955a; Clarke et al., 1994; Lubetkin et al., 2012). Being able to use variation in adult size to infer the interval of adult growth and vice-versa can have important applications in modeling the growth and size distributions of under-studied baleen whale stocks or fossil species (Lambert et al., 2010).

5| Conclusions

Previous reviews have attempted to provide accurate descriptions for the size of some large mysticete species (McClain et al., 2015; Wood, 1982), but were limited in either their accuracy or species coverage. Prioritizing primary literature has revealed several instances where the republished data was subject to typographical errors or were missing significant details addressed by the original authors (Klumov, 1962; Scheffer, 1974; Voronin, 1948).

This review on the size of large cetaceans has compiled a large breadth of morphometric parameters for postnatal growth, adult variation, and body mass relationships. Analyzing the

information from both the literature and the IWC catch database facilitated descriptions of the variance and maximum credible sizes for the current species. This review will serve as an excellent reference for future research and provide another cornerstone in advancing morphometric analysis that emphasizes the importance of variability within species.

Data availability

Supplementary figures, code, and morphometric data acquired from literature and museum records can be acquired upon contact with the corresponding author. All whaling data is available from the International Whaling Commission upon request to this address: statistics@iwc.int

IWC contact page: https://iwc.int/contact

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References

Agbayani, S., Fortune, S. M. E., & Trites, A. W. (2020). Growth and development of North Pacific gray whales (*Eschrichtius robustus*). *Journal of Mammalogy*, *101*(3), 742–754. https://doi.org/10.1093/jmammal/gyaa028

Aguilar, A., & Lockyer, C. H. (1987). Growth, physical maturity, and mortality of fin whales (*Balaenoptera physalus*) inhabiting the temperate waters of the northeast Atlantic. *Canadian Journal of Zoology*, *65*(2), 253–264. https://doi.org/10.1139/z87-040

Aguilar, A., Olmos, M., & Lockyer, C. (1988). Sexual maturity in fin whales (*Balaenoptera physalus*) caught off Spain. *Reports International Whaling Commission*, *38*, 317–322.

Anderson, J. (1878). *Anatomical and zoological research; comprising an account of zoological results of two expeditions to western Yunnan in 1868 and 1875*.

Andrews, R. C. (1908). Notes upon the external and internal anatomy of *Balaena glacialis* Bonn. *Bulletin of the AMNH*, *24*(10), Article 10.

Andrews, R. C. (1914). I.- The California gray whale (*Rhachianectes glaucus* Cope). In *Monographs of the Pacific Cetacea.* (Vol. 1, pp. 227–287). New York□: American Museum of Natural History. https://digitallibrary.amnh.org/handle/2246/5730

Attard, C. R. M., Sandoval□Castillo, J., Lang, A. R., Vernazzani, B. G., Torres, L. G., Baldwin, R., Jenner, K. C. S., Gill, P. C., Burton, C. L. K., Barceló, A., Sironi, M., Jenner, M. □N. M., Morrice, M. G., Beheregaray, L. B., & Möller, L. M. (2024). Global conservation genomics of blue whales calls into question subspecies taxonomy and refines knowledge of population structure. *Animal Conservation*, acv.12935. https://doi.org/10.1111/acv.12935

Bando, T. (2021). Improved Estimates of Some Life-History Parameters of the Pelagic Subspecies of Bryde's Whale in the Western North Pacific. *Cetacean Population Studies*, *3*, 239–245.

Best, P. B. (1977). Two Allopatric Forms of Bryde's Whales off South Africa. *Report of the International Whaling Commission (Special Issue)*, *1*, 10–38.

Best, P. B. (1989). Some Comments on the BIWS Catch Record Data Base. *Report of the International Whaling Commission*, *39*, 363–369.

Best, P. B. (2008). *Whales and Dolphins of the Southern African Subregion*. Cambridge University Press.

Best, P. B. (2011). A note on the age at sexual maturity of humpback whales. *J. Cetacean Res. Manage.*, 71–73. https://doi.org/10.47536/jcrm.vi.306

Best, P. B., Canham, P. A. S., & Macleod, N. (1984). Patterns of reproduction in sperm whales, *Physeter macrocephalus*. *Report of the International Whaling Commission (Special Issue)*, *6*, Article 6.

Best, P. B., & Lockyer, C. (2002). Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa. *South African Journal of Marine Science*, *24*. https://doi.org/10.2989/025776102784528510

Bianucci, G., Marx, F. G., Collareta, A., Di Stefano, A., Landini, W., Morigi, C., & Varola, A. (2019). Rise of the titans: Baleen whales became giants earlier than thought. *Biology Letters*, *15*(5), Article 5. https://doi.org/10.1098/rsbl.2019.0175

Bierlich, K. C., Kane, A., Hildebrand, L., Bird, C. N., Fernandez Ajo, A., Stewart, J. D., Hewitt, J., Hildebrand, I., Sumich, J., & Torres, L. G. (2023). Downsized: Gray whales using an

alternative foraging ground have smaller morphology. *Biology Letters*, *19*(8), 20230043. https://doi.org/10.1098/rsbl.2023.0043

Bisconti, M., Pellegrino, L., & Carnevale, G. (2021). Evolution of gigantism in right and bowhead whales (Cetacea: Mysticeti: Balaenidae). *Biological Journal of the Linnean Society*, *blab086*, Article blab086. https://doi.org/10.1093/biolinnean/blab086

Blyth, E. (1859). On the great rorqual of the Indian Ocean, with notices of other cetals, and of the Syrenia or marine pachyderms. *Journal of the Asiatic Society of Bengal*, *28*(5), Article 5.

Borowski, G. H. (1781). *Gemeinnüzzige Naturschichte des Tierreichs* (Vol. 2). G. L. Lange, Berlin and Stralsund.

Branch, T. A. (2008). *Biological parameters for pygmy blue whales*. 60th Annual Meeting the International Whaling Commission, Santiago.

Branch, T. A., Abubaker, E., Mkango, S., & Butterworth, D. (2007). Separating southern blue whale subspecies based on length frequencies of sexually mature females. *Marine Mammal Science*, *23*, 803–833. https://doi.org/10.1111/j.1748-7692.2007.00137.x

Branch, T. A., & Mikhalev, Y. A. (2008). Regional differences in length at sexual maturity for female blue whales based on recovered Soviet whaling data. *Marine Mammal Science*, *24*(3), Article 3. https://doi.org/10.1111/j.1748-7692.2008.00214.x

Burmeister, H. (1871). Del Año 1871. *Boletin Del Museo Público de Buenos Aires*, *1871*, 11–20.

Carwardine, M. (1995). *The Guinness book of animal records*. Enfield□: Guinness Publishing.

Chittleborough, R. G. (1955a). Aspects of Reproduction in the Male Humpback Whale, *Megaptera nodosa* (Bonnaterre). *Marine and Freshwater Research*, *6*(1), 1–29. https://doi.org/10.1071/mf9550001

Chittleborough, R. G. (1955b). Puberty, Physical Maturity, and Relative Growth of the Female Humpback Whale, *Megaptera nodosa* (Bonnaterre), on the Western Australian Coast. *Marine and Freshwater Research*, *6*(3), 315–327. https://doi.org/10.1071/mf9550315

Chittleborough, R. G. (1965). Dynamics of two populations of the humpback whale, *Megaptera novaeangliae* (Borowski). *Marine and Freshwater Research*, *16*(1), 33–128. https://doi.org/10.1071/mf9650033

Christiansen, F., Bejder, L., Burnell, S., Ward, R., & Charlton, C. (2022). Estimating the cost of growth in southern right whales from drone photogrammetry data and long-term sighting histories. *Marine Ecology Progress Series*, *687*, 173–194. https://doi.org/10.3354/meps14009

Christiansen, F., Dawson, S., Durban, J., Fearnbach, H., Miller, C., Bejder, L., Uhart, M., Sironi, M., Corkeron, P., Rayment, W., Leunissen, E., Haria, E., Ward, R., Warick, H., Kerr, I., Lynn, M., Pettis, H., & Moore, M. (2020). Population comparison of right whale body condition reveals poor state of the North Atlantic right whale. *Marine Ecology Progress Series*, *640*. https://doi.org/10.3354/meps13299

Christiansen, F., Rodriguez, F., Martínez, S., Swartz, S., Warick, H., Vivier, F., & Bejder, L. (2021). Poor body condition associated with an unusual mortality event in gray whales. *Marine Ecology Progress Series*, *658*, 237–252. https://doi.org/10.3354/meps13585

Christiansen, F., Sironi, M., Moore, M. J., Di Martino, M., Ricciardi, M., Warick, H. A., Irschick, D. J., Gutierrez, R., & Uhart, M. M. (2019). Estimating body mass of free-living whales using aerial photogrammetry and 3D volumetrics. *Methods in Ecology and Evolution*, *10*(12), Article 12. https://doi.org/10.1111/2041-210X.13298

Christiansen, F., Tervo, O. M., Heide-Jørgensen, M. P., & Teilmann, J. (2024). Prey consumption of bowhead whales in West Greenland estimated from drone measurements of body size and condition. *Polar Biology*, *47*(1), 17–39. https://doi.org/10.1007/s00300-023-03207-8

Clarke, R. (2004). Pygmy Fin Whales. *Marine Mammal Science*, *20*(2), 329–334. https://doi.org/10.1111/j.1748-7692.2004.tb01161.x

Clarke, R., Paliza, O., & Aguayo, A. L. (1994). Sperm whales of the Southeast Pacific. Part VI. Growth and breeding in the male. *Investigations on Cetacea*, *25*, 93–224.

Constantine, R., Iwata, T., Nieukirk, S. L., & Penry, G. S. (2018). Future Directions in Research on Bryde's Whales. *Frontiers in Marine Science*, *5*. https://www.frontiersin.org/articles/10.3389/fmars.2018.00333

Cope, Edw. D. (1868). On Agaphelus, a Genus of Toothless Cetacea. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *20*, 221–227.

Croll, D. A., Tershy, B. R., Newton, K. M., de Vos, A., Hazen, E., & Goldbogen, J. A. (2018). Filter Feeding. In B. Würsig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals (Third Edition)* (pp. 363–368). Academic Press. https://doi.org/10.1016/B978-0-12-804327-1.00127-8

Cummings, W. C. (1985). Right Whales *Eubalaena glacialis* (Muller, 1776) and *Eubalaena australis* (Desmoulins, 1822). In *The Sirenians and Baleen Whales* (Vol. 3, pp. 275–304). Academic Press, INC.

Desmoulins, A. (1822). *Baleine. Balaena. Mam. In: Dictionnaire Classique d'Histoire naturelle. 2* (pp. 155–165).

Donovan, G. P. (2000). A note on the possible occurrence of pygmy blue whales (*Balaenoptera musculus brevicauda*) south of 60°S. *IWC Paper SC/52/OS15*, 15 pp.

Español-Jiménez, S., Bahamonde, P. A., Chiang, G., & Häussermann, V. (2019). Discovering sounds in Patagonia: Characterizing sei whale (*Balaenoptera borealis*) downsweeps in the south-eastern Pacific Ocean. *Ocean Science*, *15*(1), 75–82. https://doi.org/10.5194/os-15-75-2019

Fairburn, W. A. (1955). *Merchant Sail*. Fairburn Marine Educational Foundation.

Fortune, S. M. E., Moore, M. J., Perryman, W. L., & Trites, A. W. (2021). Body growth of North Atlantic right whales (*Eubalaena glacialis*) revisited. *Marine Mammal Science*, *37*(2), 433–447. https://doi.org/10.1111/mms.12753

George, J. C. (2009). *Growth, Morphology And Energetics Of Bowhead Whales (Balaena Mysticetus)* [Thesis]. https://scholarworks.alaska.edu/handle/11122/9031

George, J. C., Bada, J., Zeh, J., Scott, L., Brown, S. E., O'Hara, T., & Suydam, R. (1999). Age and growth estimates of bowhead whales (Balaena mysticetus) via aspartic acid racemization. *Canadian Journal of Zoology*, *77*(4), Article 4. https://doi.org/10.1139/z99-015

George, J. C., Bockstoce, J. R., Punt, A. E., & Botkin, D. B. (2007). Preliminary Estimates of Bowhead Whale Body Mass and Length from Yankee Commercial Oil Yield Records. *Center for the Study of the Environment*, 11. SC/59/BRG5.

George, J. C., Koski, W., Suydam, R., & Rugh, D. J. (2004). Body stretching of bowhead whales during hauling and butchering during the subsistence hunt. *Presented to the Scientific Committee of the International Whaling Commission*. SC/56/BRG9.

George, J. C., Thewissen, J. G. M. "Hans," Duyke, A. V., Breed, G. A., Suydam, R., Sformo, T., Person, B., & Brower, H. K. (2021). Life history, growth, and form. In *The Bowhead Whale: Balaena Mysticetus: Biology and Human Interactions* (pp. 87–115). Academic Press.

Glarou, M., Gero, S., Frantzis, A., Brotons, J. M., Vivier, F., Alexiadou, P., Cerdà, M., Pirotta, E., & Christiansen, F. (2022). Estimating body mass of sperm whales from aerial photographs. *Marine Mammal Science*. https://doi.org/10.1111/mms.12982

Gorter, U. (2010, December). Basic Blues On Display-Articulated Blue Whale Skeletons on Public Display Throughout the World. *Spyhopper-ACS Newsletter*, 10–14.

Harding, J. P. (1949). The Use of Probability Paper for the Graphical Analysis of Polymodal Frequency Distributions. *Journal of the Marine Biological Association of the United Kingdom*, *28*(1), 141–153. https://doi.org/10.1017/S0025315400055259

Huang, S., Chou, L. S., & Ni, I.-H. (2009). Comparable length at weaning in cetaceans. *Marine Mammal Science*, *25*, 875–887.

Ichihara, T. (1966). The Pygmy Blue Whale, *Balaenoptera musculus brevicauda*, a New Subspecies. In K. S. Norris (Ed.), *Whales, Dolphins, and Porpoises* (pp. 79–113). University of California Press.

Irvine, L. G., Thums, M., Hanson, C. E., McMahon, C. R., & Hindell, M. A. (2017). Quantifying the energy stores of capital breeding humpback whales and income breeding sperm whales using historical whaling records. *Royal Society Open Science*, *4*(3), 160290. https://doi.org/10.1098/rsos.160290

Ivashchenko, Y. V., & Clapham, P. J. (2012). Soviet catches of right whales *Eubalaena japonica* and bowhead whales *Balaena mysticetus* in the North Pacific Ocean and the Okhotsk Sea. *Endangered Species Research*, *18*(3), 201–217. https://doi.org/10.3354/esr00443

Ivashchenko, Y. V., Clapham, P. J., & Jr, R. (2017). New data on Soviet catches of blue (*Balaenoptera musculus*) and right whales (*Eubalaena japonica*) in the North Pacific. *J. Cetacean Res. Manage.*, *17*, 15–22. https://doi.org/10.47536/jcrm.v17i1.427

Jackson, J. A., Steel, D. J., Beerli, P., Congdon, B. C., Olavarría, C., Leslie, M. S., Pomilla, C., Rosenbaum, H., & Baker, C. S. (2014). Global diversity and oceanic divergence of humpback whales (*Megaptera novaeangliae*). *Proceedings of the Royal Society B: Biological Sciences*, *281*(1786), Article 1786. https://doi.org/10.1098/rspb.2013.3222

Junge, G. C. A. (1950). On a specimen of the rare fin whale, *Balaenoptera edeni* Anderson, stranded on Pulu Sugi near Singapore. *Zoologische Verhandelingen*, *9*(1), 1–26.

Kakuwa, Z., Kawakami, T., & Iguchi, K. (1953). Biological investigation on the whales caught by the Japanese Antarctic whaling fleets in the 1951-52 season. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *8*, 147–213.

Kamath, G. (2015). *Bounds on the expectation of the maximum of samples from a gaussian*. http://www. gautamkamath. com/writings/gaussian max. pdf.

Kasuya, T. (1977). Age determination and growth of the Baird's beaked whale with a comment on the fetal growth rate. *Scientific Report of the Whales Research Institute*, *29*, 1–20.

Klumov, S. K. (1962). The right whale in the Pacific Ocean (I. E. Scarff, Trans.). *Proceedings of the Institute of Oceanology, Academy of Sciences, U.S.S.R.*, *58*, 202–297.

Lacépède, B. G. E. (1818). *Sur les cétacées de mers voisines du Japon*.

Lambert, O., Bianucci, G., Post, K., de Muizon, C., Salas-Gismondi, R., Urbina, M., & Reumer, J. (2010). The giant bite of a new raptorial sperm whale from the Miocene epoch of Peru. *Nature*, *466*(7302), 105–108. https://doi.org/10.1038/nature09067

Laurie, A. H. (1933). Some aspects of respiration in blue and fin whales. *Discovery Reports*, *7*, 363–406.

Lilljeborg. (1861). *Forhandlinger ved de skandinaviske naturforskeres ottende møde (1860)*. *8*, 602.

Linneaus, C. von. (1758). *Caroli Linnaei...Systema naturae per regna tria naturae□:secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis* (L. Salvius, Ed.; pp. 1–881). Impensis Direct. Laurentii Salvii. https://doi.org/10.5962/bhl.title.542

Lockyer, C. (1976). Body weights of some species of large whales. *ICES Journal of Marine Science*, *36*(3), 259–273. https://doi.org/10.1093/icesjms/36.3.259

Lockyer, C. (1977). Some Estimates of Growth in the Sei whale, *Balaenoptera borealis*. *Report of the International Whaling Commission (Special Issue)*, *1*, 58–62.

Lockyer, C. (1981). Growth and energy budgets of large baleen whales from the southern hemisphere. *Mammals in the Seas*, *3*(5), 379–487.

Lockyer, C. (1984). Review of baleen whale (Mysticeti) reproduction and implications for management. *Reports of the International Whaling Commission Special Issue*, *6*, 27–50.

Lubetkin, S., Zeh, J., & George, J. (2012). Statistical modeling of baleen and body length at age in bowhead whales (*Balaena mysticetus*). *Canadian Journal of Zoology*, *90*, 915–931. https://doi.org/10.1139/z2012-057

Mackintosh, N. A. (1942). *The Southern Stocks of Whalebone Whales*. University Press.

McClain, C. R., Balk, M. A., Benfield, M. C., Branch, T. A., Chen, C., Cosgrove, J., Dove, A. D. M., Gaskins, L., Helm, R. R., Hochberg, F. G., Lee, F. B., Marshall, A., McMurray, S. E., Schanche, C., Stone, S. N., & Thaler, A. D. (2015). Sizing ocean giants: Patterns of intraspecific size variation in marine megafauna. *PeerJ*, *3*, e715. https://doi.org/10.7717/peerj.715

McClure, J. (2024). *A summary of intraspecific size variation for large odontocetes* (p. 2024.09.05.610699). bioRxiv. https://doi.org/10.1101/2024.09.05.610699

Mikhalev, Y. A. (2019). Analysis of the Correlation Between Whale Length and Weight. In *Whales of the Southern Ocean: Biology, Whaling and Perspectives of Population Recovery* (pp. 31–62). Springer International Publishing. https://doi.org/10.1007/978-3-030-29252-2_2

Miller, B. S., Growcott, A., Slooten, E., & Dawson, S. M. (2013). Acoustically derived growth rates of sperm whales (*Physeter macrocephalus*) in Kaikoura, New Zealand. *The Journal*

of the Acoustical Society of America, *134*(3), 2438–2445. https://doi.org/10.1121/1.4816564

Mogoe, T., Bando, T., Maeda, H., Kato, H., & Ohsumi, S. (2014). *Biological observations of fin whales sampled by JARPAII in the Antarctic*. 1–18.

Monnahan, C. C., Branch, T. A., Stafford, K. M., Ivashchenko, Y. V., & Oleson, E. M. (2014). Estimating Historical Eastern North Pacific Blue Whale Catches Using Spatial Calling Patterns. *PloS One*, *9*(6). https://doi.org/doi:10.1371/journal.pone.0098974

Moore, M., Knowlton, A., Kraus, S., McLellan, W. A., & Bonde, R. (2004). Morphometry, gross morphology and available histopathology in North Atlantic right whale (Eubalaena glacialis) mortalities. *Journal of Cetacean Research and Management*, *6*, 199–214. https://doi.org/10.47536/jcrm.v6i3.762

Müller, O. F. (1776). *Zoologiæ Danicæ Prodromus, seu Animalium Daniæ et Norvegiæ indigenarum characteres, nomina, et synonyma imprimis popularium*.

Napoli, C., Hirtle, N., Stepanuk, J., Christiansen, F., Heywood, E. I., Grove, T. J., Stoller, A., Dodds, F., Glarou, M., Rasmussen, M. H., Lonati, G. L., Davies, K. T. A., Videsen, S., Simon, M. J., Boye, T. K., Zoidis, A., Todd, S. K., & Thorne, L. H. (2024). Drone-based photogrammetry reveals differences in humpback whale body condition and mass across North Atlantic foraging grounds. *Frontiers in Marine Science*, *11*. https://doi.org/10.3389/fmars.2024.1336455

Nerini, M. K. (1984). A review of gray whale feeding ecology. In *The gray whale, Eschrichtius robustus* (pp. 423–450).

Oftedal, O. (1997). Lactation in Whales and Dolphins: Evidence of Divergence Between Baleen and Toothed-Species. *Journal of Mammary Gland Biology and Neoplasia*, *2*(3), 205–230.

Ohno, M., & Fujino, K. (1952). Biological investigation on the whales caught by the Japanese Antarctic whaling fleets, season 1950/51. 125-190. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *7*, 125–190.

Ohsumi, S. (1980). Population study of the Bryde's whale in the southern hemisphere under scientific permit in the three seasons 1976/77–1978/79. *Report of the International Whaling Commission*, *30*, 319–331.

Ohsumi, S., Nishiwaki, M., & Hibiya, T. (1958). Growth of fin whale in the Northern Pacific. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *13*, 97–133.

Olesiuk, P. F., Ellis, G. M., & Ford, J. K. (2005). *Life history and population dynamics of northern resident killer whales (*Orcinus orca*) in British Columbia*. Canada: Canadian Science Advisory Secretariat.

Omura, H. (1958). North Pacific Right Whale. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *13*, 1–52.

Omura, H. (1984). Measurements of body proportions of the pygmy blue whale, left by the late Dr. Tadayoshi Ichihara. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *35*, 199–203.

Omura, H., Ichihara, T., & Kasuya, T. (1970). Osteology of Pygmy Blue Whale With Additional Information on External and Other Characteristics. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *22*, 1–27.

Omura, H., Ohsumi, S., Nemoto, T., Nasu, K., & Kasuya, T. (1969). Black Right Whales in the North Pacific. *Scientific Reports of The Whales Research Institute Tokyo, Japan*, *21*, 1–78.

Ortega-Ortiz, C. D., Mata Cruz, R. M., Gerrodette, T., & Gendron, D. (2022). A photogrammetric method to estimate total length of the largest mammal, the blue whale (Balaenoptera musculus). *Mammalian Biology*. https://doi.org/10.1007/s42991-022-00307-6

Panfilov, B. G. (1978). Postnatal Linear Growth of the Fin Whales from the Indian Ocean Waters of the Southern Hemipshere. *Report of the International Whaling Commission*, *28*, 297–300.

Pastene, L. A., Acevedo, J., & Branch, T. A. (2020). Morphometric analysis of Chilean blue whales and implications for their taxonomy. *Marine Mammal Science*, *36*(1), 116–135. https://doi.org/10.1111/mms.12625

Pease, Z. W. (Zephaniah W. (with Claire T. Carney Library, U. of M. D.). (1918). *History of New Bedford*. New York□: The Lewis historical publishing company. http://archive.org/details/historyofnewbedf01peas

Pershing, A. J., Christensen, L. B., Record, N. R., Sherwood, G. D., & Stetson, P. B. (2010). The Impact of Whaling on the Ocean Carbon Cycle: Why Bigger Was Better. *PLoS ONE*, *5*(8), Article 8. https://doi.org/10.1371/journal.pone.0012444

Pike, G. C., & MacAskie, I. B. (with Fisheries Research Board of Canada). (1969). *Marine mammals of British Columbia*. Fisheries Research Board of Canada.

Potvin, J., Goldbogen, J. A., & Shadwick, R. E. (2012). Metabolic Expenditures of Lunge Feeding Rorquals Across Scale: Implications for the Evolution of Filter Feeding and the Limits to Maximum Body Size. *PLOS ONE*, *7*(9), e44854. https://doi.org/10.1371/journal.pone.0044854

Redman, N. (2019). *Whales' Bones of Africa and Asia* (Vol. 8). Redman Publishing.

Rice, D. W. (1978). Blue Whale. In D. Haley, *Marine Mammals of Eastern North Pacific and Arctic Waters* (pp. 40–45). Pacific Search Press.

Rice, D. W. (1998). *Marine Mammals of the World: Systematics and Distribution*. Society for Marine Mammalogy.

Rice, D. W., & Wolman, A. A. (1971). *The life history and ecology of the gray whale (Eschrichtius robustus)*. The American Society of Mammalogists. https://portals.iucn.org/library/node/17576

Risting, S. (1922). *Av hvalfangstens historie*. J.W. Cappelen. https://www.biodiversitylibrary.org/bibliography/16212

Risting, S. (1928). Whales and Whale Foetuses: Statistics of catch and measurements collected from the Norwegian whalers' association 1922-25. *Rapports et Procès-Verbaux Des Réunions*, 122.

Rosel, P. E., & Wilcox, L. A. (2014). Genetic evidence reveals a unique lineage of Bryde's whales in the northern Gulf of Mexico. *Endangered Species Research*, *25*(1), Article 1. https://doi.org/10.3354/esr00606

Rosenbaum, H. C., Brownell, R. L., Brown, M. W., Schaeff, C., Portway, V., White, B. N., Malik, S., Pastene, L. A., Patenaude, N. J., Baker, C. S., Goto, M., Best, P. B., Clapham,

P. J., Hamilton, P., Moore, M., Payne, R., Rowntree, V., Tynan, C. T., Bannister, J. L., & DeSalle, R. (2000). World-wide genetic differentiation of *Eubalaena*: Questioning the number of right whale species. *Molecular Ecology*, *9*(11), Article 11. https://doi.org/10.1046/j.1365-294x.2000.01066.x

Russell, G., Christiansen, F., Colefax, A., Sprogis, K. R., & Cagnazzi, D. (2023). Comparisons of morphometrics and body condition between two breeding populations of Australian humpback whales. *Wildlife Research*. https://doi.org/10.1071/WR23026

Russell, G., Jolliffe, C., Elsdon, B., Christiansen, F., Colefax, A., & Cagnazzi, D. (2024). Comparatively poorer body condition of south-east Indian Ocean pygmy blue whales on their southern migration. *Australian Mammalogy*, *46*(2). https://doi.org/10.1071/AM23029

Scheffer, V. B. (1974). The largest whale. *Defenders of Wildlife International*, *49*(4), 272–274.

Schultz, L. P. (1938). Can the Weight of Whales and Large Fish be Calculated? *Journal of Mammalogy*, *19*(4), Article 4. https://doi.org/10.2307/1374238

Slijper, E. J. (1948). On the thickness of the layer of blubber in Antarctic Blue and Fin Whales. II. *Proceedings of Koninklijke Nederlandse Akademie van Wetenschappen*, *51*(9), 1114–1124.

Stevick, P. T. (1999). Age-Length Relationships in Humpback Whales: A Comparison of Strandings in the Western North Atlantic with Commercial Catches. *Marine Mammal Science*, *15*(3), 725–737. https://doi.org/10.1111/j.1748-7692.1999.tb00839.x

Stewart, J. D., Durban, J. W., Knowlton, A. R., Lynn, M. S., Fearnbach, H., Barbaro, J., Perryman, W. L., Miller, C. A., & Moore, M. J. (2021). Decreasing body lengths in North

Atlantic right whales. *Current Biology*, *31*(14), 3174-3179.e3. https://doi.org/10.1016/j.cub.2021.04.067

Sumich, J. (1986). *Latitudinal Distribution, Calf Growth and Metabolism, and Reproductive Energetics of Gray Whales, Eschrichtius Robustus*. Oregon State University.

Sumich, J., Blokhin, S., & Tiupeleyev, P. A. (2013). Revised estimates of foetal and post-natal growth in young gray whales (*Eschrichtius robustus*). *Journal of Cetacean Research and Management*, *13*, 89–96.

Tamura, T., Konishi, K., & Isoda, T. (2016). Updated prey consumption by common minke whales and interaction with fisheries in coastal areas of the Pacific side of Japan. *Presented to IWC SC JARPNII Review Workshop*. SC/F16/JR15 ICR.

Tarpley, R., Hillman, D. J., George, J. C., & Thewissen, J. G. M. (2021). Female and male reproduction. In *The Bowhead Whale: Balaena Mysticetus: Biology and Human Interactions* (pp. 185–211). Academic Press.

Thompson, D. W. (1928). *On Whales Landed at the Scottish Whaling Stations During the Years 1908-1914 and 1920-1927*. H.M. Stationery Office.

Tønnessen, J. N., & Johnsen, A. O. (1982). *The History of Modern Whaling*. University of California Press.

Tormosov, D. D., Mikhaliev, Y., Best, P. B., Zemsky, V., Sekiguchi, K., & Brownell, R. (1998). Soviet catches of southern right whales *Eubalaena australis*, 1951–1971. Biological data and conservation implications. *Biological Conservation - BIOL CONSERV*, *86*, 185–197. https://doi.org/10.1016/S0006-3207(98)00008-1

Víkingsson, G. A., Sigurjónsson, J., & Gunnlaugsson, T. (1988). On the Relationship Between Weight, Length and Girth Dimensions in Fin and Sei Whales Caught off Iceland. *Report of the International Whaling Commission*, *38*, 323–326.

Voronin, V. (1948). Pervyi pokhod Sovetskoi flotilii Slava za kitami v Antarktiku [The first voyage of the Soviet whaling flotilla Slava to the Antarctic]. *Izvestiya Vsesoyuznogo Geograficheskogo Obshchestva [News of the All Union Geographical Society]*, *80*(3), 213–222.

Walsh, Q. R. (2010). *Whaling Expedition of the Ulysses, 1937-38* (P. J. Capelotti, Ed.). University Press of Florida. https://muse.jhu.edu/book/17646

Williams, C. A. (1904). Early Whaling Industry of New England. In *Records and Papers of the New London County Historical Society* (Vol. 2, pp. 3–22). New London County Historical Society (Conn.).

Wood, G. L. (with Internet Archive). (1982). *The Guinness book of animal facts and feats*. Enfield, Middlesex□: Guinness Superlatives.

Woodby, D. A., & Botkin, D. B. (1993). Stock sizes prior to commercial whaling. In *The Bowhead whale* (pp. 387–407). Society for Marine Mammalogy.

Zar, J. H. (2010). Two-Sample Hypotheses. In *Biostatistical Analysis* (5th ed., pp. 130–178). Prentice Hall. Inc.

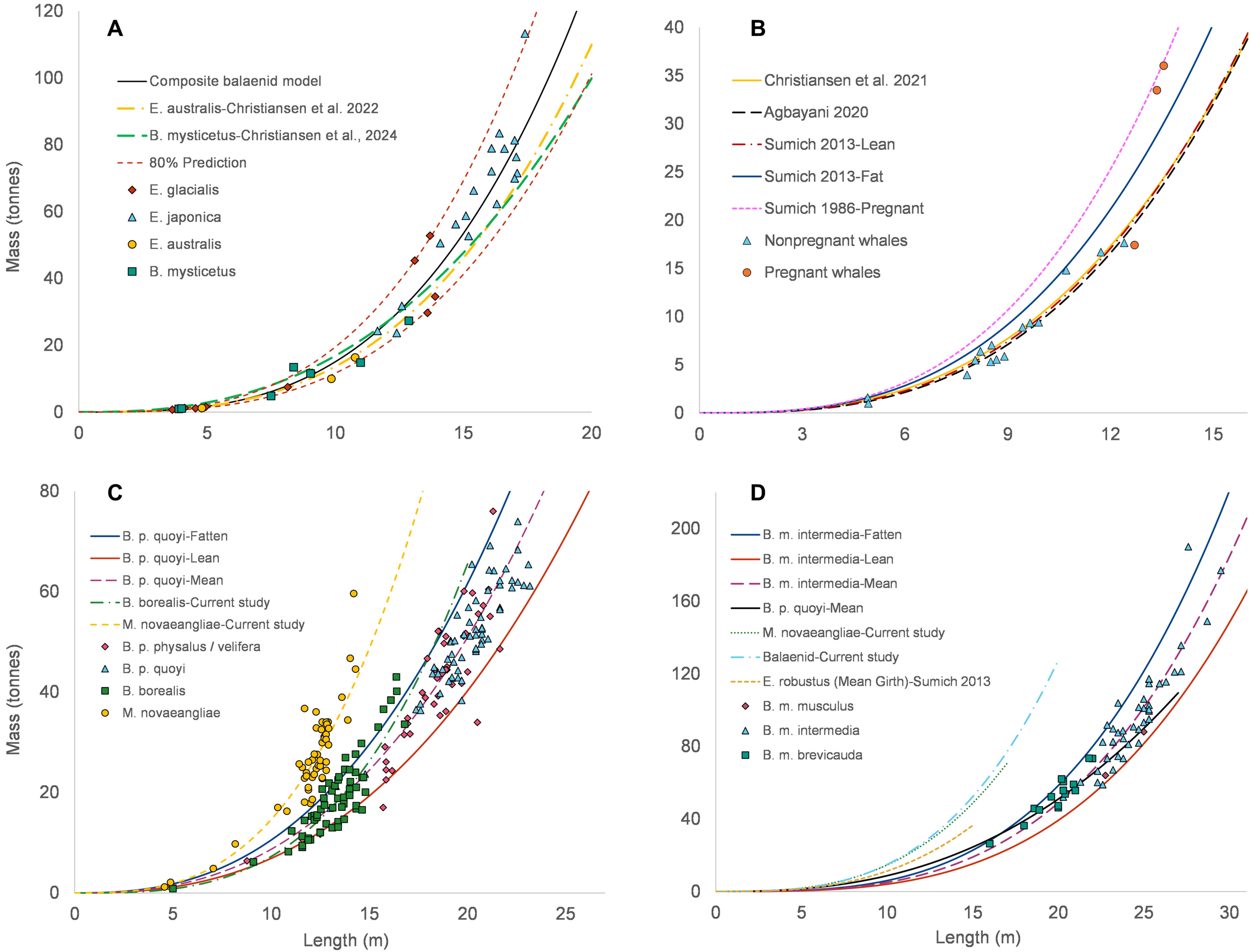
Zenkovich, B. A. (1934). Materials on the Study of the Large Cetaceans of the Seas of the Far East the California Gray Whale (*Rhachianectes glaucus* Cope). *Bulletin of the Far Eastern Branch of the Academy of Sciences of the USSR*, *10*, 9–27.

Zenkovich, B. A. (1937). Further Studies on the Grey or California Whale (*Rhachianectes glaucus* Cope). *Bulletin of the Far Eastern Branch of the Academy of Sciences of the USSR*, *23*, 91–104.

Zenkovich, B. A. (1954). *Around the world for whales* (2nd edition). State Publishing House of Geographical Literature.

Zhu, X., He, X., Jingong, X. Y., Song, C., Shan, K., & Liu, W.-L. (2018). Identification of fin whale specimens using mtDNA control region sequences. *Chinese Journal of Zoology*, *53*(2), 234–242.

中国最大长须鲸骨骼标本来了 [China's largest fin whale skeleton specimen arrives]. (2021, December 10). *Chinese Journal of Science-China Science Daily*.


A
Composite balaenid model
E. australis-Christiansen et al. 2022
B. mysticetus-Christiansen et al., 2024
80% Prediction
E. glacialis
E. japonica
E. australis
B. mysticetus
Mass (tonnes)
B
Christiansen et al. 2021
Agbayani 2020
Sumich 2013-Lean
Sumich 2013-Fat
Sumich 1986-Pregnant
Nonpregnant whales
Pregnant whales
C
B. p. quoyi-Fatten
B. p. quoyi-Lean
B. p. quoyi-Mean
B. borealis-Current study
M. novaeangliae-Current study
B. p. physalus / velifera
B. p. quoyi
B. borealis
M. novaeangliae
Mass (tonnes)
Length (m)
D
B. m. intermedia-Fatten
B. m. intermedia-Lean
B. m. intermedia-Mean
B. p. quoyi-Mean
M. novaeangliae-Current study
Balaenid-Current study
E. robustus (Mean Girth)-Sumich 2013
B. m. musculus
B. m. intermedia
B. m. brevicauda
Length (m)