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Assignment of South Georgia catches between southeast Pacific blue whales and Antarctic blue whales

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INTERNATIONAL
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ABSTRACT

Mixture models of sexually mature female blue whales are used to assess the proportion of historical catches at South Georgia that may have been Southeast Pacific ("Chilean") blue whales rather than Antarctic blue whales. Earlier data before 1923/24 were considered unreliable due to large proportions of very small mature females (14% were ≤ 70 ft) and high proportions of rounding to the nearest 5 ft interval in the length data (14%), therefore analyses focused on data from 1923/24 onwards. An estimated 3.3% (95% CI 1.6–5.1%) of catches during this later period were Southeast Pacific blue whales, but when the analysis is restricted to lengths with no rounding, the estimates were much lower and not statistically different from zero (mean 0.6%, 95% CI 0.0–2.6%). When this information is combined with the evidence from acoustics (a few distant calls in one month) and genetics (one Southeast Pacific individual in the Antarctic), it is most likely that any Southeast Pacific blue whales encountered at South Georgia are rare vagrants and not a common occurrence.

INTRODUCTION

Southern Hemisphere blue whales include three known subspecies: Antarctic blue whales, Southeast Pacific blue whales, and pygmy blue whales. Within these subspecies there is further debate about populations, with pygmy blue whales divided at present into five populations: Northwest Indian Ocean, North-central Indian Ocean, Southwest Indian Ocean, Southeast Indian Ocean and Southwest Pacific Ocean (Branch 2020). Antarctic blue whales have some population structure but evidence for separate populations is ambiguous (Lang et al. 2020).

South Georgia was the site of the largest catches of blue whales ever recorded, mostly caught during the early parts of the 20th century. It has long been accepted that these catches were Antarctic blue whales, and indeed the careful morphometric measurements of South Georgia blue whales in the 1920s by Mackintosh and Wheeler (1929) are used as the standard dataset for Antarctic blue whales to distinguish them from other blue whale subspecies and populations (Ichihara 1966, Sazhinov 1970, Pastene et al. 2020).

Previous analyses have sought to estimate the proportion of pygmy blue whales caught at South Georgia (Branch et al. 2007a) using mixture models based on the length frequencies of sexually mature females blue whales, finding that 9-12% may have been pygmy blue whales prior to 1937, but only 0.1–6.0% thereafter. However, a variety of data problems including substantial rounding complicated the interpretation of the catches in the earlier years (Branch et al. 2007a). No song records from any pygmy blue whale populations have been recorded off South Georgia, and the distribution and size of pelagic catches, and regions inhabited by pygmy blue whales are considerably far east of South Georgia, such that it is not very plausible that pygmy blue whales were caught in substantial numbers off South Georgia (Branch et al. 2007b, Branch et al. 2019).

However, recent findings have now raised the possibility that some South Georgia blue whales may come from the Southeast Pacific (Chilean blue whales). Notably, a genetic analysis found one blue whale with an assignment probability of 0.941 of belonging to the Chilean grouping at 70°S in IWC Area II, 0–60°W, i.e. in the region where South Georgia is located (LeDuc et al. 2007). In addition, several faint Chilean song types were recorded near South Georgia in August 2006 (Pangerc 2010), but this seems to be a rare occurrence, and other acoustic recordings have found only Antarctic blue whales around South Georgia (e.g. Širović et al. 2018). A preliminary mark-recapture analysis found no matches between 23 South Georgia blue whales with 473 Southeast Pacific blue whales (Olson et al. 2020). Assuming an inter-year resighting rates of 31% in the Southeast Pacific, a rough calculation based on these data implies that anywhere from 0–23% of South Georgia blue whales could be Southeast Pacific (TAB, personal analysis).

To address whether some Southeast Pacific blue whales may have been caught off South Georgia, a mixture analysis is conducted here, with the assumption that catch length frequencies of blue whales off South Georgia should comprise some proportion of Southeast Pacific blue whales and the remainder being Antarctic blue whales.

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METHODS

Known data recording issues

Whale catch length frequencies are known to be affected by a variety of biases. For blue whales, the introduction of a minimum length for all countries of 70 ft in 1937 (following Norway's lead in 1929) lead to fewer blue whales shorter than this length being reported, partly because of avoidance of shorter blue whales, and partly because shorter blue whales were sometimes euphemistically "stretched", i.e. the lengths of illegally-short blue whales were misreported as being exactly 70 ft (Branch et al. 2007a). This analysis therefore focuses on sexually mature female blue whales, which are nearly all considerably longer than 70 ft for both Antarctic and Southeast Pacific blue whales, and are well fitted by normal distributions (Branch et al. 2007a). Larger whales were preferred in most years, since they are more valuable; but smaller whalers were preferred in the earliest years at South Georgia and the South Shetlands, because the whaling boats and shoreside equipment could not easily handle and process the largest whales (Hinton 1915, Anon 1920, Harmer 1921).

Measurement methods also changed over time. Especially prior to the mid-1920s, many blue whales were not measured accurately or in a standardized manner. One pattern easily visible in length frequencies is the presence of substantial rounding of lengths to the nearest 5-ft interval resulting in prominent spikes in frequencies at 75, 80, and 85 ft (Branch et al. 2007a). For South Georgia, this is especially noticeable, with an estimated 14% of lengths rounded in years prior to 1937 and 8% thereafter; compared to 1–6% of rounding in Antarctic pelagic catches after 1937 (Branch et al. 2007a).

Data

Blue whale catches were extracted from the IWC's individual catch database and lengths obtained for three groupings of catches: (1) Southeast Pacific, comprising all catches taken in the rectangle west of South America between 2°N and 50°S, and 69°W to 120°W; (2) Antarctic south of 54°S, pelagic catches only, excluding any catches labelled as being pygmy by Soviet expeditions; and (3) South Georgia, land stations only, based on expedition codes listed by the IWC as operating out of South Georgia. For all regions, only the catches listed as female and mature (codes 1 or 3) were extracted. Most length data were recorded in English feet; any records recorded in metric units were converted to feet. All mature females listed as being below 60 ft were placed in a group at 60 ft; similarly, those listed as longer than 99 ft were placed in a group at 99 ft. Few records fell in the two extreme categories. Previous analyses have found the mean length of sexually mature females to be 84–85 ft (SD 4–5 ft) for Antarctic blue whales and 77 ft (SD 4 ft) for Southeast Pacific blue whales (Branch et al. 2007a), and thus these limits of 60–99 ft should encompass likely length ranges.

Mixture model

The assumption was made that the South Georgia catches comprised a mixture of SE Pacific and Antarctic blue whales. Thus the predicted proportion of whales at each length in South Georgia was obtained by:

$$\hat{p}_i^{SG} = (1 - p_{SEP} \times p_i^{Ant}) + p_{SEP}\, p_i^{SEP}$$

where p_{SEP} is a parameter to estimate that is the proportion at South Georgia that are SE Pacific blue whales, $1 - p_{SEP}$ is the proportion of whales at South Georgia that are Antarctic blue whales, p_i^{Ant} is the observed proportion of Antarctic blue whales at length *i* (in ft), p_i^{SEP} is the observed proportion of SE Pacific blue whales at length *i* (in ft).

The model then estimated the value of p_{SEP} that provided the best fit to the observed numbers at length *i* at South Georgia, x_i^{SG}, by minimizing the negative log likelihood, assuming a multinomial likelihood. The negative log likelihood that was minimized, after removing terms that are constant and depend only on the data, is given by:

$$-\ln L = -\sum_i x_i^{SG} \ln \hat{p}_i^{SG} .$$

The South Georgia data were examined for each year to determine in which time period rounding appeared to have been reduced (this occurred in 1923/24), and only data after that period were included in the analysis. In addition, since rounding is an indication of poor data quality, a second mixture model was fitted only to the length intervals that did not end with 0 or 5, to remove data likely to be inaccurate.

Likelihood profiling was used to find the 95% confidence intervals for the proportion of SE Pacific blue whales in South Georgia, p_{SEP}. In short, values of p_{SEP} were found that resulted in the negative log likelihood being 1.92 units above the negative log likelihood at the maximum likelihood estimate of the model parameter (Hilborn and Mangel 1997).

RESULTS

Mature female blue whale catches at South Georgia included substantial portions of smaller individuals (≤70 ft) in years prior to 1923/24 (14.2%), but markedly fewer (3.0%) thereafter (Fig. 2). This shift also coincides with a major decline in the proportion of catches recorded at 5-ft intervals from 35% to 27%, suggesting that much of the earlier data were, at best, inaccurately recorded, and at worst, included data points that were not based on actual whale measurements. Therefore, only the data from 1923/24 onward were included in the model-fitting analysis.

Lengths of SE Pacific blue whales were markedly shorter, with a peak at 77 ft, whereas both Antarctic and South Georgia blue whales had their modes at 85 ft. In both Antarctic and South Georgia, even in the later period of time, there was evidence of rounding to the nearest 5-ft interval: 25% and 27% of lengths were recorded at 5-ft intervals vs. the expected 20%. There was little evidence of "whale stretching", in which small whales shorter than the minimum allowable length of 70 ft were recorded as being 70 ft long.

When based on the full dataset, the mixture model estimated that 3.3% (95% CI 1.6–5.1%) of the blue whales caught at South Georgia were from the SE Pacific population. However, when data at the rounding intervals (65 ft, 70 ft, 75 ft, etc.) were excluded, the mixture model estimated that only 0.6% (95% CI 0.0–2.6%) of the blue whales caught at South Georgia were from the SE Pacific population. In other words, accounting for rounding of measurements to the nearest 5-ft interval resulted in an estimate that was not statistically distinguishable from zero.

DISCUSSION

These results suggest that a small portion of South Georgia catches could be from the Southeast Pacific: 3.3% when all data are considered, or 0.6% when only the non-rounded data are considered. However, given the latter estimate has 95% confidence intervals that include zero, it is also possible that the results are driven mostly by data quality issues such as non-standard measurements, rounding, or other inaccurate reported lengths. It is certainly odd that so many small sexually mature females were caught at South Georgia before 1923/24—14.2% of the total—but this same pattern was never observed in the pelagic Antarctic catches or in the later period of time off South Georgia. Indeed, only 0.4% of Antarctic pelagic catches were shorter than 70 ft. If there were substantial portions of SE Pacific or pygmy blue whales in South Georgia at the start of the whaling period, it would seem more likely that their proportion would increase over time given the near elimination of Antarctic blue whales by targeted whaling compared to the relatively low exploitation rates on the other two subspecies.

The acoustic and genetic data provide evidence that if Southeast Pacific blue whales do venture as far south and east as South Georgia, they are likely to be rare vagrants rather than moving as part of a population-wide migration. In other blue whale populations, individuals sometimes wander far afield, and this has been observed for Northeast Pacific blue whales venturing west towards Hawaii (Calambokidis et al. 2009), calls of the Sri Lanka type (North-central Indian Ocean) being heard off Angola (Cerchio et al. 2010), and Antarctic blue whales venturing into the North Atlantic and North Pacific Ocean (Širović et al. 2018, Samaran et al. 2019). Given the vast distances that blue whales are capable of travelling, their movements may be more driven by food availability than by the urge to follow predictable migration pathways as seen in other species such as right, gray, and humpback whales. Put simply, if there is food, they will forage; and if there is not, they will wander.

The totality of the available evidence from genetic, acoustic, and length data points towards any Southeast Pacific blue whales detected at South Georgia being rare vagrants, rather than a substantial portion of blue whales present off South Georgia.

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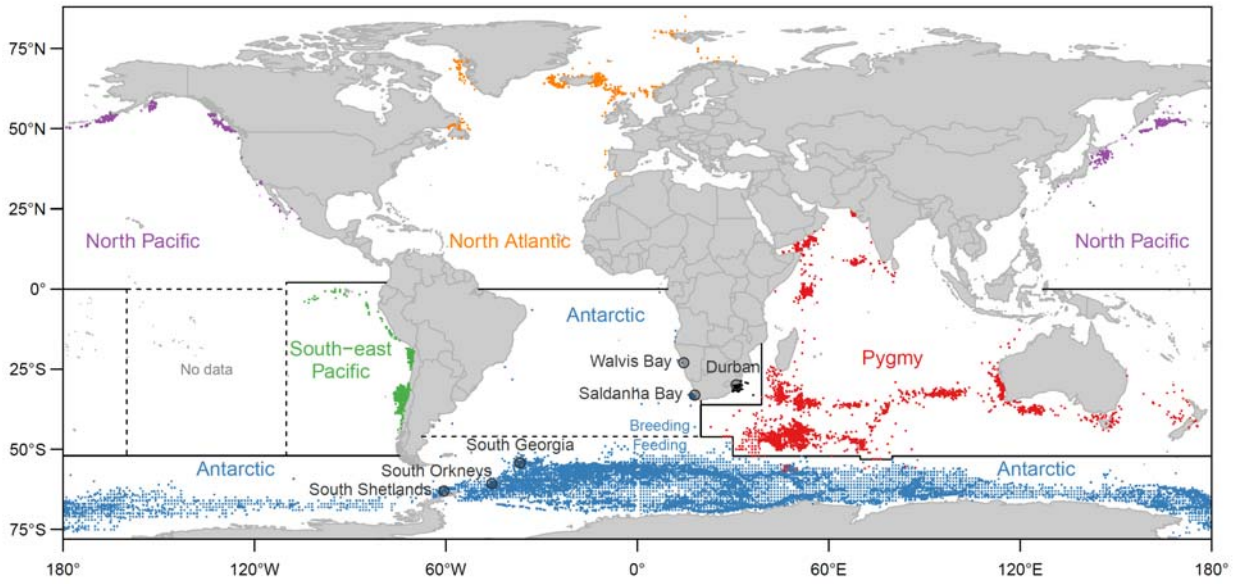

Fig. 1. Blue whale catches, showing the key land stations where it has long been presumed Antarctic blue whales were caught (South Shetlands, South Orkneys, South Georgia, Saldanha Bay and Walvis Bay), and the presumed distribution of Chilean (South-east Pacific) blue whales and their catches. SEP blue whale catch locations (green) are closer to the three southern land stations than pygmy blue whale catches (red).

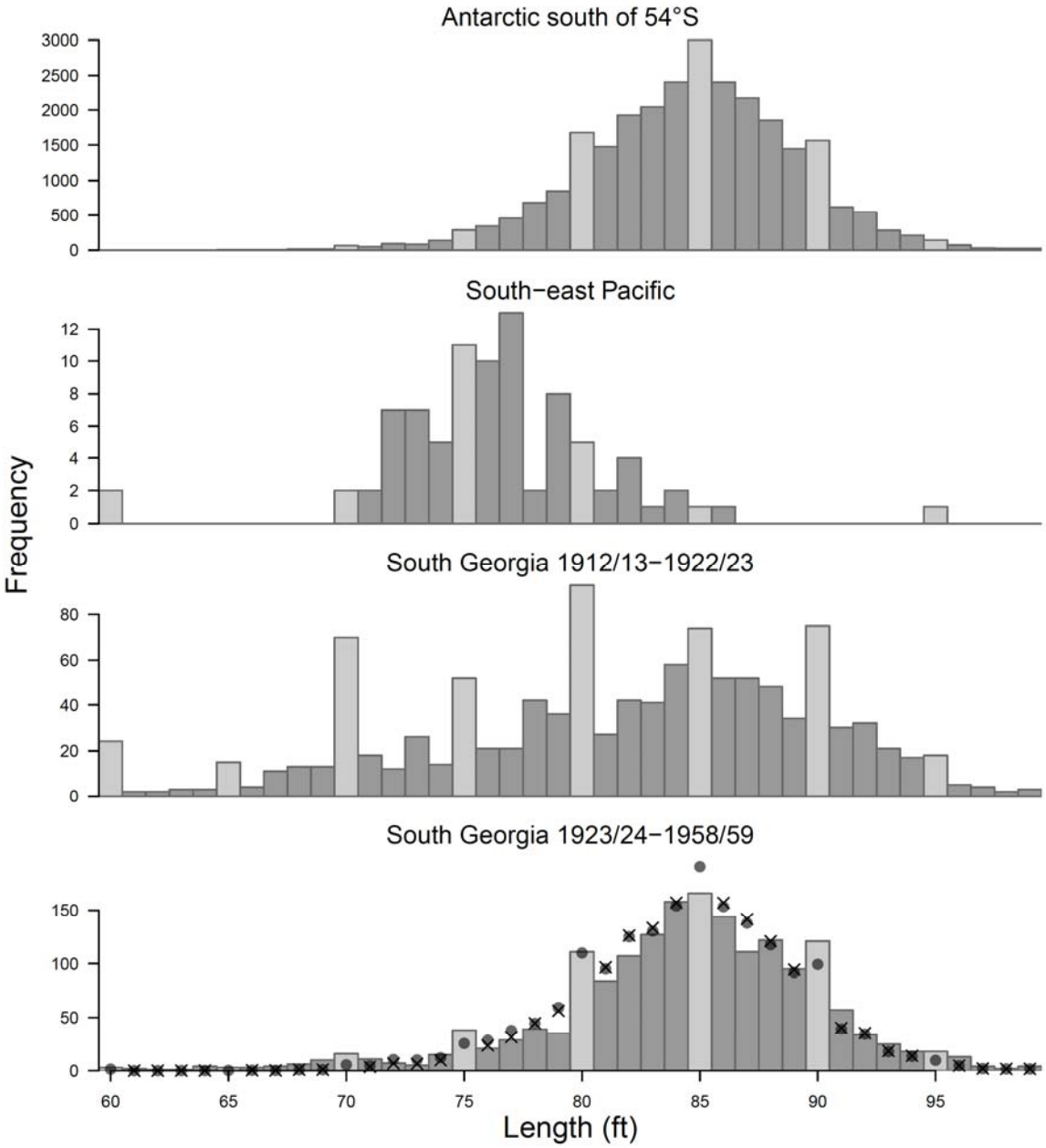

Fig. 2. Length frequencies of mature (pregnant) female blue whales caught in the Antarctic south of 54°S, South-east Pacific, and from land stations at South Georgia during the early period (before 1923/24) and later period (from 1923/24 onwards). In the early period at South Georgia, many short pregnant females were recorded, and a high percentage of reported catches were rounded to the nearest 5-ft interval (lighter bars), likely because of poor data reporting or measuring methods. The mixture model fits are shown when fitted to all data (circles) and when fitted to non-5-ft interval data (crosses).