

The world's smallest whale population?

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The North Pacific right whale (*Eubalaena japonica*) was heavily exploited by both nineteenth century whaling and recent (1960s) illegal Soviet catches. Today, the species remains extremely rare especially in the eastern North Pacific. Here, we use photographic and genotype data to calculate the first mark–recapture estimates of abundance for right whales in the Bering Sea and Aleutian Islands. The estimates were very similar: photographic = 31 (95% CL 23–54), genotyping = 28 (95% CL 24–42). We also estimated the population contains eight females (95% CL 7–18) and 20 males (95% CL 17–37). Although these estimates may relate to a Bering Sea subpopulation, other data suggest that the total eastern North Pacific population is unlikely to be much larger. Its precarious status today—the world's smallest whale population for which an abundance estimate exists—is a direct consequence of uncontrolled and illegal whaling, and highlights the past failure of international management to prevent such abuses.

Keywords: North Pacific; right whale; *Eubalaena japonica*; abundance; mark–recapture; Bering Sea

1. INTRODUCTION

The first whalers to arrive in the Gulf of Alaska in the mid-1800s spoke in hyperbolic terms of the number of right whales they saw. While the historic abundance is uncertain, there is no doubt that North Pacific right whales were then abundant throughout much of the North Pacific from North America to the Okhotsk Sea and Japan. Intensive nineteenth-century whaling, primarily by American whalers, may have killed more than 23 000 whales and drastically reduced these populations by the 1850s [1,2].

Despite international protection agreed in 1949, in the 1960s, the USSR killed 372 right whales in the Gulf of Alaska and Bering Sea [3]. These catches, which were part of a massive 30 year campaign of illegal whaling by the USSR [4,5], decimated what was probably a small but slowly increasing eastern

population [6]. Right whales have since been so rare in the eastern North Pacific that single sightings have been published.

Right whales were 're-discovered' in the eastern Bering Sea in 1996 [7]. Since then, NOAA surveys conducted in 1997–2008 have encountered small numbers of right whales in the Bering Sea and Aleutian Islands, and have collected identification photographs and biopsy tissue samples (figure 1). All encounters have been on the southeastern Bering Sea shelf, with the exception of one whale seen south of Unimak Pass in the Aleutian Islands in September 2004. A sufficient sample size of identified individuals has now been accumulated from both genetic and photographic methods to allow mark–recapture analysis methods to be applied to both datasets.

We present here the first abundance estimates for eastern North Pacific right whales. These remarkably low estimates underscore the precarious status of this population, which ranks among the smallest and most endangered in the world. They also highlight the grim legacy of uncontrolled nineteenth-century whaling and the failure of twentieth-century regulations and management to prevent overexploitation from illegal whaling.

2. MATERIAL AND METHODS

(a) Photo-identification methods

Identification photographs of North Pacific right whales were taken from vessels (oblique photos) and from airplanes (overhead photos). Aerial surveys occurred in 1998–2001 and in 2008. The 1998–2000 aerial surveys were documented in LeDuc *et al.* [8], and surveys using identical methods were conducted in 2001 (by the Southwest Fisheries Science Center) and in 2008 (by the National Marine Mammal Laboratory (NMML)).

Oblique identification photographs were taken on surveys in 1999 [8], in 2004 [9], and in 2008. NMML conducted right whale ship surveys in the Bering Sea in 2005 and 2007, but did not detect any right whales in those years. Right whales were also photographed during a right whale survey in 2002 [10] but only one quality 2/3 photograph was obtained of the right side of one individual. Additional information available from all photographs (e.g. partial views of the left side of the animals from head-on shots) suggests that three individuals identified from right-side only photographs were indeed different individuals. However, as noted below, right-side identifications were excluded from this study to preclude the occurrence in our analysis of a single whale as two individuals.

All photographs were evaluated for photo quality (focus, exposure, view of the whale) on a scale of 0–3. The analysis was restricted to quality 2/3 (good and excellent) photographs, which are sufficient to allow matching between an aerial photograph and an oblique view of one side of the head. Photographs of both the left and the right side of the head were not always obtained in each ship encounter. As more left-side oblique identifications were available, a total sighting history was created using only aerial and left-side identifications, resulting in photographs being available for the analysis for the years 1998, 1999, 2000, 2001, 2004 and 2008 (electronic supplementary material, table S1). In the time-dependent models, capture probability was fixed to zero in the years for which no quality 2/3 identifications were available.

(b) Genetic-identification methods

Biopsy tissue samples were obtained on surveys conducted in 1997, 1999 [8], 2002 [10] and 2004 ([9]; electronic supplementary material, table S1). Photographs and biopsy samples of North Pacific right whales have not been linked in every case in the field. Therefore, there is not necessarily any direct correspondence between photo and genetic identifications in the same year.

Forty-three biopsy samples from the Bering Sea were used in the mark–recapture analysis. Methods used for the genotyping of individuals, with minor modifications, are those described in LeDuc *et al.* [8]; details are provided in the electronic supplementary material. Each sample was sexed according to the methods described in Fain & LeMay [11].

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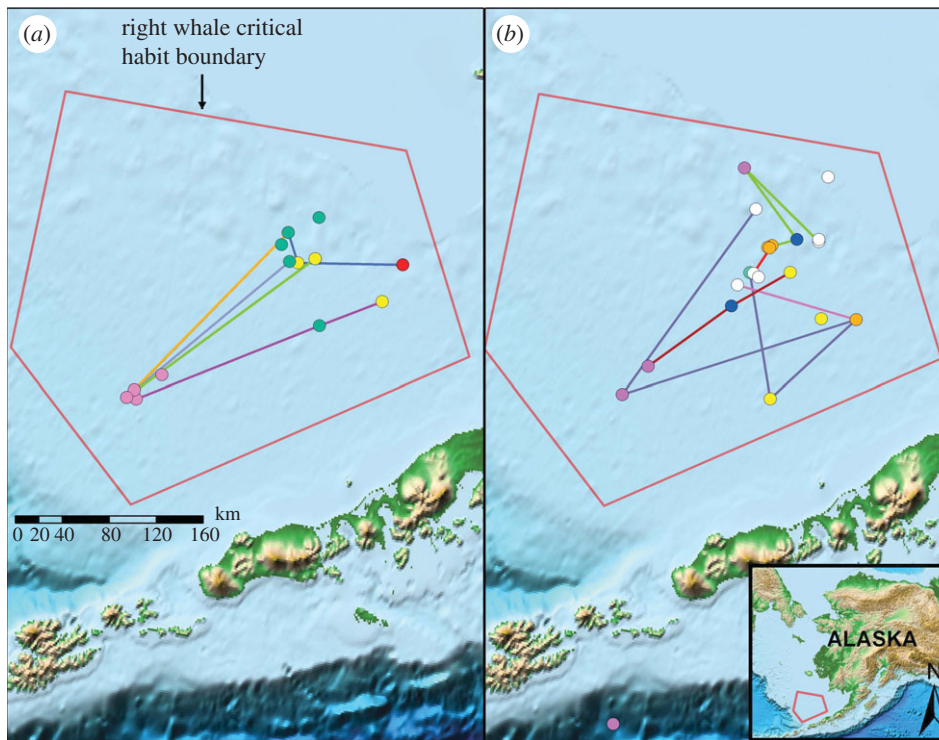


Figure 1. Locations in the Bering Sea and Aleutian Islands of eastern North Pacific right whales individually identified (a) through genetics or (b) through photographs. Lines connect sightings of the same individual in different years. The pentagon shows the critical habitat established by NOAA in 2007. (a) Red, 1997; yellow, 1999; green, 2002; pink, 2004. (b) Green, 1998; dark blue, 2001; yellow, 1999; pink, 2004; orange, 2000; white, 2008.

(c) *Mark-recapture methods*

The POPAN Jolly–Seber open population model was used for both analyses, using all combinations of both constant and time-dependent capture probability (p), survival (ϕ), and the probability of entry into the population ($pent$) [12]. The sex of each whale was determined from genetic methods, so in the genetic dataset, a sex-specific model was also specified for p , ϕ and $pent$. Given the apparent differences in the number of males and females [9], one additional model was specified for capture probability—an additive model between sex and year. Program MARK was used for the analyses selecting the model POPAN [13]. AICc was used for model selection.

3. RESULTS

Twenty-one individuals were identified from genotyping from the Aleutian Islands and the Bering Sea, comprising 15 males and six females. In aggregate, there were eight matches across years involving five individuals (electronic supplementary material, table S2a). Wade *et al.* [9] reported 17 individuals (including seven females) identified from genotyping in 2004; that number has been revised here to 16 individuals (including six females) because a typographical error was subsequently discovered that masked a duplicate sample. Eighteen unique individuals were identified from photographs of callosity patterns and scars, with 10 resights across years involving five individuals (electronic supplementary material, table S2b).

The best model for each dataset (as chosen by AICc) was a constant parameter model (unsurprising given the small sample sizes). The full model selection results and parameter estimates are presented in electronic supplementary material, tables S3–S6. As

expected, the estimates of survival were imprecise (photographic estimate 0.97 (95% CL 0.09–1.00) and genetic estimate 0.90 (95% CL 0.64–0.98)). The photo-identification estimate of capture probability was 0.35 (95% CL 0.14–0.65) and the genetic estimate was 0.71 (95% CL 0.22–0.95). The best model in the photo-identification analysis had a Δ AICc of 8.7 over the next best model, so only the results of the best model are considered here. The abundance estimate from that model was 31 (95% CL 23–54). In the genetic results, several models had AICc model weights >0.05 ; abundance was therefore averaged across the top models using AICc weights, resulting in a genetic total estimate of 28 (95% CL 24–42), with an estimated eight females (95% CL 7–18) and 20 males (95% CL 17–37). Abundance estimates were not overly sensitive to the estimated survival rate (electronic supplementary material, table S7), indicating the imprecision of the survival estimate did not greatly affect the results.

4. DISCUSSION

The photographic and genetic abundance estimates reported here are in close agreement, and represent the first such estimates for the eastern North Pacific right whale population. The estimates may relate to a subpopulation with strong site fidelity to the Bering Sea; nonetheless, their small size and the low number of sightings of right whales elsewhere, make it very unlikely that the eastern North Pacific population is much larger than these estimates suggest. Extensive illegal Soviet whaling also occurred in the Gulf of

Alaska during the 1960s, but few right whales are currently found there; visual sightings are extremely rare, and acoustic instruments in seven widespread locations detected right whale calls on only 6 days out of a total of 80 months of recordings [14]. Only two whales have been photo-identified from the Gulf and neither of these individuals has been seen in the Bering Sea.

The western North Pacific population of right whales is considered isolated from the eastern Pacific population. The western population is also small and at risk of extinction; however, while no reliable published estimate of abundance exists, survey data suggest it is much larger than the eastern population, numbering in the several hundreds or more [6]. Our abundance estimates strongly support the recent IUCN 'critically endangered' designation for eastern North Pacific right whales (defined as less than 50 mature individuals). This is the smallest whale population in the world for which an abundance estimate exists; in comparison, the critically endangered western population of grey whale (*Eschrichtius robustus*) is estimated to be approximately 100 [15]. Eastern North Pacific right whales may be on par with other relict (but unestimated) populations decimated by whaling for which there is a similar rarity of sightings, such as bowhead whales (*Balaena mysticetus*) near Svalbard, right whales (*Eubalaena glacialis*) in the eastern North Atlantic or right whales (*Eubalaena australis*) in Chile and Peru. The long-term persistence of the population is in doubt given the exceptionally small number of females. The sex ratio observed here (approx. 2:1 males to females) is more encouraging than the greater skew reported in LeDuc *et al.* [8], but the paucity of females is still a major cause for concern. Other species of right whales are highly vulnerable to ship collisions, and these whales cross a major Trans-Pacific shipping lane when travelling to and from the Bering Sea; their probability of ship-strike mortalities may increase with the likely future opening of an ice-free Northwest Passage. A plan needs to be developed to reduce or mitigate current and future threats to these whales from ship strikes, disturbance from seismic activities and entanglement in fishing gear.

Had no further catches occurred, eastern North Pacific right whales would have been recovering from nineteenth- and early twentieth-century whaling, though the population would probably still have been severely depleted. Their precarious status today (only tens of animals) is a sad legacy of the massive campaign of illegal whaling conducted by the USSR in the 1960s. Their situation presents us with a grim reminder that international fisheries and whaling agreements are largely worthless if unaccompanied by stringent international monitoring and regulation of catches [4].

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