

Acoustic detection and satellite-tracking leads to discovery of rare concentration of endangered North Pacific right whales

Paul Wade¹, Mads Peter Heide-Jørgensen², Kim Shelden^{1,*}, Jay Barlow³, James Carretta³, John Durban¹, Rick LeDuc³, Lisa Munger⁴, Shannon Rankin³, Allan Sauter⁴ and Charles Stinchcomb³

¹National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, National Marine Mammal Laboratory, Seattle WA 98115, USA

²Greenland Institute of Natural Resources, PO Box 570, 3900 Nuuk, Greenland

³NOAA, NMFS, Southwest Fisheries Science Center, La Jolla CA 92037, USA

⁴Scripps Institution of Oceanography, La Jolla CA 92093, USA

*Author for correspondence (kim.shelden@noaa.gov).

The North Pacific right whale, *Eubalaena japonica*, is one of the most endangered species of whale in the world. On 10 August 2004, two right whales were located in the Bering Sea using headings to right whale calls provided by directional sonobuoys. A satellite-monitored radio tag attached to one of these whales functioned for 40 days. Over the 40-day period, this whale moved throughout a large part of the southeast Bering Sea shelf, including areas of the outer-shelf where right whales have not been seen in decades. In September, multiple right whales were acoustically located and subsequently sighted by another survey vessel approaching a near-real-time position from the tag. An analysis of photographs confirmed at least 17 individual whales (not including the tagged whales). Genetic analysis of biopsy samples identified 17 individuals: 10 males and 7 females. The discovery of seven females was significant, as only one female had been identified in the past. Genetics also confirmed the presence of at least two calves. Although the future of this population is highly uncertain, the discovery of additional females and calves gives some hope that this most critically endangered of all whale populations may still possess the capacity to recover.

Keywords: North Pacific right whale; *Eubalaena japonica*; genetics; sonobuoy; Bering Sea; satellite-monitored radio tag

1. INTRODUCTION

Thousands of North Pacific right whales, *Eubalaena japonica*, were killed in the Gulf of Alaska and Bering Sea during intensive commercial whaling in the 1800s (Scarff 2001). By the 1950s, there was evidence that the population was small but recovering, and fed in waters of the middle-shelf, slope and abyssal plain of

these regions (Shelden *et al.* 2005). However, illegal takes of 372 right whales by the Soviet Union in the 1960s reduced the population to a precariously low level (Brownell *et al.* 2001). Since then, sightings of right whales have been extremely rare anywhere in the eastern North Pacific (Clapham *et al.* 2004; Shelden *et al.* 2005).

On 30 July 1996, scientists from the Alaska Fisheries Science Center located a small group of right whales ($n=4$) in the southeast Bering Sea (Goddard & Rugh 1998). Since that initial detection, dedicated surveys have found right whales in the same general vicinity of the Bering Sea from 1997 to 2004 (Moore *et al.* 2000, 2002; LeDuc *et al.* 2001; this study). Acoustic detections of right whale calls have been documented on the Bering Sea shelf from May to November (Munger *et al.* 2003). The extent to which right whales move between feeding areas on the shelf and slope, or to feeding areas in the Gulf of Alaska, is not known. There have been a small number of detections of right whales in the Gulf of Alaska in summer since 1979: four visual (Waite *et al.* 2003; P. Wade *et al.* 2005, unpublished data) and several acoustic (Mellinger *et al.* 2004). In August 2004, the National Marine Mammal Laboratory (NMML) and the Greenland Institute for Natural Resources (GINR) initiated a North Pacific right whale tagging project.

2. MATERIAL AND METHODS

A charter vessel was used to conduct a 10-day survey in the southeast Bering Sea where any right whale encountered would be tagged, photographed and biopsy sampled for genetic studies. Nine scientists participated in the survey, including a sighting team of six scientists using binoculars to visually scan for whales, two acoustic technicians using directional sonobuoys to listen for right whale calls, and a technician to deploy the tags.

Once right whale vocalizations were detected, arrays of directional frequency and ranging (DIFAR) sonobuoys were deployed to determine the direction and location of the calling whale(s) (as per McDonald & Moore 2002). The uniformly flat and shallow shelf waters of this region act as a waveguide for sounds reflecting and channelling them over long distances (McDonald & Moore 2002; Wiggins *et al.* 2004). Right whale calls have been detected at distances over 50 km (Wiggins *et al.* 2004).

Tags containing Argos satellite-transmitters (SPOT 4, TAGWARE v. 4.03) produced by Wildlife Computers (Redmond, Washington) were attached in the blubber layer of each whale (see Heide-Jørgensen *et al.* 2003). The cylindrical body of the tag was 11.5 cm long and 2.5 cm in diameter. A smaller diameter rod with retention flanges extended 16.5 cm from the front of the tag, for a total length of 27.5 cm. When deployed, approximately 4 cm of the tag remained external to the body, with a 14.5 cm antenna extending out of the back of the tag. Transmissions occurred when a saltwater conductivity switch indicated the tag was at the surface. To extend the life of the battery (one AA cell), the tags were programmed to transmit every third day with a daily maximum of 300 transmissions restricted to the period between 06.00 and 18.00 local time. Assuming the whales retained the tags, this transmission schedule allowed more than 300 days of data acquisition.

The Argos data location and collection system was used to track the tagged whales. Argos assigns location classes (LC 0–3, A and B) to indicate the accuracy of each position obtained during a transmission. For classes 1, 2 and 3, Argos predicts that 68% of the time the position will be within 1000, 350 and 150 m, respectively. However, satellite-tracking studies of captive pinnipeds suggest that these errors in prediction may be smaller than previously reported (Vincent *et al.* 2002). This study also found that A positions were nearly as reliable as 1 positions. Our daily average positions were calculated using all LC data ($n=11$ transmission days). These were compared to daily average positions where B records were excluded, where possible ($n=10$ transmission days). Differences between the two positions ranged from 1.4 to 17.5 km (average=6.1 km, s.e.=1.8). Half of the positions were within 2.1 km of each other, only

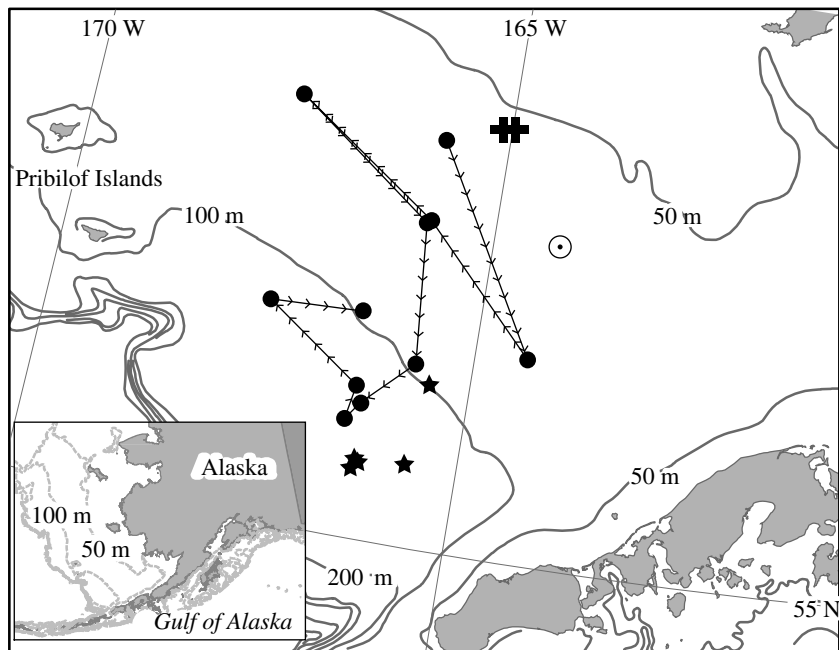


Figure 1. Locations and movements of a tagged North Pacific right whale. The open circle represents the site of the acoustic detection, the crosses the tagging locations, the filled circles indicate where the tagged whale travelled during the 40 days of tag transmission, and the stars indicate where the scientists on the NOAA RV *MacArthur II* found at least 17 right whales.

one set of positions was greater than 11.5 km apart. Therefore, we included B records in the daily average positions shown in figure 1.

The sex of sampled individuals was genetically determined using the method described by Fain & LeMay (1995). Individuals were identified by genotyping using the microsatellite markers EV37 (Valsecchi & Amos 1996), GATA028 (Palsbøll *et al.* 1997), DlrFCB5 (Buchanan *et al.* 1996) and rw4-5, 4-10, 25, 31 and 48 (all from Waldick *et al.* 1999).

3. RESULTS

On 10 August 2004, calling right whales were acoustically located in the Bering Sea in the vicinity of previous sightings in the last decade (figure 1). Directional sonobuoys provided a heading to the calls and two right whales were visually located at $57^{\circ}44.7' N$, $164^{\circ}53.9' W$, at 93 km from the site of the acoustic detection. Sighting conditions were optimal so these were thought to be the same whales that were heard. Both whales were tagged and photographed. Argos positions were only received from one tag. Temperature data were received from both tags showing a decline in temperature over time indicating that the tags were migrating out of the blubber layer. It is not clear why the other tag failed to provide transmissions useful for calculating its position, though the placement of the tag was lower on the flank of this whale potentially reducing uplink opportunities to available satellites.

The number of positions obtained per transmission day ranged from 2 to 12 (average = 5.1). We obtained 56 positions over a 40-day period from 11 August to 19 September comprised of: LC 0–2 (4, 5 and 2), A (16) and B (29) positions. B positions made up 52% of the sample and occurred on all transmission days. This whale moved over a large part of the Bering Sea shelf, including areas of the outer-shelf (figure 1).

In September, right whales were again acoustically located and subsequently sighted by another survey vessel approaching a near-real-time position obtained

from the tag. From 7 to 9 September 2004, researchers photographed and biopsied several groups of right whales, including three probable mothers with calves. The observers estimated that 23 right whales were seen over the 3 days. Photo-identification data confirmed at least 17 individual whales (none of which matched the two tagged whales). The microsatellite-based genotyping identified 17 individuals, 10 males and 7 females. Among these, at least one male had been previously photographed and four animals biopsied in other years; the latter included the only female seen prior to this encounter. Two of the females shared at least one allele for each microsatellite marker, as well as a mitochondrial haplotype, with their accompanying calves (both of which were male), suggesting they were indeed the mothers.

4. DISCUSSION

The combination of the acoustic detection methodology and tag data led to the discovery of the largest concentration of right whales observed in the eastern North Pacific since the Soviet catches of the 1960s. The number of unique individuals seen in 2004 nearly tripled the number seen in any previous year in the last four decades, and the size of the genetic catalogue of individuals more than doubled (now totalling 23 individuals). Detection of seven females and two calves was particularly significant; of 10 individuals previously identified from genetics, only one was female and only one mother with calf had previously been seen in the region in the last 100 years. Movements of the tagged whale between the middle-shelf and outer-shelf (greater than 100 m depth), and additional sightings on the outer-shelf, confirmed that right whales were using both oceanographic domains in the southeast Bering Sea in 2004, consistent with their historical distribution (Shelden *et al.* 2005).

Although this study has provided more information about the current status of right whales on their summer feeding grounds in the Bering Sea, little is known about their distribution in winter and no calving areas have been identified (Clapham *et al.* 2004). Only 10 sightings and 4 days of acoustic detections have occurred during winter. Additional tagging is planned to identify the migratory destinations and routes of these whales from the summer feeding domains. Although the eastern North Pacific right whale's future is highly uncertain, the discovery of six additional females and several mothers with calves give hope that this endangered whale population may still possess the capacity to recover.

We thank Anders Villum Jensen (GINR) for his skilful tagging of these whales. We greatly appreciate reviews by Phil Clapham, Dave Rugh, Gary Duker and James Lee. This research was conducted under NMFS permits 782-1719 and 774-1714.

- Brownell Jr, R. L., Clapham, P. J., Miyashita, T. & Kasuya, T. 2001 Conservation status of North Pacific right whales. *J. Cetacean Res. Manage. Special Issue 2*, 269–286.
- Buchanan, F. C., Friesen, M. K., Littlejohn, R. P. & Clayton, J. W. 1996 Microsatellites from the beluga whale *Delphinapterus leucas*. *Mol. Ecol.* **5**, 571–575. (doi:10.1046/j.1365-294X.1996.00109.x)
- Clapham, P., Good, C., Quinn, S., Reeves, R. R., Scarff, J. E. & Brownell Jr, R. L. 2004 Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. *J. Cetacean Res. Manage.* **6**, 1–6.
- Fain, S. R. & LeMay, J. P. 1995 Gender identification of humans and mammalian wildlife species from PCR amplified sex linked genes. *Proc. Am. Acad. Forensic Sci.* **1**, 34.
- Goddard, P. D. & Rugh, D. J. 1998 A group of right whales seen in the Bering Sea in July 1996. *Mar. Mammal Sci.* **14**, 344–349.
- Heide-Jørgensen, M. P., Laidre, K. L., Wiig, Ø., Jensen, M. V., Dueck, L., Schmidt, H. C. & Hobbs, R. C. 2003 From Greenland to Canada in ten days: tracks of bowhead whales, *Balaena mysticetus*, across Baffin Bay. *Arctic* **56**, 21–31.
- LeDuc, R. G., Perryman, W. L., Gilpatrick Jr, J. W., Hyde, J., Stinchcomb, C., Carretta, J. V. & Brownell Jr, R. L. 2001 A note on recent surveys for right whales in the southeastern Bering Sea. *J. Cetacean Res. Manage. Special Issue 2*, 287–289.
- McDonald, M. A. & Moore, S. E. 2002 Calls recorded from North Pacific right whales (*Eubalaena japonica*) in the eastern Bering Sea. *J. Cetacean Res. Manage.* **4**, 261–266.
- Mellinger, D. K., Stafford, K. M., Moore, S. E., Munger, L. & Fox, C. G. 2004 Detection of North Pacific right whale (*Eubalaena japonica*) calls in the Gulf of Alaska. *Mar. Mammal Sci.* **20**, 872–879.
- Munger, L., Moore, S., Hildebrand, J., Wiggins, S. & McDonald, M. 2003 Calls of North Pacific right whales recorded in the southeast Bering Sea. Abstract in marine science in the northeast Pacific: science for resource dependent communities, session EVOS/NPRB-4: birds and mammals, Joint Scientific Symposium. Anchorage, AK, 13–17 January, 2003.
- Moore, S. E., Waite, J. M., Mazzuca, L. L. & Hobbs, R. C. 2000 Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. *J. Cetacean Res. Manage.* **2**, 227–234.
- Moore, S. E., Waite, J. M., Friday, N. A. & Honkalehto, T. 2002 Cetacean distribution and relative abundance on the central-eastern and the southeastern Bering Sea shelf with reference to oceanographic domains. *Prog. Oceanogr.* **55**, 249–261. (doi:10.1016/S0079-6611(02)00082-4)
- Palsbøll, P. J., Bérubé, M., Larsen, A. H. & Jørgensen, H. 1997 Primers for the amplification of tri- and tetramer microsatellite loci in baleen whales. *Mol. Ecol.* **6**, 893–895. (doi:10.1046/j.1365-294X.1997.d01-214.x)
- Scarff, J. 2001 Preliminary estimates of whaling-induced mortality in the 19th century North Pacific right whale (*Eubalaena japonica*) fishery, adjusting for struck-but-lost whales and non-American whaling. *J. Cetacean Res. Manage. Special Issue 2*, 261–268.
- Shelden, K. E. W., Moore, S. E., Waite, J. M., Wade, P. R. & Rugh, D. J. 2005 Historic and current habitat use by North Pacific right whales, *Eubalaena japonica*, in the Bering Sea and Gulf of Alaska. *Mammal Rev.* **35**, 129–155. (doi:10.1111/j.1365-2907.2005.00065.x)
- Valsecchi, E. & Amos, W. 1996 Microsatellite markers for the study of cetacean populations. *Mol. Ecol.* **5**, 151–156.
- Vincent, C., McConnell, B. J., Ridoux, V. & Fedak, M. A. 2002 Assessment of Argos location accuracy from satellite tags deployed on captive gray seals. *Mar. Mammal Sci.* **18**, 156–166.
- Waite, J. W., Wynne, K. & Mellinger, D. K. 2003 Documented sighting of a North Pacific right whale in the Gulf of Alaska and post-sighting acoustic monitoring. *Northwestern Nat.* **84**, 38–43.
- Waldick, R. C., Brown, M. W. & White, B. N. 1999 Characterization and isolation of microsatellite loci from the endangered North Atlantic right whale. *Mol. Ecol.* **8**, 1763–1765. (doi:10.1046/j.1365-294x.1999.00723-6.x)
- Wiggins, S. M., McDonald, M. A., Munger, L. M., Moore, S. E. & Hildebrand, J. A. 2004 Waveguide propagation allows range estimates for North Pacific right whales in the Bering Sea. *Can. Acoust.* **32**, 146–154.