WESTERN GRAY WHALE ADVISORY PANEL **WGWAP 4/INF.21**
4th Meeting **11 April 2008**
Agenda Item: (14) **ENGLISH**

NON-SEIC GROUPS MONITORING

Russia-US 2007 interim report

Submitted by Dave Weller

December 2007

Interim Report

Western Gray Whales off Sakhalin Island, Russia: A Joint Russia-U.S. Scientific Investigation July-September 2007

David W. Weller [1], Amanda L. Bradford [2], Aimée R. Lang [1], Hyun Woo Kim [3], Maxim Sidorenko [4], Grigory A. Tsidulko [5], Alexander M. Burdin [6, 7, 8], Robert L. Brownell, Jr. [1]

[1] NOAA Fisheries
Southwest Fisheries Science Center
La Jolla, California USA

[2] University of Washington
Seattle, Washington USA

[3] Cetacean Research Institute
Ulsan, KOREA

[4] Pacific Oceanological Institute – Far East Branch
Russian Academy of Sciences
Vladivostok, RUSSIA

[5] International Fund for Animal Welfare
Moscow, RUSSIA

[6] Kamchatka Branch of Pacific Institute of Geography
Russian Academy of Sciences - Far East Division
Petropavlovsk, Kamchatka, RUSSIA

[7] Alaska Sealife Center
Seward, Alaska USA

[8] University of Alaska Fairbanks
Fairbanks, Alaska USA

Corresponding Author: dave.weller@noaa.gov

ABSTRACT

A collaborative Russia-U.S. research program on western gray whales (*Eschrichtius robustus*) summering off northeastern Sakhalin Island, Russia, has been ongoing since 1995 and has produced important new information on the present day conservation status of this critically endangered population. This interim report reviews preliminary findings from 2007 research activities and combines such with data from previous years, in some cases ranging back to 1994. Photo-identification research conducted off Sakhalin Island in 2007 resulted in the identification of 83 whales, including nine calves and two previously unidentified non-calves. When combined with data from 1994-2006, a catalog of 169 photo-identified individuals has been compiled. Not all of these 169 whales can be assumed to be alive, however. The most current mark-recapture analyses conducted estimated the abundance for the population to be 98 (95% CI=89-110) in 2002 and 99 (95% CI = 90-109) in 2003. A recent population assessment using a Bayesian individually based stage-structured model fitted to the same photo-identification data as used in the mark-recapture studies, but also including data from 2004 through 2006, estimated the median non-calf population size to be 110 in 2004 and, should current population and demographic trends continue, projected a median non-calf estimate of 121 (90% Bayesian CI = 112-130) in 2007. Of the 169 whales photo-identified, 142 (84%) have been biopsy sampled. From genetic analysis of samples (n = 129) collected through 2006, an overall sex ratio of 58% male and 42% female was determined. Clear genetic differentiation from the eastern gray whale population and negligible gene flow of either sex between populations, based on mitochondrial DNA haplotype frequencies and nuclear DNA, have been documented. A minimum of 24 reproductive females has been observed since 1995. Of the 83 whales observed in 2007, 7.2% (n = 6) were recorded as "skinny". In addition to the biological difficulties that western gray whales are facing, the large-scale offshore oil and gas development programs near their summer feeding ground, as well as fatal net entrapments off Japan during migration, pose significant threats to the future survival of the population.

INTRODUCTION

The western gray whale population is critically endangered (Hilton-Taylor, 2000; Weller *et al*., 2002a; Baillie *et al*., 2004) and its continued ability to survive is of concern. Hunted to such low numbers in the mid 20th century that some thought it to be extinct, the population remains highly depleted today (Weller *et al*., 2002a: IISG, 2006). The International Whaling Commission (IWC) and the World Conservation Union (IUCN) have each expressed serious concern about the status of this population and have called for urgent measures to be taken to help ensure its protection (see Baillie *et al*., 2004; IWC, 2004; Reeves *et al*., 2005).

This interim report reviews preliminary findings from 2007 research activities of our Russia-U.S. research program on western gray whales off Sakhalin Island, Russia, and combines such with data from previous years, in some cases ranging back to 1994. Discussion of the current status of the population and a review of threats to its continued survival, including potential impacts associated with large-scale oil and gas development activities on the summer feeding ground and entrapments in trap nets off Japan during migration, are provided herein. The final report from our 2007 research program will be available in April 2008.

METHODS

Photo-identification research methodologies employed during the 2007 field study were identical to those used during earlier studies by our team between 1997 and 2006. The overall consistency in research design, data collection techniques and data analysis maintained in 2007 allowed inter-annual comparisons to be made. Additional information, collected during more limited surveys off Piltun in 1994 and 1995 (Brownell *et al.*, 1997; Weller *et al.*, 1999a), is also presented here to better describe inter-annual trends and facilitate a long-term interpretation for some results. Data from these 1994 and 1995 studies include gray whale photographs obtained between 7-12 September 1994 during the filming of a wildlife documentary by H. Minakuchi (for description see Weller *et al*., 1999a) and from 14-20 August 1995 during a pilot study to

determine the feasibility of conducting boat- and shore-based research in the study area (Brownell *et al.,* 1997).

Study Area

Zaliv Pil'tun (referred to as Piltun Lagoon) is on the northeastern shore of Sakhalin Island, Russia (Fig. 1). The lagoon is approximately 80-90 km long and 15 km across at its widest point. A single channel connecting the inner lagoon with the Okhotsk Sea occurs at 52° 50' N and 143° 20' E, and has considerable biological influence on the surrounding marine environment. A lighthouse, near the lagoon channel, served as the base from which studies reported here were conducted. The nearshore marine environment of the study site is mostly sand substrate, characterized by a gradually sloping and broad continental shelf. Water depths within 5 km of shore are mostly less than 20 m deep. Despite the similarity of Piltun Lagoon to the coastal lagoons used by eastern gray whales off Baja, whales do not enter this lagoon.

Photo-Identification and Biopsy Surveys

Boat-based photo-identification surveys were conducted on all good weather days during the 2007 study period. Identical methodology was employed during each survey, with the primary objective of encountering and photographically identifying as many whales as possible. Previous photo-identification data gathered in the Piltun area between 1995 and 2006 used right-side dorsal flank markings for identification (Brownell *et al.*, 1997; Weller *et al.*, 1999a, 2006a), and for the sake of intra- and inter-annual reliability, we continued this methodological approach. Attempts were made to simultaneously photograph and videotape the right dorsal flank of each whale, followed by efforts to photograph the left dorsal flank and flukes. The majority of whales identified to date now have images of right and left flanks as well as ventral surface of flukes in the photo-identification catalog allowing for useful identification images to be collected from nearly any body region (Fig. 2). As of May 2006, the western gray whale photo-identification catalog complied by our Russia-U.S. research program is available on request to all interested parties (Weller *et al*., 2006a).

In tandem with our ongoing photo-identification program, biopsy sampling for genetic research has also been conducted (see LeDuc *et al*., 2002; Lang *et al*., 2004, 2005). Identical methods have been used since the inception of this effort and in all cases sampling attempts are made only for whales that have not been previously biopsied.

RESULTS

Survey Effort and Photo-Identification

Between 1994 and 2007, 169 western gray whales have been identified during 337 boat-based surveys off northeastern Sakhalin Island (Table 1). Sixty-eight of the whales in the photo-catalog were animals first identified as calves, while the remaining 101 whales were considered non-calves (i.e. adults or subadults). Not all of these 169 whales are assumed to be alive, however.

Twenty photo-identification surveys, including 32.3 hrs spent in direct observation of 187 whale groups, were conducted between 26 July and 9 September 2007 (Table 1). In total, 3,814 photographic images were obtained during the 2007 research effort. Eighty-three naturally marked individual whales, including nine calves, were identified during 2007 (Table 2). Of the 74 non-calves identified in 2007, 97.3% (n = 72) had previous sightings in the Piltun area during 1994-2006 photographic efforts (Table 2).

Mother-Calf Pairs

Nine mother-calf pairs were identified during 2007. The observed Gross Annual Reproductive Rate (GARR) for 2007 was 10.8% (Table 2). These nine mothers all had sightings in the study area prior to 2007, and all but one had been observed in previous years with a calf. Therefore, the number of known reproductive females recorded between 1995 and 2007 is 24.

Physical Condition and Health Status

During the 2007 field season, as was also true in previous years, our team observed and documented whales that were unusually thin or also referred to as "skinny whales" (see Weller *et al*., 2002b). This condition was first documented to be widespread in 1999 and could be noticed, in most cases, within several minutes of approaching individuals by small boat for photo-identification purposes. Initial laboratory analysis of photographs and video collected between 1997 and 2005 revealed several morphological attributes correlated with a particular individual being described as unusually thin. Diagnostic features varied between individuals, but consisted of at least one of the following: (1) an obvious protrusion of the scapula(s) with associated thoracic depressions at the posterior and anterior insertion points of the flipper; (2) the presence of noticeable depressions or concavities around the blowholes and head; and (3) a pronounced depression along the neural/dorsal spine of the lumbar and caudal vertebrae resulting in the appearance of a bell-shaped body (see Brownell and Weller, 2001; Weller *et al*., 2002b).

Field observations in 2007 recorded six whales as "skinny" (Table 3). This number of skinny whales is higher in number and overall proportion than that reported in 2006 (Table 3). These numbers concerning skinny whales do not include mothers accompanying calves. This approach was employed to prevent the body condition of lactating mothers, which is normally skinny due to increased energetic expenditure, from contributing to any analyses.

Genetic Sampling

In tandem with our ongoing photo-identification program, biopsy sampling for genetic research has also been conducted (see LeDuc *et al*., 2002; Lang *et al*., 2004, 2005). Fifteen biopsy samples were collected for genetic research in 2007. In total, 142 (84%) of the 169 whales photographically identified during the study have now been sampled. This number includes biopsies collected from 59 (86.8%) of the 68 calves observed between 1995 and 2007.

For all individuals (n = 129) sampled between 1995 and 2006 (analysis of 2007 samples has yet to be conducted), a male biased sex ratio of 58% male and 42% female has been documented. When the subset of whales sampled as calves (n = 50) was examined, 66% were male and 34% female.

International Collaboration

As part of our broader research objective, in 2003 we initiated a collaborative training program for scientists and students from other range states (i.e. outside of Russia) where western gray whales occur. Each summer from 2003 to 2007, Mr. Hyun Woo Kim, a graduate student from Pukyong National University and the Cetacean Research Institute in the Republic of Korea has participated in our research program.

DISCUSSION

A number of biological parameters in concert with a variety of human-related threats, as identified during the current long-term study and discussed below, raise concern about the ability of the western gray whale population to rebound from its highly depleted state and highlight the importance of continuing the long-term Russia-U.S. collaborative research and monitoring program.

Population Size

The size of the western gray whale population is small. Photo-identification studies off northeastern Sakhalin Island have identified only 169 individual whales during 337 surveys conducted between 1994 and 2007. While "new" non-calf whales continue to be identified annually, the rate at which this happens is low. Although the photo-catalog now contains 169 whales, not all of these individuals are assumed to be alive. The most current mark-recapture analyses conducted estimated the abundance for the population to

be 98 (95% CI=89-110) in 2002 and 99 (95% CI = 90-109) in 2003 (Wade *et al*. 2002; Bradford *et al*., submitted). A recent population assessment using a Bayesian individually based stage-structured model fitted to the same photo-identification data as used in the mark-recapture studies, but also including data from 2004 through 2006, estimated the median non-calf population size to be 110 in 2004 and, should current population and demographic trends continue, projected a median non-calf estimate of 121 (90% Bayesian CI = 112-130) in 2007 (Cooke *et al*., 2007).

Reproduction and Survival

Although estimates of GARR show that the western gray whale population is producing a seemingly reasonable number of calves annually, the limited number of known reproductive females (n = 24) in combination with relatively low calf survival (Cooke *et al*., 2006, 2007; IISG, 2006; Bradford *et al*., 2006) is likely to be slowing potential population growth. In recent years, the interval between calves in the western population appears to be shifting from a three-year interval to a two-year interval. If this change persists, a general increase in calf production could be expected.

Mother-Calf Pairs

Of the nine females identified with calves in 2007, all had previous sightings in the study area. The annual return of reproductive females while pregnant, resting and lactating indicates that the nearshore Sakhalin Island feeding area is of significant importance to the continued survival of this population. That is, both lactating and pregnant females are under especially high energetic demands, therefore it is imperative that they feed in regions capable of meeting their elevated energetic requirements. If it is assumed that the elevated energetic requirements of reproductive females leads them to seek out the highest quality feeding areas, the behavior of these females indicates that this feeding ground is vital to population survival and growth. This hypothesis is further supported by the fact that observations of mother-calf pairs have never been reported from any other region where western gray whales are occasionally sighted, including a nearby offshore feeding area (Weller *et al*., 2002c, 2003).

Genetics

Given the small size of the western population and its isolation from the eastern population, the potential for continued loss of genetic diversity due to genetic drift or removal of individuals with rare alleles is of concern (Lang *et al*., 2004; 2005). The limited number of females in the population may hinder reproductive output and in turn slow population recovery. The male bias observed for calves indicates lower recruitment of females into the adult population. This pattern further perpetuates the problem of a limited number of females being available to reproduce.

Previous genetic research on the western gray whale population has documented clear genetic differentiation from the eastern population on the basis of mitochondrial DNA haplotype frequencies (LeDuc *et al*., 2002). More recently, a study by Lang *et al*. (2004) used bi-parentally inherited nuclear DNA markers to measure the differentiation and relative levels of genetic diversity in the nuclear genome between the western and eastern populations. For these purposes, 93 western gray whales and 126 eastern gray whales were genotyped at six polymorphic microsatellite loci. All six microsatellite loci showed higher levels of genetic diversity in the eastern population (mean H_e = 0.759) when compared with the western population (mean H_e =0.724), mirroring results found using mtDNA haplotypes. A comparison of allele frequencies between the western and eastern populations confirmed them to be genetically distinct ($p<0.001$) and indicated negligible gene flow between populations.

Future directions of our genetic research on western gray whales (see Lang *et al*., 2004) will provide significant new information regarding the population and include the following: (1) combine nuclear genetic data from microsatellite analysis with mitochondrial data to determine if sex-specific patterns of gene flow exist; (2) examine relatedness of individuals; (3) determine potential paternity of animals first identified as calves, allowing differential male reproductive success to be explored; (4) estimate the effective population size (number of breeding adults); (5) determine the level of genetic diversity present

within the population and thereby evaluate loss of genetic diversity through inbreeding; and (6) catalog DNA "fingerprints" of all individuals sampled to facilitate matching to stranded animals and whales caught directly or taken incidentally in fishing gear.

Skinny Whales

Although the number of skinny whales observed in 2007 is slightly higher than in 2006, the cause of such remains unexplained (see Brownell and Weller, 2001) and continues to be a point of concern for this critically endangered population. Possible explanations for the observed deterioration in physical condition and apparent health status of some whales may include any of the following factors, alone or in combination: 1) natural or human produced changes in prey availability or habitat quality; 2) physiological changes related to stress; or 3) disease. While the cause of this condition clearly results in poor physical condition and related nutritional stress (Brownell and Weller 2001) the underlying reason(s) for such remains unknown.

During 1999 and 2000 the eastern gray whale population experienced unusually high mortality of immature/adult whales, with annual stranding rates approximately ten times greater than reported during the previous decade (LeBoeuf *et al*., 2000; Brownell *et al*., 2001; Moore *et al*., 2001). Coincident with the high mortality, estimates of calf production in 1999, 2000 and 2001 were the lowest recorded in an eight-year time series of data (Perryman and Rowlett, 2003). Although the causal mechanism(s) responsible for this event are yet to be fully understood, some researchers hypothesize that eastern gray whale benthic prey biomass had been depleted due to the combined influence of increased annual water temperatures in the Bering Sea and over grazing of the feeding grounds by a population that may now exceed pre-exploitation levels (LeBoeuf *et al*., 2000; Moore *et al*., 2001).

While the above explanations regarding the eastern population appear plausible, observations of skinny western gray whales between 1999 and 2007 are less easily explained. It is unrealistic to think that the western population over grazed its benthic food base or exceeded the carrying capacity of the feeding ground (Brownell and Weller, 2001). The interplay between benthic prey communities and environmental parameters such as primary production, ice, water temperature, and fresh water inflow from coastal lagoon systems (such as Piltun Lagoon) due to snow melt and river/stream system input, for example, may be at least partially responsible. It is also possible, however, that influences from industrial activities near the feeding ground (see following section on *Threats to the Population*) and other potential factors in the southern range of the western population are contributing to the skinny whale phenomenon, and any connection to similar events in the eastern population are purely coincidental. For example, the poor physical condition noted for some whales in the present study may be compounded by cumulative physiological stress correlated with long-term exposure to anthropogenic variables such as underwater noise (Richardson *et al*., 1995; Brownell and Yablokov, 2001; Weller *et al*., 2002d, 2006b, 2006c).

Various pathologies and exposure to other potentially deleterious agents like contaminants and pollution could also be important contributors to the poor physiological condition of the whales observed to be skinny. Regardless of the causes, any disruption of normal feeding behaviors, total cumulative time spent feeding, or feeding locations off northeastern Sakhalin is of concern for all whales, but especially those observed to be skinny in addition to mother-calf pairs that are under high energetic demands.

Therefore, it is essential that skinny whales continue to be carefully monitored to evaluate their survival. As such, a detailed photographic analysis examining the body condition of western gray whales is presently underway (Bradford *et al*., 2007a) and will provide a more refined evaluation of long-term health status. As part of this analysis, an inter-individual comparison of physical condition for females with calves will also be conducted. This approach will provide a baseline index of physical condition specific to reproductive females and allow individual variation to be documented.

Threats to the Population

In addition to the biological difficulties that western gray whales face, the onset of large-scale oil and gas development programs off Sakhalin Island in the mid-1990s introduced new threats to the future survival of

the population (Weller *et al*., 2002a; Reeves *et al.*, 2005; IISG, 2006). Sakhalin Island is a region rich with large reserves of offshore oil and gas that, until recently, have been unexploited. Industrial activities on the continental shelf of this region have steadily increased in the past ten years and are scheduled to expand at a rapid pace into the future. Oil and gas development activities that may negatively impact western gray whales include: (1) disturbance from underwater noise associated with seismic surveying (Weller *et al*., 2002d; 2006b, 2006c), pipeline dredging, ship and air traffic and platform operations; (2) direct interactions between whales and an oil spill or other waterborne chemicals, ships, and possible entanglements in cables or lines; and (3) habitat changes related to seafloor modifications associated with dredging and sand pumping activities that may adversely impact gray whale prey (for complete review see Reeves *et al.*, 2005; IISG, 2006).

Another significant threat to the western gray whale population involves incidental catches in coastal net fisheries, particularly off Japan, within their migratory route (Weller *et al*., 2002a; Kato *et al*., 2005; Brownell *et al*., 2007). In 2005, three female western gray whales (one mother-calf pair and one yearling) died in fishing nets on the Pacific shore of Japan during their northward migration. Projections from a recent population assessment suggest that the loss of one additional female per year, over and above the levels in 2005, will likely cause the population to decline to extinction (IISG, 2006; Cooke *et al*., 2006, 2007). Unfortunately, in 2007 another young female western gray whale died after being entrapped in a trap net off the Pacific coast of Japan (Anonymous, 2007a,b,c: Brownell *et al*., 2007). In addition, an analysis of anthropogenic scarring of western gray whales found that 18.7% (n = 28) of 150 individuals identified between 1994 and 2005 were determined to have been previously entangled in fishing gear (Bradford *et al.*, 2007b), further highlighting the overall risks coastal fisheries pose to western gray whales.

Other threats to the western gray whale population include continued mortality from an undetermined level of suspected poaching in the central portion of the range (Brownell and Kasuya, 1999; Baker *et al*., 2002), as well as a potential increase in the likelihood of disturbance, exposure to pollution, and probability of ship strikes due to substantial nearshore industrialization and shipping congestion throughout the migratory corridor(s).

CONCLUSIONS

Based on the results reported here, it is clear that the western gray whale population is precariously balanced between survival and extinction. In addition to the variety of biological factors that may be slowing population growth, large-scale oil and gas development programs that may alter the prey base or introduce disturbance to feeding whales, as well as entrapment and entanglement in fishing gear, especially in trap nets off Japan during migration, are of serious concern with regard to the future survival of the population.

The high rates of annual return and pronounced seasonal site fidelity to the study area displayed by most whales, especially true for females with dependent offspring and females that are pregnant, clearly indicate the population-level importance of the feeding habitat off northeastern Sakhalin Island. That is, members of the western gray whale population annually utilize this feeding area and depend upon the benthic food base available there for their survival (Weller *et al*., 1999a, 2002a; Reeves *et al.*, 2005; IISG, 2006). As no other feeding area(s) outside of northeastern Sakhalin Island has been identified, it is clear that the conservation of the western gray whale is intricately related to this particular habitat. The annual aggregation of feeding whales in this region, but not other regions, is likely a reflection of the site-specific biological richness (i.e. high benthic biomass; see Koblikov, 1986; Fadeev, 2004) of the area; perhaps related to enrichment of near-shore marine waters by nutrient laden tidal effluent from Piltun Lagoon and other nearby lagoon systems.

Mother-calf pairs and newly-pregnant females rank among the most commonly sighted individuals on an intra- and inter-seasonal basis in the study area, and no sighting records of a mother-calf pair have ever been recorded outside of this area. In general, females with calves, as well as calves weaned during the summer/fall, utilize an area approximately 60 km long (north-south) and 5 km wide (east-west). Theodolite determined locations for mother-calf pairs show that, on average, they are found 1.2 km from shore in waters about 6.0 m deep while other whales (non-calf groups) are distributed, on average, 2.3 km from

shore in waters 15.0 m deep (Weller *et al*., 1999b). This behavioral pattern of remaining mostly in nearshore waters may serve a variety of purposes. For example, females in other large whale species are known to remain near to shore when tending a calf to avoid killer whale predation and to possibly help teach feeding behavior. However, since both lactating and pregnant females are under especially high energetic demands it is imperative that they feed in regions capable of meeting their elevated physiological requirements. Thus, the seasonal site fidelity and annual return of reproductive females reported here is likely to be related to feeding and suggests that the northeastern Sakhalin Island coast, particularly the nearshore waters off Piltun Lagoon, represents special habitat critical for their summer feeding and nurturance of offspring.

Given the continued uncertainty regarding the ability of the western gray whale population to increase from its depleted state, impacts from oil and gas development activities off the northeastern Sakhalin Island coast need to be closely monitored and stringently mitigated to reduce disturbance to the lowest possible level. In addition, net entrapments of western gray whales off Japan and possibly elsewhere can lead the population to extinction (IISG, 2006; Cooke *et al*., 2006, 2007; Brownell *et al*., 2007). Thus, human related mortality during migration and in the (yet to be determined) wintering area(s) must be addressed and mitigated to the lowest possible level. Where scientific knowledge is lacking, the precautionary principle should be applied as the best measure of protection. With this in mind, the photo-identification and genetic biopsy research conducted since 1995, and reviewed here, must be continued to further monitor survival of individuals, describe the overall population trend and to recommend further conservation and protection measures.

In conclusion, protection of the Sakhalin Island feeding habitat, including the coastal lagoon systems that appear integrally related to the high benthic biomass in the area, is clearly paramount to successful conservation of the western gray whale population. The unique method of benthic feeding by these whales makes them an "umbrella" species (Hooker and Gerber, 2004), whereby protection of their habitat provides protection for the biological diversity of the entire northeastern Sakhalin Island shelf. Thus, the feeding habitat of the western gray whale needs to be considered a "hot spot" for conservation planning now and in the future and every effort should be taken to protect its biological integrity.

ACKNOWLEDGEMENTS

We were fortunate to work with a wonderful cast of characters during the 2007 field season, thank you Ira, Valera, Renat and Ilya. We are especially indebted to Justin Cooke who has been instrumental in the recent population assessments and we thank him for his collaboration. We gratefully acknowledge the support of (in alphabetical order) the: Alaska SeaLife Center, International Fund for Animal Welfare, International Whaling Commission, Ocean Park Conservation Foundation, University of Washington, U.S. Marine Mammal Commission and the U.S. National Marine Fisheries Service. This project was conducted as part of the Marine Mammal Project under Area V: Protection of Nature and the Organization of Reserves within the U.S.-Russia Agreement on Cooperation in the Field of Environmental Protection.

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Table 1. Annual survey effort, groups encountered and whales identified 1994 to 2007.

Year	Sampling Period (mo, d)	Number of Surveys	Hours of Observation	Groups Encountered	Whales Identified
1994	09/07 - 09/12	1			10
1995	08/15 - 08/19	5	10.1	23	28
1997	07/09 - 09/08	22	33.4	114	47
1998	07/06 - 09/29	35	50.5	125	54
1999	06/29 - 10/13	56	122.0	434	69
2000	06/25 - 09/16	40	56.5	365	58
2001	06/25 - 09/25	49	101.8	448	72
2002	06/25 - 09/25	36	75.6	411	76
2003	07/15 - 09/13	22	41.7	219	75
2004	07/29 - 09/12	21	33.8	194	93
2005	07/04 - 09/09	20	40.9	160	93
2006	07/23 - 08/25	10	24.1	96	79
2007	07/26 - 09/09	20	32.2	187	83
Overall		337	622.6	2777	169[1]

[1] The number of whales identified annually includes resightings of individuals from previous years, resulting in a total of 169 identified individuals. The number of whales identified does not correspond to the size of the population.

Table 2. Annual sighting trends and resighting percentages 1994 to 2007.

Year	Whales Identified	Number of Calves	New Non-Calves	GARR	Percent Non-Calves Previously Identified
1994[1]	10				
1995[1]	28	2	20		23.1%
1997	47	2	25	4.3%	44.4%
1998	54	8	5	14.8%	89.1%
1999	69	3	12	4.3%	81.8%
2000	58	3	3	5.2%	94.5%
2001	72	6	6	8.3%	91.0%
2002	76	7	5	9.2%	92.8%
2003	75	11	2	14.6%	96.9%
2004	93	7	2	7.5%	97.7%
2005	93	6	5	6.5%	94.3%
2006	79	4	3	5.1%	96.0%
2007	83	9	2	10.8%	97.3%

[1] Data from 1994 and 1995 were opportunistic and pilot in nature (respectively) and are thereby viewed as incomplete for some of the reported values.

Table 3. Summary of skinny whales recorded during fieldwork 1999 to 2007.

Year	Number of Whales Photo-Identified	Number of Whales Recorded as Skinny	Percentage of Whales Recorded as Skinny
1999	69	16	23.2%
2000	58	30	51.7%
2001	72	21	29.2%
2002	76	9	11.8%
2003	75	3	4.0%
2004	93	5	5.4%
2005	93	14	15.1%
2006	79	4	5.1%
2007	83	6	7.2%

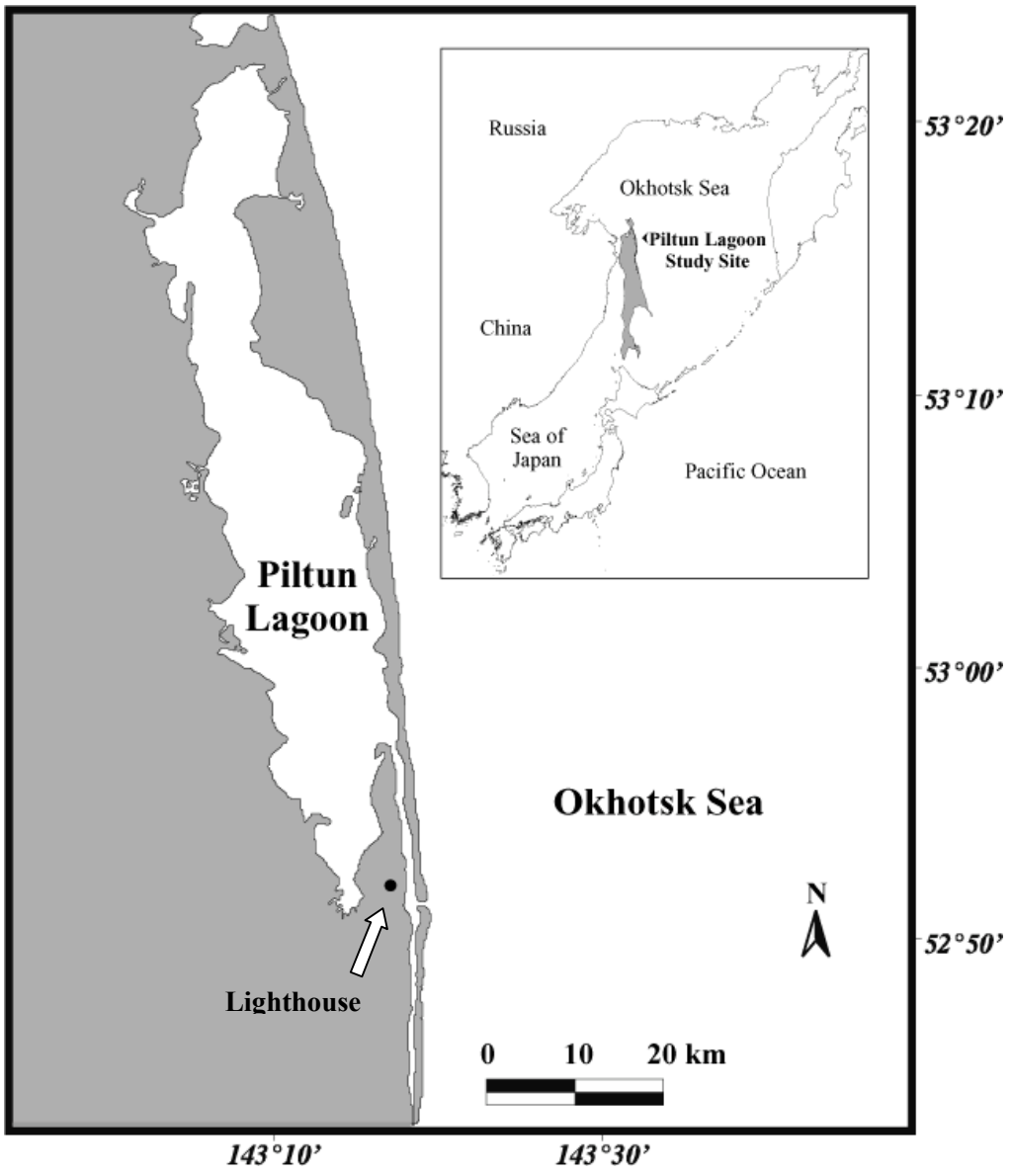

Figure 1. Map of the Piltun study area. Inset shows relative location of Sakhalin Island in the Okhotsk Sea.

Figure 2. Pigmentation and other patterns used to photographically identify individual whales.