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WESTERN GRAY WHALE RESEARCH AND MONITORING PROGRAM IN 2010, SAKHALIN ISLAND, RUSSIA

VOLUME I

BACKGROUND AND METHODS

Photo taken by Y.M. Yakovlev

Prepared for
Exxon Neftegas Limited and Sakhalin Energy Investment Company Limited

March 2011

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CHAPTER 1

WESTERN GRAY WHALE RESEACH AND MONITORING BACKGROUND[1]

Photo taken by Y.M. Yakovlev

by

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CHAPTER 1: RESEARCH AND MONITORING BACKGROUND

1.1 INTRODUCTION

Exxon Neftegas Limited (ENL), operator of the Sakhalin-1 consortium, and Sakhalin Energy Investment Company, operator of the Sakhalin II consortium, are developing oil and gas reserves on the continental shelf off northeast Sakhalin Island, Russia. These projects are located in proximity to the summer feeding grounds of the western gray whale (*Eschrichtius robustus*). Due to the critically endangered status of the western gray whale, this population was identified in Environmental Impact Assessments (EIAs) for the Sakhalin-1 and Sakhalin II projects and during State Ecological Expert Reviews (SEERs) as being a species of primary concern on the northeast Sakhalin shelf. As part of the project SEERs, further studies were recommended to increase the understanding of western gray whale ecology, and to monitor the individual and cumulative impact of oil and gas developments on the western gray whale population. The sections below briefly describe aspects of western gray whale ecology, and the research and monitoring programs that are being conducted.

1.2 WESTERN GRAY WHALE ECOLOGY

1.2.1 Population Status

There are two extant populations of gray whales: the eastern North Pacific and western North Pacific (or Korean-Okhotsk) (LeDuc *et al.* 2002; Weller *et al.* 2002b; Moore and Clarke 2002). The eastern North Pacific population annually migrates from warm wintering ground lagoons in coastal Baja California and Mexico to summer foraging areas in the Bering and Chukchi Seas off northern Alaska and Russia (Jones, *et al.*, 1984; Swartz *et al.* 2006, Allen and Angliss 2010). Not all eastern gray whales follow this migration pattern. A small subset of the eastern population feeds in coastal water off of British Columbia, Washington, and Oregon (Reeves and Mitchell 1988; Calambokidis *et. al.* 2002, 2010). In addition, gray whale calls have been recorded throughout the winter in the Beaufort Sea near Barrow, Alaska, suggesting that some gray whales remain in arctic waters during this season (Stafford *et al.* 2007).

The western North Pacific population is presently believed to range from wintering grounds in the South China Sea to feeding grounds in the Sea of Okhotsk and along the south-eastern coast of the Kamchatka Peninsula. It should be noted that the wintering range for this population remains unconfirmed. Data from a 13 year old male WGW “Flex” that was satellite tagged in September 2010 suggests that at least some WGWs do not migrate south along the Asia coast in the winter. “Flex” travelled east from Sakhalin

Island to the Bering Sea shelf break and then southeast across the Gulf of Alaska and Northeast Pacific Basin to join the eastern gray whale migration route near Washington State. "Flex" continued to head south, wth the last transmission from "Flex" received near Silitz Bay, Oregon on February 4, 2011 (OSU MMI 2011). "Flex" is known in the IBM photo ID catalogue as KOGW068, or "Belochvost" (in English, "White Tail"). "Belochvost" has been photographed by the IBM team every year in 2003-2010, and only in the Piltun feeding area (Yakovlev and Tyurneva 2004, 2005a, 2006, 2008; Yakovlev *et al.* 2007, 2009b, 2010).

While the two populations are considered to be separated geographically and genetically (LeDuc *et al.* 2002; Swartz *et al.* 2006), it is hypothesized that their distribution may overlap in their known summer feeding ranges off the east coast of the Kamchatka Peninsula (Vertyankin *et al.* 2004, 2007; Yakovlev *et al.* 2009; Tyurneva et al. 2010) (Figure 1) and, as demonstrated by "Flex", some degree of range overlap occurs within the Bering Sea and the eastern gray whale migration corridor along the North American pacific coast.

Both gray whale populations were depleted by commercial whaling by the early- to mid- 20th century. Today, the eastern population has recovered and is estimated to consist of approximately 20,000 individuals (Laake *et al.* 2009; Punt and Wade 2010). The western stock, however, remains one of the most endangered baleen whale populations in the world. In contrast to the eastern population, the western gray whale (WGW) population has probably never been large, and according to some estimates did not exceed 2,000–2,500 individuals at its peak (Berzin 1974; Yablokov and Bogoslovskaya 1984). Whaling brought the population to near extinction (Brownell and Chun 1977; Weller *et al.* 2002b), but on 10 September 1983 about 20 gray whales were sighted off northeastern Sakhalin near Piltun Bay (Blokhin *et al.* 1985). The International Convention for the Regulation of Whaling has been protecting this population since 1946, although range countries joined the International Whaling Commission (IWC) that implements the convention at various times: the Soviet Union joined in 1948, Japan in 1951, the Republic of Korea in 1978 and China in 1980. Even with such a long protection period, the recovery of the western population of gray whales has been slow.

For several years, the WGW population was estimated to be between 100 and 250 individuals (Vladimirov 1994; Blokhin 1996; Perlov *et al.* 1996; Weller *et al.* 1999, 2000, 2004; Würsig *et al.* 1999, 2000), although Sobolevsky (2000) estimated a maximum of 100 individuals. A recent population assessment based on 1994 to 2007 photo identification data estimates that 130 non-calf individuals

(90% confidence interval 120-142) remain in this remnant population as of 2008, with a 22% (14-31%) and 2.2% (1.3%-3.3%) annual mortality of calves and non-calves, respectively (Cooke *et al.* 2008). This population estimate is based on data collected on the Sakhalin shelf. However, some western gray whales, including yearlings that were seen the previous year with mothers nearshore Sakhalin Island, have been observed offshore eastern Kamchatka (Yakovlev and Tyurneva, 2008; Yakovlev *et al.* 2007; Vertyankin *et al*. 2007). Thus, Cooke *et al.* (2008) may have underestimated the WGW population size and over estimated its mortality rates. An update of the population assessment will be done in the near future.

Yearly individual identifications of WGWs by photo-identification research conducted by the Institute of Marine Biology (IBM) of the Far East Branch of the Russian Academy of Science (DVO RAN) have been consistent with the Cooke *et al.* (2008) population size estimate. In 2007, 125 whales (including 6 calves and 2 possible calves) were identified in the Sakhalin area (Yakovlev and Tyurneva 2008). A total of 124 whales (including 3 calves and 2 possible calves) in 2008 (Yakovlev *et al.* 2009) and a total of 138 individuals (including 6 calves and 2 possible calves) in 2009 (Yakovlev *et al.* 2010) from the Sakhalin WGW catalogue were identified in both Sakhalin and Kamchatka. Because photo ID effort is not expected to observe all WGWs in a given year, the total number of identified individuals is likely an underestimate of the WGW population size.

The western gray whale population was classified as critically endangered by the International Union for Conservation of Nature (IUCN) in 2000 and remains in this classification to date (http://www.iucnredlist.org/). WGWs have also been placed in Category I ("threatened with extinction") of the Russian Federation Red Book (2000).

1.2.2 WGW Geographic Range and Seasonal Distribution

Gray whales have a migratory life history, which is hypothesized to have evolved as a response to the seasonal production of prey in arctic waters. Gray whales feed at higher latitudes where waters have abundant food during the summer-autumn season when there is limited or no ice cover. They are forced to leave these productive waters when the ice returns, and migrate to warmer waters in the south to overwinter, mate, and calve (Rice and Wolman 1971). Only limited feeding occurs along the migration route and on the wintering grounds (Swartz *et al.* 2006), and gray whales survive during this time almost entirely on accumulated energy reserves stored in a layer of subcutaneous blubber.

Western gray whales begin to forage off the eastern coast of Sakhalin in late May – early June, when the area is free of ice, and remain there until as late as November or early December (Vladimirov *et al.* 2005). The whales begin their migration to the wintering grounds in the autumn and most have left Sakhalin waters by the time the sea starts to freeze. There is little evidence of WGW migration routes and the exact location of their wintering grounds remains unknown although these grounds were long thought to be the shallow bays on the southern coast of the Korean Peninsula (hence the name of this gray whale stock) (Rice and Wolman 1971). Although direct evidence is scarce, it is now thought that western gray whales likely winter, breed and calve somewhere in the coastal waters of the South China Sea, most probably off the coast of Guangdong Province and in the waters around Hainan Island (Rice, 1998; Kato and Kasuya 2002; Jones and Swartz 2002, 2009; Weller *et al.* 2008). Between 2005 and 2007 four gray whales were fatally entangled in fishing nets and an additional gray whale was found stranded along the Pacific coast of Japan, indicating that a migration pathway along this coast may be used by part of the WGW population (Cooke *et al.* 2008). Historical catches of gray whales off the western coast of Japan (Omura 1984) suggest the existence of yet another potential migration route. However, as described earlier, recent satellite tagging data from a single male western gray whale revealed that some WGWs do not follow a winter migration route southwards along the Asian coast each year, but instead travel northeast across the Sea of Okhotsk and Bering Sea during their winter migration (OSU 2011). Future tagging efforts will provide more insight on the exact migration routes.

Recent sightings have placed photo-identified known WGWs off the eastern coast of Kamchatka (Yakovlev and Tyurneva 2008; Yakovlev *et al.* 2007, 2009, 2010). In addition, gray whales, presumably of the western stock, have occasionally been observed in other coastal areas of the Sea of Okhotsk, i.e., near Magadan, the Shantar Islands, around the northern tip of Sakhalin Island, near Terpeniye Point, in Aniva Bay, along the Kurile Islands and along the southwestern coast of Kamchatka (Meier et al. 2002; Vertyankin et al. 2004, 2007; Maminov and Blokhin 2004; Weller et al. 2002c, 2003; A. V. Andreyev [Institute of Biological Problems of the North of FEB RAS, Magadan], S. I. Kornyev [KamchatNIRO, Petropavlovsk-Kamchatsky] and V. N. Malakhov [Rosselkhoznadzor, Magadan] – personal communications) (Figure 1). When available, photographs of these gray whales have been compared with identified individuals in the IBM WGW catalogue. Two of these gray whales have been matched with the IBM catalogue.

1.2.3 Study Areas

The primary study area of the joint ENL/ Sakhalin Energy WGW research and monitoring program covers the northeast coast of Sakhalin Island (Figure 2). This area includes offshore license areas for the Sakhalin-1 (Odoptu, Chayvo and Arkutun-Dagi fields) and Sakhalin II projects (Piltun-Astokhskoye). In addition, opportunistic surveys are conducted annually by the research vessel en route from Vladivostok to the northeast Sakhalin Island shelf. Some research effort has also taken place off the southeastern Kamchatka peninsula, primarily in Olga and Vestnik Bays, since 2006.

Feeding gray whales have been sighted during the summer season along the entire northeast coast of Sakhalin Island (Wűrsig *et al.* 1999; Sobolevsky 2000; Blokhin *et al.* 2004; Vladimirov *et al.* 2008a) and around its northern tip (Severnyi Bay; Fadeev 2005). However, most sightings of feeding whales are in the coastal waters of northeastern Sakhalin adjacent to Piltun and the northern part of Chayvo Bays (the "Piltun" feeding area) and in deeper waters offshore Chayvo and Nyyskiy Bays (the "Offshore" feeding area"). For many years, the nearshore Piltun feeding area was the only known gray whale feeding ground off the east coast of Sakhalin Island, although small groups of whales were sometimes sighted in deeper waters eastward of Chayvo and Nyyskiy bays (Sobolevsky 1998, 2001; Vladimirov *et al.* 2000; Miyashita *et al.* 2001). Observations of ten gray whales feeding 25 to 30 km seaward from Chayvo Bay made by observers aboard a seismic research support ship in 2001 resulted in aerial and ship-based surveys of the area being conducted (Maminov and Yakovlev 2002; Blokhin *et al.* 2002). Large numbers of feeding gray whales were recorded during these surveys, and a second "Offshore" gray whale feeding area was discovered (Maminov and Yakovlev 2002; Blokhin *et al.* 2002; Yazvenko *et al.* 2002; Meier *et al.* 2007).

The Piltun feeding area is about 120 km long and is located in nearshore waters along the northeastern Sakhalin coast approximately from the mouth of Ekhabi Bay in the north to the mouth of Chayvo Bay in the south (between N52°20' and N53°30') (see Fig.2). Whales normally remain in shallow waters with depths up to 20-25 m, primarily within 4-5 km from shore. The shallow Piltun area has special importance for WGW feeding, since it was the only known location where cow-calf pairs were observed until the summer-autumn season of 2008. In 2008, Yakovlev *et al*. (2009) recorded, for the first time, one cow-calf pair offshore eastern Kamchatka (the cow had been observed offshore Sakhalin in previous years). Seven cow-calf pairs were also observed offshore eastern Kamchatka in 2009, with four of these cows seen previously off Sakhalin (Yakovlev et al. 2010). The Offshore feeding area is located 40-50 km south-southeast of the Piltun area and seaward of the middle of Chayvo Bay to southern Nyiskiy Bay,

25–45 km offshore in depths of 30–65 m (between approximately N51°50' and N52°30') (see Figure 2). Changes in the gray whale distribution in both the Piltun and the Offshore feeding areas within and between seasons have been noted by a number of studies (Johnson 2002; Weller *et al.* 2004; Perlov *et al.* 2003; Blokhin *et al.* 2003, 2004; Vladimirov *et al*. 2005, 2006, 2007, 2008a,b, 2009, 2010; Meier *et al.* 2007) and are considered to be at least partly a reaction to seasonal changes in the distribution and abundance of prey (Fadeev 2003 2004, 2005, 2006, 2007, 2008, 2009, 2010).

In contrast to all other cetaceans, gray whales feed primarily on benthic (bottom) and epibenthic (near-bottom) invertebrates. The exceptionally high biomass of preferred prey items along Sakhalin Island, particularly amphipod crustaceans, is apparently the reason for the formation of gray whale feeding aggregations in this region. For instance, amphipod biomass values up to 1351.2 g/m^2 have been recorded in grid samples in the Offshore WGW feeding area since 2002, with average values ranging from 247.72 to 650.14 g/m^2 (Fadeev, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). Coastal feeding sites (areas offshore Piltun and Chayvo bays) typically have lower biomass values of amphipods, ranging from 35.7±9.8 to 51.3±8.6 g/m^2 off Chayvo Bay and from 35.2±3.2 to 101.34±11.11 g/m^2 off Piltun Bay (Fadeev, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). However, different species of amphipods, with different growth rates and potentially different energetic values, inhabit coastal and offshore areas. In addition, the substantially greater water depths in the Offshore feeding area makes foraging there more energetically "expensive" than in coastal areas. Therefore, direct comparisons of the biomass values between the Piltun and Offshore feeding areas may be misleading.

The Piltun nearshore feeding area is particularly rich in benthic prey, particularly amphipods, isopods, bivalve molluscs and worms, at depths of 5 to 15 m (Fadeev 2009). In this region, the epibenthic amphipod, *Monoporeia affinis,* is the dominant species and forms the major part of the WGW diet (Sobolevsky 2000; Fadeev 2007). Although their preferred prey are amphipods, gray whales are known to be opportunistic feeders that can switch among prey species (Nerini 1984; Blokhin and Pavlyuchkov 1999; Dunham and Duffus 2001, 2002). Sand lance, *Ammodytes hexapterus*, may also be an occasional food source for WGWs (Fadeev 2004, 2005, 2006, 2009). Distribution surveys in 2004-2005 recorded larger densities of gray whales in the deeper waters of the northern Piltun feeding area, where the frequencies of occurrence of sand lance were highest, suggesting that whales might have been attracted to the sand lance as a potential food source (Fadeev 2005, 2006; Vladimirov *et al.* 2009).

The Offshore feeding area is characterized by patches of tube-dwelling ampeliscid amphipods (primarily *Ampelisca eschrichti*) with biomass up to 1351.2 g/m^2 (Fadeev 2003, 2004, 2005, 2006, 2007, 2008, 2009) and up to 1,077 g/m^2 in 2009 (Fadeev 2010). The density and biomass of these ampeliscid colonies are comparable to, and in some cases exceed, values in eastern gray whale feeding grounds (Stoker 1981; Nerini and Oliver 1983; Oliver *et al*. 1983; Dunham and Duffus 2001, 2002), suggesting that the Offshore feeding area provides high quality foraging habitat for gray whales.

1.3 WESTERN GRAY WHALE RESEARCH AND MONITORING

1.3.1 Study Areas

The start of offshore commercial oil and gas development on the eastern Sakhalin Shelf in the mid-1990's necessitated a comprehensive study of the WGW population to assess possible anthropogenic impacts on the population and to develop appropriate measures to mitigate potential impacts (Berzin and Vladimirov 1996; Vladimirov 2000). Following the joint declaration of the Gore–Chernomyrdin Commission, "On Measures to Ensure Biodiversity Conservation in the Sakhalin Island Area," dated 7 February 1997, the Russian and American parties prepared a joint "Okhotsk–Korean Gray Whale Population Monitoring and Research Program" in 1998, which was approved by the Russian State Committee on Environmental Protection (Goskomekologiya) and the U. S. Fish and Wildlife Service (Weller *et al*. 2001). The program proposed multidisciplinary studies of the WGW population during the summer and autumn feeding season off eastern Sakhalin that included the studies of whale abundance and distribution, as well as photo identification and behavioral programs. In addition, studies of the acoustic environment and a study of benthos as the main food resource of WGWs were conducted.

To maximize the efficiency of the required WGW research and monitoring studies, ENL and Sakhalin Energy initiated a joint industry-sponsored WGW monitoring and assessment program in 2002. This program primarily focuses on the northeast Sakhalin shelf and is conducted by scientists from leading Russian research institutes of the Far Eastern Russian Academy of Sciences. In 2006, limited photo-ID and distribution work in Kamchatka was added to the program. The Kamchatka program included a limited amount of benthic sampling in 2009 and 2010 . The joint ENL/ Sakhalin Energy WGW research and monitoring program is endorsed by the required Russian organizations and agencies, i.e., the Russian Federation Ministry of Natural Resources (MNR), the Federal Oversight Service for Natural Resource Use (ROSPRIRODNADZOR), the Russian Federal Fishery Agency, and the local Sakhalin department of ROSPRIRODNADZOR.

1.3.2 Potential Impacts to Western Gray Whales

Gray whales have a high affinity for coastal habitats. Much of the WGW life cycle is believed to take place in the coastal waters of densely populated countries with intensive fishing and shipping activities. Western gray whales are likely exposed to anthropogenic activity during all three stages of their life cycle: (1) during whale reproduction in the southern part of their range, the location of which is currently unknown; (2) during their long north-south migrations, the exact route of which is currently unknown; and (3) in their known feeding areas off the northeast coast of Sakhalin Island and the southeastern Kamchatka peninsula, Russia.

WGWs face several threats to their future survival throughout their range. Anthropogenic-related mortality south of the Sea of Okhotsk poses one of the most serious threats to this population. As described above, between 2005 and 2007, five female WGWs were stranded or found entangled in fishing gear near Japan, resulting in their deaths (Cooke *et al.* 2008). If such mortality continues, even at a level of one individual per year, population projections suggest a 25% probability of population decline and a 10% probability of population extirpation by 2050 rather than the estimated high probability (> 99%) of population increase in the absence of such mortality (Cooke *et al.* 2008).

Other threats to population survival include ship strikes, pollution, habitat damage, oil spills, and disturbance/displacement from key habitats (Richardson *et al*. 1989; Brownell 1999; Bradford *et al.* 2006, 2009). Possible displacement of WGWs from critical feeding habitat due to anthropogenic activities is a concern. For example, increased dredging and vessel traffic from 1957 to 1967 resulted in eastern gray whales temporarily abandoning an entire lagoon previously used as a nursing habitat; whales re-occupied the lagoon several years after the activity ceased (Gard 1974; Bryant *et al.* 1984). Disturbance caused by coastal development has also been implicated in the abandonment of breeding grounds by eastern gray whales (Reeves 1977).

One of the primary short- and long-term concerns in relation to oil and gas project development and operation (vessel traffic, platforms, construction activities, dredging, seismic surveys) is the duration and levels of sound these activities produce while individuals are feeding. The effects of underwater noise on baleen whales have been documented for a number of species, such as bowhead whales (Ljungblad *et al.* 1988; Reeves *et al.* 1984; Richardson *et al.* 1986, 1999), humpback whales (McCauley *et al.* 1998, 2000), and gray whales (Malme and Miles 1985; Malme *et al.* 1986, 1988). For eastern gray whales, Malme *et al.* (1986) found that ~10% of the whales stopped feeding and temporarily moved away from

seismic sounds when received sound levels near the whales exceeded 163 dB re 1µPa (rms). For continuous sounds, Malme *et al.* (1986) observed 10-50% of feeding eastern gray whales avoiding an area exposed to industrial noise levels of 120 dB re 1µPa (rms). Tyack and Clark (1998) found that migrating eastern gray whales avoided a low frequency acoustic sound source when it was located directly in their migratory path. However, when the same sound source was placed offshore of the migration corridor, no apparent avoidance behavior was observed.

Western gray whales have also been documented to respond to sounds produced during seismic surveys (Gailey *et al.* 2007; Johnson *et al*. 2007; Weller *et al.* 2002a,b; Würsig *et al.* 1999; Yazvenko *et al.* 2007a). Gailey *et al.* (2007) found that whales traveled faster, changed directions of movement less, moved further from shore, and stayed under water longer between respirations when exposed to higher received sound levels. Similarly, Würsig *et al.* (1999) found that whales traveled faster and more linearly with short respiration intervals during seismic operations that occurred near the WGW feeding grounds in 1997. Yazvenko *et al.* (2007a) found that the distribution of gray whales shifted about 10 km south within the Piltun feeding groups during a seismic survey. However, using mud plumes as an index of feeding, Yazvenko *et al.* (2007b) did not find statistically significant changes in feeding activity of gray whales during periods of this seismic survey.

Due to these concerns, studies to understand potential disturbance by noise on western gray whales from seismic surveys, onshore and offshore construction activities, vessel activity, other industrial activities, and the cumulative impact of all anthropogenic activity continue to be conducted offshore Sakhalin during the WGW summer/autumn feeding season.

1.3.3 Research and Monitoring Objectives

To date, the joint ENL/ Sakhalin Energy WGW research and monitoring program has provided important information about WGW life history characteristics that can be used to assess the status of the WGW population and to minimize potential impacts associated with the exploration and production activities of the Sakhalin-1 and Sakhalin II projects. The joint ENL/ Sakhalin Energy WGW research and monitoring program (hereafter referred to as the joint program) is designed to provide information on the following key questions:

- **How do WGWs utilize their feeding grounds offshore northeast Sakhalin on a daily, seasonal, and annual basis?**

- **What are the intra and inter seasonal variations in WGW habitat use and WGW movement between feeding habitats?**

- **How do individually identified WGWs inform us about the status of the population, including reproduction, survival rate and body condition?**

- **What is the benthic community composition in the WGW feeding areas?**

- **What key prey species are targeted by WGWs, and what are the natural temporal and spatial variations in the availability of these species?**

- **How does natural variability in food benthos impact WGW habitat use?**

- **What are the sources of the organic matter that support the production of the food benthos for gray whales?**

- **What is the importance of feeding habitats other than the northeast Sakhalin shelf, i.e., the southeast coast of Kamchatka?**

- **What is the level of anthropogenic pollutants (e.g., petroleum hydrocarbons, heavy metals and organochlorine pesticides) in the benthos of the WGW feeding areas and how does it affect the biomass or composition of the benthic communities that WGWs feed on?**

- **What is the natural variation in WGW behavior, such as movement and respiration patterns, while engaged in feeding and non-feeding activities?**

- **Are there any observed changes in WGW feeding activity, distribution, population size or health that result from anthropogenic activities, and what kind of mitigation measures are needed to avoid effects of anthropogenic activity at the population level?**

- **How does reproduction change in years following construction or seismic that resulted in behavioral modification?**

- **How do observed changes in WGW distribution, movements, prey base, and behavior translate into population level processes and trends? Which changes are biologically and statistically significant, and which are not?**

Presently, the joint ENL/ Sakhalin Energy WGW research and monitoring program consists of five main components to collect the data needed to answer the above questions. These annual programs are:

1. Underwater sound propagation and monitoring studies to understand the variation in the ambient sound environment and the level of sound generated by development activities. These studies are conducted by the Pacific Oceanological Institute in Vladivostok (also of the Far Eastern Branch of the Russian Academy of Science).

2. Shore-based and vessel-based distribution and relative abundance studies to understand seasonal and annual variation in distribution and abundance. These studies are conducted by

the all Russian Fisheries Research Institute in Moscow (VNIRO) in collaboration with the Institute of Marine Biology (IBM) of the Far Eastern Branch of the Russian Academy of Science.

3. Photo-identification studies to understand the site fidelity of the whales, population status, reproduction rates and body condition; conducted by IBM.

4. Vessel-based prey studies to understand prey distribution and feeding activity, and monitoring of contamination with heavy metals, petroleum hydrocarbons and organochlorine pesticides; conducted by IBM.

5. Shore-based behavioral studies measuring individual whale behavior parameters; studies led by Texas A&M University with Russian scientists from the Far East State University in Vladivostok.

This report presents the background and methods for four of these programs: distribution, photo-identification, prey studies and behavioral studies.

Figure 1 The Sea of Okhotsk—northern range of the Western Gray Whale

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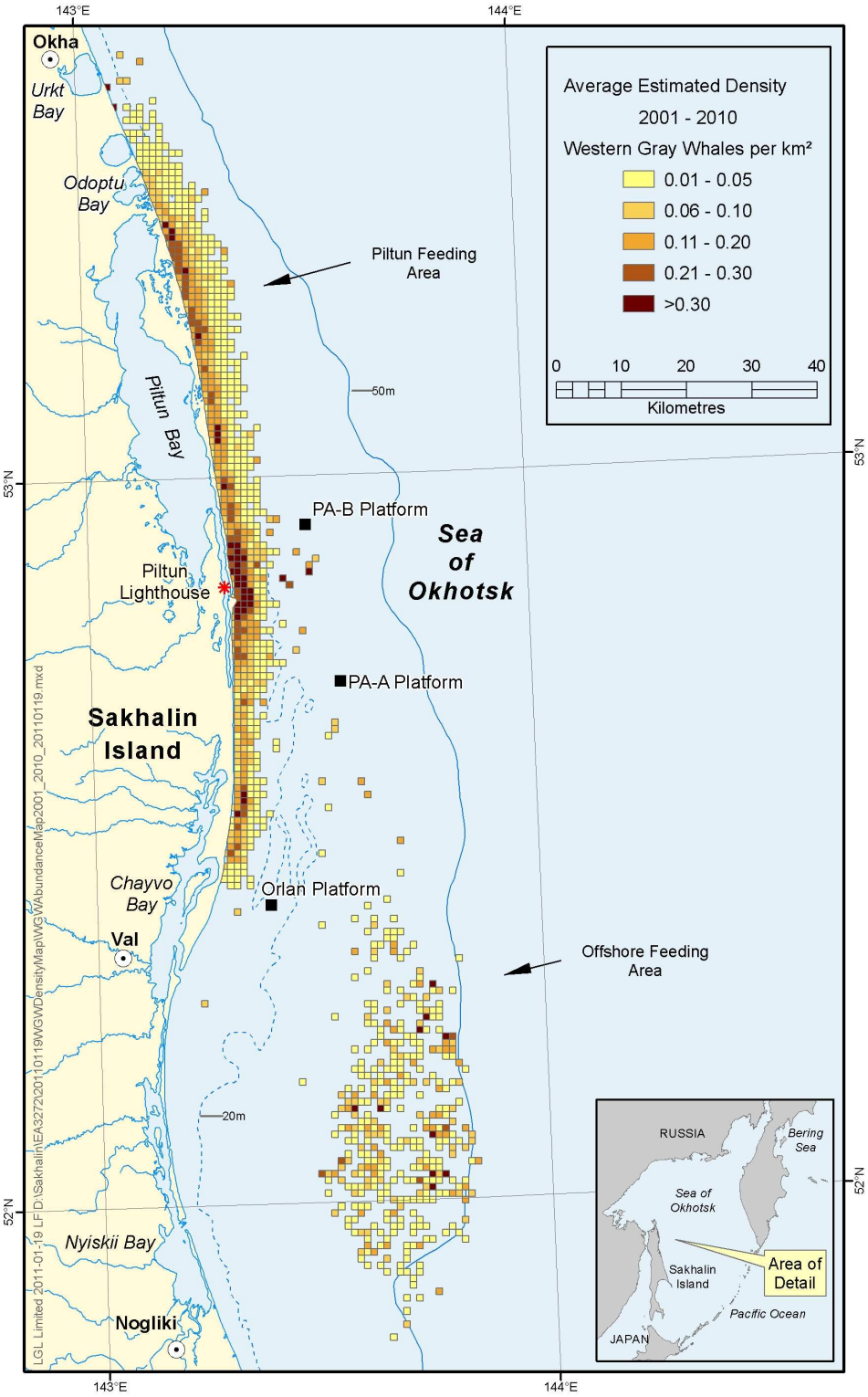

Figure 2 Western gray whale average estimated density map based on 2001-2010 aerial, vessel and shore-based systematic survey data.

1.4 LITERATURE CITED

Allen , B.M. and R.P. Angliss. 2010. Alaska marine mammal stock assessments, 2009. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-206, 297 p.

Berzin A.A 1974. Practical Problems in the study of whales (using the example of Pacific whales) // Vertebrate Zoology, Vol.6, pp. 159-189.

Berzin, A.A. and V.L. Vladimirov. 1996. Anthropogenic impact on whales of the Sea of Okhotsk // TINRO Pub. 1996. Vol. 121. Pages 4-8.

Blokhin, S.A., M.K.Maminov and G.M.Kosygin. 1985. On the Korean-Okhotsk population of gray whales. Rep. Int. Whaling Comm., v. 35 - p. 375-376.

Blokhin, A. 1996. Distribution, abundance and behaviour of the American and Asian gray whale populations (Eschrichtius robustus) in regions of their summer distribution along the Far East coast. Izvestiya of the Pacific Research and Fisheries Centre, Vol. 21, pp. 36-53.

Blokhin, S. A., and V. A. Pavlyuchkov. 1999. Feeding of Gray Whales of the California-Chukotka Population in Mechigmen Bay. Izv. TINRO, 1999, v. 126, pp. 442-446.

Blokhin, S.A., S.B. Yazvenko V.L. Vladimirov and S.I. Lagerev. 2002. The abundance, distribution, and behavior of gray whale (*Eschrichtius robustus*) in coastal waters of the northeast Sakhalin during the summer-fall period of 2001 (from aerial survey data). Marine Mammals of Holarctic: Proceedings of the 2nd International Conference, Baikal, Russia, pp. 36-38.

Blokhin, S.A., N.V. Doroshenko and I.P. Marchenko. 2003. The abundance, distribution, and movement patterns of gray whales (*Eschrichtius robustus*) in coastal waters off the northeast Sakhalin Island coast in 2002 based on the aerial survey data. Report by TINRO Centre, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia.

Blokhin S.A., N.V. Doroshenko and S.B. Yazvenko. 2004. Distribution, Abundance, and Movement Patterns of Western Gray Whales (*Eschrichtius robustus*) in Coastal Waters of Northeastern Sakhalin Island, Russia, in June-December 2003 Based on Aerial Survey Data. Report by TINRO-Centre, Vladivostok, for VNIRO, Exxon Neftegaz Limited and Sakhalin Energy Investment Company [available on the Sakhalin Energy Investment Company website]. 136 p + Append.

Bradford, A.L., P.R., Wade, D.W. Weller, A.M. Burdin, Y.V. Ivashchenko, G.A. Tsidulko and R.L. Brownell Jr. 2006. Survival estimates of western gray whales (Eschrichtius robustus) incorporating individual heterogeneity and temporary emigration. Marine Ecology. Progress Series. 315: 293-307.

Bradford, A.L. D.W. Weller, Y.V. Ivashchenko, A.M. Burdin, and R.L. Brownell, Jr. 2009. Anthropogenic scarring of western gray whales (*Eschrichtius robustus*). Marine Mammal Science 25:161-175.

Brownell, R. L., Jr. 1999. Okhotsk gray whales: One of the most endangered whale populations. Sphere Square 13:2-3. CETUS Newsletter, Tokyo, Japan. (in Japanese).

Brownell, R.L. Jr., and C.I. Chun. 1977. Probable existence of the Korean stock of the gray whale (*Eschrichtius robustus*). J. Mammal. 58:237-239.

Bryant, P. J., C. M. Lafferty, and S. K. Lafferty. 1984.Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. Pp. 375–387 in The gray whale, *Eschrichtius robustus* (M. L. Jones, S. L. Swartz, and S. Leatherwood, eds.).Academic Press, Orlando, Florida.

Calambokidis, J., Darling, J.D., Deecke, V., Gearin, P., Gosho, M., Megill, M., Tombach, C. M., Goley, D., Toropova, C., and B. Gisborne. 2002. Abundance, range and movements of a feeding aggregation of gray whales (Eschrichtius robustus) from California to southeastern Alaska in 1998. Journal of Cetacean Research and Management. 4(3): 267-276.

Calambokidis, J., Laake J.L. and A. Klimek. 2010. Abundance and population structure of seasonal graywhales in the Pacific Northwest, 1998-2008. International Whaling Commission Publication SC/62/BRG32, 50 p.

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2008. Population assessment of western gray whales in 2008. Paper SC/60/BRG11 presented to the IWC Scientific Committee.

Dunham, J.S. and D.A. Duffus. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia. Marine Ecology Progress Series 223:299-310.

Dunham, J.S. and D.A. Duffus. 2002. Diet of gray whales (*Eschrichtius robustus*) in Clayoquot Sound, British Columbia, Canada. Marine Mammal Science 18: 419-437.

Fadeev, V.I. 2003. Benthos and Prey Studies in Feeding Grounds of the Okhotsk-Korean Population of Gray Whales. Report on materials from field studies on the research vessel *Nevelskoy* in 2002. Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia - 118 pp. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V.I. 2004. Benthos and Prey in Feeding Grounds of the Okhotsk-Korean Population of Gray Whales. Report on materials from field studies on the research vessel *Nevelskoy* in 2003 // Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia - 191 pp. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V. I. 2005. Benthos and food supply in feeding areas of the Okhotsk-Korean gray whale population. Report based on results of field work aboard the research vessel Akademic Oparin. Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 157 pp. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V. I. 2006. Benthos and food supply in feeding areas of the Okhotsk–Korean gray whale population in 2005. Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia, 133 pp. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V.I. 2007. Benthos and food supply in feeding areas of the Okhotsk-Korean gray whale population. Unpublished contract report by the Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Science, Vladivostok, Russia, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 119 pp. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V.I. 2008. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2007. Report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev. V.I. 2009. Benthos studies in feeding grounds of the Okhotsk-Korean gray whale population. Report by the Marine biology institute (The Far East Branch), Russian Academy of Sciences. Vladivostok, Russia for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Fadeev. V.I. 2010. Benthos studies in feeding grounds of the Okhotsk-Korean gray whale population in 2009. Chapter 3 *In*: Western Gray Whale Research and Monitoring Program in 2009, Sakhalin Island, Russia. Volume II Results and Discussion. Report by the Marine Biology Institute (The Far East Branch), Russian Academy of Sciences. Vladivostok, Russia for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Gailey, G., Würsig, B. and T.L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. *Environ. Monit. Ass.* 134:75-92.

Gard, R. 1974. Aerial Census of GrayWhales in Baja California Lagoons, 1970 and 1973, with Notes on Behavior, Mortality, and Conservation. *California Fish and Game* 60 (3):132-134.

IUCN 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>.

Johnson, S.R. 2002. Marine mammal mitigation and monitoring program for the 2001 Odoptu 3-D seismic survey, Sakhalin Island Russia: Executive summary. Report from LGL Limited environmental research associates, Sidney, B.C., for Exxon Neftegas Limited., Yuzhno-Sakhalinsk, Russia. 49 p. [available from Exxon Neftegas Limited upon request]. Also available as Working Paper SC/02/WGW/19, Int. Whal. Comm., Western Gray Whale Working Group Meeting, Ulsan, South Korea, 22-25 October 2002. 48 p.

Johnson, S. R., Richardson,W. J., Yazvenko, S. B., Blokhin, S.A., Gailey, G., Jenkerson, M. R., S. K. Meier, H. R. Melton, M. W. Newcomer, A. S. Perlov, S. A. Rutenko, B. Würsig, C. R. Martin, and D. E. Egging. 2007. A western gray whales mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. Environmental Monitoring and Assessment 134: 1-20.

Jones, M.L. and S..L. Swartz. 2002. GrayWhale (*Eschrichtius robustus*). Pp. 524-536 in The Encyclopedia of Marine Mammals, ed. byW.F. Perrin, B. Würsig, and J.G.M. Thewissen, Academic Press, San Diego, CA.

Jones, M.L. and S..L. Swartz. 2009. GrayWhale (*Eschrichtius robustus*). Pp. 503-511 in The Encyclopedia of Marine Mammals, 2nd edition, ed. byW.F. Perrin, B. Würsig, and J.G.M. Thewissen, Academic/Elsevier Press, San Diego, CA.

Jones, M.L., Swartz, S.L., and S. Leatherwood. 1984. The Gray Whale: Eschrichtius robustus. Academic Press, Inc. Orlando, Fl. 600pp.

Kato, H. and Kasuya, T. 2002. Some analyses on the modern whaling catch history of the western North Pacific stock of gray whales (*Eschrichtius robustus*), with special reference to the Ulsan whaling ground. J. Cetacean Res. Manage. 4:277-282.

Laake, J., A. Punt, R. Hobbs, M. Ferguson, D. Rugh, and J. Breiwick. 2009. Re-analysis of gray whale southbound migration surveys, 1967-2006. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC203, 55 p.

LeDuc, R.G., D.W. Weller, J. Hyde, A.M. Burdin, P.E. Rosel, R.L. Brownell, B. Würsig, and A.E. Dizon. 2002. Genetic differences between western and eastern gray whales (*Eschrichtius robustus*). Journal of Cetacean Research & Management. 4(1): 1-5.

Ljungblad, D.K., B. Würsig, S.L. Swartz and J.M. Keene. 1988. Observations on the behavioral responses of Bowhead Whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41:183-194.

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 In: G.D. Greene, F.R. Engelhardt and R.J. Paterson (eds.), Proc. workshop on effects of explosives use in the marine environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin, Environ. Prot. Br., Ottawa, Ont. 398 p.

Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1986. Behavioral responses of gray whales to industrial noise: feeding observations and predictive modeling. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 56(1988):393-600. BBN Rep. 6265. 600 p. OCS Study MMS 88-0048; NTIS PB88-249008.

Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73 In: W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (eds.), Port and ocean engineering under arctic conditions, vol. II. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111 p.

Maminov, M. K. and S. A. Blokhin. 2004. Gray whales *(Eschrichtius robustus)* in coastal waters of southern Far East. Marine mammals of the Holarctic (collect. of scient. papers after the 3rd Int'1 conf. - Koktebel, Crimea, Ukraine, 11-17 October 2004) - p.362-368

Maminov, M.K. and Yu.M. Yakovlev. 2002. New data on the abundance and distribution of gray whale on the northeastern Sakhalin shelf. Marine mammals of Holarctic. Abstracts of reports of the 2nd Int'1 conf. - Baikal, Russia, 10-15 September 2002. p. 170-171.

McCauley, R.D., M.N. Jenner, C. Jenner, K.A. McCabe and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: Preliminary results of observations about a working seismic vessel and experimental exposures. APPEA Journal 1998:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K.A. McCabe. 2000. Marine seismic surveys – a study of environmental implications. APPEA Journal:692-708.

Meier, S.K., J. Lawson, S.B. Yazvenko, A. Perlov, M. Maminov, S.R. Johnson, Y. Yakovlev, M. Newcomer, P. Wainwright, I. Moroz, A. Aschepkov, I. Piskunov, and M. Propp. 2002. Vessel-based marine mammal monitoring during the 2001 3-D seismic survey of the Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia. Report by LGL Limited environmental research associates, Sidney, BC, for Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia. 38 p + Append.

Meier, S.K., S.B. Yazvenko, S.A. Blokhin, P. Wainwright, M.K. Maminov, Y.M. Yakovlev, and M. Newcomer. 2007. Distribution and abundance of gray whales off northeastern Sakhalin Island, Russia, 2001-2003. *Environ. Monit. Ass.*, 134: 107-136. doi 10.1007/s10661-007-9811-2

Miyashita, T., S. Nishiwaki, V.A. Vladimirov and N.V. Doroshenko. 2001. Cruise report on the minke whale sighting surveys in the Sea of Okhotsk, 2000. In: Int'1 Whaling Com., 53rd meeting, doc. SC/53/RMP5 – 12 pp.

Moore, S. E., & Clarke, J. T. 2002. Potential impact of offshore human activities on gray whales (Eschrichtius robustus). Journal of Cetacean Research Management, 4, 19–25.

Nerini, M. 1984. A review of gray whale feeding ecology. In: The Gray Whale, (*Eschrichtius robustus*). M.L. Jones, S.L. Swartz and S. Leatherwood (eds). Academic Press, Inc., Orlando, Flordia, pp.451-463.

Nerini, M. K., and J. S. Oliver. 1983. Gray whales and the structure of the Bering Sea benthos. Oecologia, 59:224 – 225.

Oliver, J. S., P. N. Slattery, M. A. Silberstein and E. F. O'Connor. 1983. A comparison of gray whale feeding in the Bering Sea and Baja California // Fisheries Bull V. 81. P.:501-512.

Omura, H. 1984. History of gray whales in Japan. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) "The gray whale *Eschrichtius robustus*", Academic Press, Orlando etc., pp. 57-77.

OSU MMI 2011. Oregon State University Marine Mammal Institute Western Pacific Gray Whale, Sakhalin Island 2010. available at: http://mmi.oregonstate.edu/Sakhalin2010

Perlov, A.S., V. Vladimirov, Z.V. Reviankina, J. Ismail-Zade, S. Yazvenko, and S.R. Johnson. 1996. Review of literature/information regarding marine mammals in the vicinity of Sakhalin Island, Okhot Sea, Russia. Rep. from Pacific Research Institute of Fisheries and Oceanography (TINRO), State Committee for Fisheries and Oceanography, Vladivostok, Russia and LGL Limited, environmental research associates, Sidney B.C. for Marathon Oil Company, Littleton, CO. 32 p.

Perlov, A.S., S.A. Blokhin and M.K. Maminov. 2003. Abundance, distribution, and behavior of gray whales (*Eschrichtius robustus*) offshore northeastern Sakhalin in 2002: vessel-based observations. Unpublished contract report by TINRO Center, Vladivostok, Russia, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 28 pp. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Punt, A. E., and P. R. Wade. 2010. Population status of the eastern North Pacific stock of gray whales in 2009. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-207, 43 p.

Reeves, R.R. 1977. The problem of gray whale (*Eschrichtius robustus*) harassment at the breeding lagoons and during migration. Washington, D.C.: U.S. Marine Mammal Commission.

Reeves, R.R , and E. Mitchell. 1988. Current status of the gray whale, *Eschrichtius robustus*. Canadian Field Naturalist. 102(2): 369-390.

Reeves, R.R., D.K. Ljungblad and J.T. Clark. 1984. Bowhead whales and acoustic seismic surveys in the Beaufort Sea. Journal of Acoustic Society of America 62:271-280.

Rice, D.W. 1998. Marine mammals of the world: Systematics and distribution. Soc. Mar. Mam. Spec. Pub. 4. 231 p.

Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale. Spec. Publ. Am. Soc. Mammal. No. 3, 142 pp.

Richardson, W.J., B. Würsig and C.R. Greene. 1986. Reactions of Bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea J. Acoust. Soc. Am. 79:1117-1128.

Richardson, W.J., G.W. Miller and C.R. Greene. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. J. Acoust. Soc. Am. 106:2281.

Richardson, W.J., C.R. Greene, J.P. Hickie, R.A. Davis and D.H. Thompson. 1989. Effects of offshore petroleum operations on cold water marine mammals: a literature review, 2nd edition. API Publication 4485. American Petroleum Institute, Washington D.C. 385 pp.

Rugh, D.J., R.C. Hobbs, J.A. Lerczak and J.M. Breitwick. 2005. Estimates of abundance of the eastern North Pacific stock of gray whales (*Eschrichtius robustus*) 1997-2002. Journal of Cetacean Research and Management 7(1): 1-12, 2005.

Russian Federation Red Book (Animals). 2000. Ast and Astrel - Balashikha, Aginskoe, 862 pp. (in Russian).

Swartz, S.L., B.L. Taylor and D.J. Rugh. 2006. Gray whale *Eschrichtius robustus* population and stock identity. Mammal Rev. Vol. 36. N 1. pp. 66-84.

Sobolevsky, E.I. 1998. Observations of the behavior of gray whales (*Eschrichtius gibbosus* Erxl. 1777) on the Northeastern Sakhalin Shelf // Ekologiya, № 2. Pages 121-126.

Sobolevsky, E.I. 2000. Marine mammal studies offshore northeast Sakhalin, 1999. Final Report by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 149 p.

Sobolevsky, E.I. 2001. Marine Mammals Studies Offshore North East Sakhalin in 2000. Final report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia, 144 pp.

Stafford, K.M., S.E. Moore, M. Spillane and W. Wiggins. 2007. Gray whale calls recorded near Barrow, Alaska, throughout the Winter of 2003-04. Arctic 60(2): 167-172.

Stoker, S.W. 1981. Benthic invertebrate macrofauna of the eastern Bering/Chukchi continental shelf. In: Hood, D. W., Calder, J. A. (eds.) The eastern Bering Sea shelf: oceanography and resources, Vol. 2. Univ. Wash. Press, Seattle, p. 1069-1090.

Swartz S.L., Taylor, B.L. and D.J. Rugh. 2006. Gray whale *Eschrichtius robustus* population and stock identity. Mammal Rev. 36 (1): 66-84

Tyack, P.L. and C.W. Clark. 1998. Quick-look report: Playback of low-frequency sound to gray whales migrating past the central California coast. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Tyurneva, O. Yu., Yakovlev, Y.M., Tombach Wright, C. and Meier, S.K. 2007. The Western North Pacific Gray Whales of Sakhalin Island. Trafford Publishing, Victoria, B.C., Canada. 195pp.

Tyurneva, O.Yu., V. Vertyankin, V.V., Yakovlev, Yu. M. and Selin, N.I., 2010 a. The peculiarities of foraging migrations of the Korean–Okhotsk gray whale (*Eschrichtius robustus*) population in Russian waters of the Far Eastern seas. Russian Journal of Marine Biology, 2010, Vol. 36 N 2, p. 117-124.

[Тюрнева, О. Ю., Ю. М. Яковлев, В. В. Вертянкин, Н. И. Селин. 2010. Особенности нагульных миграций охотско-корейской популяции серого кита Eschrichtius robustus в Росийских водах дальневосточных морей. Биология моря. Том 36, № 2. С. 117-123.]

Tyurneva, O. Yu., Yakovlev,Yu.M., Vertyankin, V. V., Gailey, G., Sychenko, O. and Muir, J. E. 2010 b. Discovering a new feeding area for calf-cow pairs of western gray whales on the southeast shelf of Kamchatka in 2009 and their utilization of different feeding regions within one season. In the book of abstract "North Pacific Ecosystems Today, and Challenges in Understanding and Forecasting Change" International Conference PICES-2010 (North Pacific Marine Science Organization) October 22 – 31, 2010. Portland, OR, U.S.A. p. 184.

Tyurneva, O. Yu., Yakovlev, Yu. M., Vertyankin, V. V., Gailey, G., Sychenko, O. and Muir, J. E. 2010 c. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeast Sakhalin Island and southeast Kamchatka peninsula (Russia), 2009. The article SC/62/BRG submitted to the IWC 62 Scientific Committee Meeting, Agadir, Morocco, June 2010. 12 pp.

Tyurneva, O. Yu., Yakovlev, Yu. M., Vertyankin, V. V., Gailey, G., Sychenko, O. and Muir, J. E. 2010 d. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeast Sakhalin Island and southeast Kamchatka peninsula (Russia), 2009. The article SC/62/BRG submitted to the IWC 62 Scientific Committee Meeting , Agadir, Morocco, June 2010. 12 pp.

Vertyankin, V.V., V.C. Nikulin, A.M. Bednykh and A.P. Kononov. 2004. Sighting of gray whales (*Eschrichtius robustus*) near southern Kamchatka. In the book: Marine Mammals in the Holarctic. Collection of scientific papers of International Conference Koktebel, Krimea, Ukraine, October 11-17, 2004. P. 126-128.

Vertyankin V.V., Vladimirov V.A., Tyurneva O.Yu., Yakovlev Y.M., Andreev A.V., Burkanov V.N., 2007. Sightings of Gray whales (Eschrichtius robustus) offshore Eastern Kamchatka and in the northern Sea of Okhotsk, 2006 In: Int'1 Whaling Com., 59_{th} meeting, doc. SC/59/WP6 – 8 pp.

Vladimirov V.L. 1994. The current distribution and abundance of whales in the Far East seas. Biol. Morya (Vladivostok), 1994, vol. 20, no. 1, pp. 3–13.

Vladimirov, V.A. 2000. Problems in Conservation of Endangered Bowhead and Gray Whale Populations in the Sea of Okhotsk. In: Marine Mammals of the Holarctics. Archangelsk, pp. 82-86 (in Rus.)

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, V.L. Vladimirov, N.V. Doroshenko, and M.K. Maminov. 2005. Distribution and Abundance of Gray Whales of the Okhotsk-Korean Population in the Northeastern Sakhalin Waters in July-September 2004 (based on shore, aerial and vessel-based surveys). Final Report by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, to Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 136 pp. + Apps. Available at http://www.sakhalinenergy.com

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, M.K. Maminov, S.P. Starodymov, and E.P. Shvetsov. 2006. Distribution and abundance of gray whales of the Okhotsk-Korean population off northeastern Sakhalin, June–November 2005 (based on data from onshore, aerial and vessel-based surveys). Report by the All-Russian Research Institute for Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Center for Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, to Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 189 pp. Available at http://www.sakhalinenergy.com

Vladimirov, V.A, S.P. Starodymov, A.T. Ashchepkov, A.G. Afanasyev-Grigoryev, J.E. Muir, and A.V. Vladimirov. 2007. Distribution and Abundance of Gray Whales of the Okhotsk-Korean Population in the waters of Northeastern Sakhalin in June-October 2006 (based on shore, aerial and vessel-based surveys). Report by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, to Exxon Neftegas Limited and Sakhalin

Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 81 pp. + Apps. Available at http://www.sakhalinenergy.com/en/library.asp?p=lib_environment_shelf&l=lib_environment_greywhales

Vladimirov, V.A., S.P. Starodymov, A.G. Afanasyev-Grigoriyv, and J.E. Muir. 2008a. Distribution and abundance of Korean stock gray whales in the waters of northeastern Sakhalin Island during June – October 2007 (based in data from onshore and vessel based surveys). Final report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia.

Vladimirov, V.A., S.P. Starodymov, A.G. Afanasyev-Grigoryev, J.E. Muir, O.Yu. Tyurneva, Y.M. Yakovlev, V.I. Fadeev, V.V. Vertyankin, 2008b. Distribution and abundance of Western Gray whales off the northeast coast of Sakhalin Island (Russia), 2007 // Int'1 Whaling Com., 60th meeting, doc. SC/60/BRG9 – 9 pp.

Vladimirov, V.A., S.P. Starodymov, A.G. Afanasyev-Grigoriyv, and J.E. Muir. 2009. Distribution and abundance of Korean stock gray whales in the waters of northeastern Sakhalin Island during July – October 2008 (based on data from onshore and vessel based surveys). Final report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia.

Vladimirov, V.A., S.P. Starodymov, M.S. Kornienko, and J.E. Muir. 2010. Distribution and abundance of Okhotsk-Korean (western) gray whales in the waters off northeast Sakhalin Island during June – September 2009 (based on data from onshore and vessel-based surveys). Chapter 1 *In*: Western Gray Whale Research and Monitoring Program in 2009, Sakhalin Island, Russia. Volume II Results and Discussion. Final report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia.

Weller, D., B. Würsig, A. Bradford, A. Burdin, S. Blokhin, H. Minakuchi, and R.L Brownell (Jr.). 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia: seasonal and annual patterns of occurrence. Marine Mammal Science 15: 1208-1227.

Weller, D., B. Würsig, A. Burdin, S. Reeve and A. Bradford. 2000. Gray whales summering off Sakhalin Island, Far East Russia: June-October 1999. A joint U.S.-Russian scientific investigation. Report by Texas A&M University, College Station, TX and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, 69 pp.

Weller, D.W., B.G. Würsig, and A.M. Burdin. 2001. Gray whales off Sakhalin Island, Russia: June-September 2000. A joint U.S.-Russian scientific investigation. Interim Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Petropavlosk-Kamchatkii, Russia, for Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 24 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, G.A. Tsidulko, Y.V. Ivashchenko, and R.L. Brownell Jr. 2002a. Gray whales off Sakhalin Island, Russia: June-September 2001. A joint US-Russia scientific investigation. Final contract report prepared by Texas A&M University, Kamchatka Institute of Ecology and Nature Management, and National Marine Fisheries Service, for Sakhalin Energy Investment Company. 75 pp.

Weller, D.W., A.M. Burdin, B. Würsig, B.L. Taylor, and R.L. Brownell, Jr. 2002b. The western gray whale: A review of past exploitation, current status and potential threats. J. Cetacean Res. Manage. 4:7-12.

Weller, D.W., A.L. Bradford, A.M. Burdin, T. Miyashita, T. Kariya, A.M. Trukhin, S.A. MacLean, V.A. Vladimirov and N.V. Doroshenko. 2002c. Photographic recaptures of western gray whales in the Sea of Okhotsk. In: Int'1 Whaling Com., 54th meeting, doc. SC/54/BRG13 - 5 pp.

Weller, D.W., A.M. Burdin, A.L. Bradford, G.A. Tsidulko, Y.V. Ivashchenko and R.L. Brownell Jr. 2003. Gray whales off Sakhalin Island, Russia: June-September 2001. A joint U.S.-Russian scientific investigation. Unpublished contract report by Texas A&M University, College Station, TX, Kamchatka Institute of Ecology and Nature Management, RAS, Petropavlovsk-Kamchatskii, Russia, and National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, USA for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 75 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, Y.V. Ivashchenko, G.A. Tsidulko, A.R. Lang and R.L. Brownell Jr. 2004. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2003. Report to the International Whaling Commission. SC/56/BRG40.

Weller, D.W., A.L. Bradford, H. Kato, T. Bando, S. Ohtani, A.M. Burdin, R.L. Brownell, Jr. 2008. Photographic match of a western gray whale between Sakhalin Island, Russia and Honshu, Japan: First link between feeding ground and migratory corridor. Journal of Cetacean Research and Management 10: 89-91.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L Bradford, S.A. Blokhin, and R.L Brownell, Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Final Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited and Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia. 101 p.

Würsig, B., D.W.Weller, A.M.Burdin, S.Y.Reeve, A.L.Bradford, S.A.Blokhin and R.L.Brownell, Jr. 2000. Gray Whales summering off Sakhalin Island, Far East Russia: June-September 1998. A Joint US-Russia scientific investigation. Report by Texas A&M University and the Kamchatka Institute of Ecology and Nature Management for Sakhalin Energy Investment Company and Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia - 133 pp. [available on the Sakhalin Energy Investment Company website]

Yablokov, A.V., and L.S. Bogoslovskaya. 1984. A review of Russian research on the biology and commercial whaling of the gray whale. Pages 465-485 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The gray whale *Eschrichtius robustus*, Academic Press, Orlando, FL.

Yakovlev, Y.M., O.Y. Tyurneva and V.V. Vertyankin. 2007. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island and southeastern Kamchatka, Russia, 2006. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 99 стр. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yakovlev, Y.M. and O.Y. Tyurneva. 2008. Photographic identification of the Korean- Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island, 2007. Report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk,Russia.126p.[available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yakovlev, Y. Tyurneva, O., and Vertyankin, V. 2009. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island and southeastern shore of Kamchatka peninsula, 2008. Final report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia.

Yakovlev, Y. Tyurneva, O., and Vertyankin, V. 2010. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island and southeastern shore of Kamchatka peninsula, 2009 results and discussion. Chapter 2 *In*: Western Gray Whale Research and Monitoring Program in 2009, Sakhalin Island, Russia. Volume II Results and Discussion. Final report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia.

Yazvenko, S., T. MacDonald, S.K. Meier, S. Blokhin, S.R. Johnson, V. Vladimirov, S. Lagerev, M. Maminov, E. Razlivalov and M. Newcomer. 2002. Aerial marine mammal monitoring during the 2001 3-d seismic survey of Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia. Report by LGL Limited environmental research associates, Sidney, BC, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia. 163 pp.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. Environ. Monit. Ass.. 134: 45-73. doi: 10.1007/s10661-007-9809-9.

Yazvenko, S.B., McDonald, T. L., Blokhin, S. A., Johnson, S.R., Melton, H. R., Newcomer, M. W., R. Nielson and P. W. Wainwright. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. Environmental Monitoring and Assessment. 134: 93-106. doi: 10.1007/s10661-007-9810-3.

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_____ 2010

CHAPTER 2

WESTERN GRAY WHALE DISTRIBUTION SURVEYS (VESSEL-BASED AND ONSHORE): INTRODUCTION AND METHODS[1]

by
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CHAPTER 2: DISTRIBUTION

2.1 INTRODUCTION

The main objective of the distribution surveys is to study and monitor spatial and temporal variation in western gray whale (WGW) distribution and relative abundance[3] patterns in the coastal waters of northeastern Sakhalin in order to understand the natural variation in the feeding habitat usage by these animals. The distribution and relative abundance information additionally serves as an indicator of the WGW population status and provides insight into the condition of the summer-fall feeding habitat. Data are also collected on the distribution and abundance of other marine mammal species that are observed during the surveys.

Two types of distribution surveys are conducted: vessel-based and shore-based. Vessel-based surveys cover both the Piltun and Offshore feeding areas, and the offshore license areas for the Sakhalin-1 (Arkutun-Dagi field) and Sakhalin 2 projects (Piltun-Astokh field). Shore-based surveys are performed from the Sakhalin Island northeastern coast, and provide daily sampling, weather permitting, of most of the Piltun feeding area. During 2001–2005, aerial surveys were flown in the Piltun and Offshore feeding areas to monitor the abundance and distribution of gray whales. However, these surveys were cancelled after the 2005 field season due to their limited value in providing the systematic data needed for the distribution studies, low cost-efficiency and increased safety risk. Past aerial survey data are included in the density analyses, but are not further discussed in this report. Details of the aerial surveys may be found in Yazvenko et al. 2002, Blokhin et al. 2002, 2003, 2004, and Vladimirov et al. 2005, 2006.

Line transect vessel-based surveys have been conducted in the Piltun and Offshore feeding areas since 2002. The Arkutun-Dagi license area was added to the surveys in 2006; the coastal area from the south end of Piltun feeding area to Nyiskiy Bay in 2007; and the Piltun-Astokh license area in 2009. The main objectives of the vessel-based surveys are:

- monitoring the presence of and estimating the relative abundance of WGWs that are using the Offshore feeding area;
- gathering data on intra- and interseasonal variability in usage of the Offshore feeding area by the whales;

[3] Relative abundance is an index of the true abundance of WGWs. A relative abundance provides a relatively constant, but unknown relationship to the true abundance (Krebs 1994, p 159)

- monitoring the presence of and estimating relative abundance of WGWs in the waters of the Arkutun-Dagi license area, where oil and gas development is scheduled for the Sakhalin-1 Project in the near future;

- monitoring the presence of and estimating the relative abundance of WGWs in the waters of the Sakhalin 2 Piltun-Astokh license area;

- surveying the nearshore Piltun area from Urkt Bay in the north to Nyiskii Bay in the south to monitor the presence and estimate relative abundance of WGWs in deeper water portions and areas outside the visibility range of the shore-based observers in the Piltun feeding area. This includes the nearshore Piltun area from Chaivo to Nyiski Bay, i.e., south from the most southern onshore station, and from Odoptu to Okha, i.e., north from the most northern onshore station.

Point transect shore-based surveys have been performed in the Piltun feeding area since 2004. The main objectives of these shore-based surveys are:

- gathering detailed data on the spatial and temporal distribution of WGWs during the feeding season in the nearshore waters of the Piltun Feeding area from Odoptu Bay in the north to Chayvo Bay in the south;

- gathering data on intra- and interseasonal variability in whale distribution in the Piltun feeding area;

- estimating (based on the collected data) the relative abundance of WGWs that are using the Piltun area during the feeding season, the number of cow-calf pairs and also the approximate time period over which cow-calf pairs separate and calves transition to independent feeding.

All surveys were conducted following systematic protocols that were designed to reduce biases in the estimation of relative gray whale abundance, and to ensure minimal disturbance of marine mammals.

2.2 STUDY AREA

Please refer to Chapter 1 section 1.2.3 in this volume for a detailed description of the northeast Sakhalin shelf study area, and the Piltun and Offshore WGW feeding areas.

2.2.1 Vessel-Based Surveys

As described above, there are currently four different areas in which systematic vessel based distribution surveys are conducted (Figure 1). These are summarized below.

Piltun

Surveys in the nearshore Piltun area were conducted on a single transect parallel to and at a distance of 4.0 km from the Sakhalin shoreline. The density of whales decreases at this distance from shore, and consequently, the potential for disturbance of the whales is reduced. The Piltun survey transect is 180

km in length and extends in a southerly direction to Nyisky Bay (52°01′30′′ N), and in a northerly direction to Urkt Bay (53°36′ N) to monitor for the presence of whales north and south of the area covered by the onshore-based teams.

Offshore

The Offshore area surveys were conducted on eight transects oriented east to west that were 6.5 km apart. The survey area was bounded to the south and north by latitudes 51°50′ - 52°14′ N, and to the west and east by longitudes 143°30′ and 143°50′ E.

Arkutun-Dagi

Surveys in the Arkutun-Dagi license area were performed on seven transects running east to west, which were bounded to the south and north by latitudes 52°18′ - 52°39′ N, and to the west and east by longitudes 143°30′ and 143°55′ E.

Piltun-Astokh

Surveys in the Piltun-Astokh license area were performed on seven transects running east to west, which were bounded to the south and north by latitudes 52°39′ - 53°00′ N, and to the west and east by longitudes 143°22′ and 143°45′ E.

2.2.2 Shore-Based Surveys

The Sakhalin Island shoreline adjacent to the Piltun feeding area is partitioned into two parts by a natural channel connecting Piltun Bay to the sea. This channel is impassable by vehicles and the survey area was therefore divided into two parts – the Odoptu-Piltun (north) section, covering the waters north of the mouth of Piltun Bay, and the Astokh-Chayvo (south) section, occupying the near-shore waters south of the mouth of Piltun Bay. Two survey teams conducted the shore-based surveys; the north team performed surveys in the Odoptu-Piltun section, while the south team monitored the Astokh-Chayvo section.

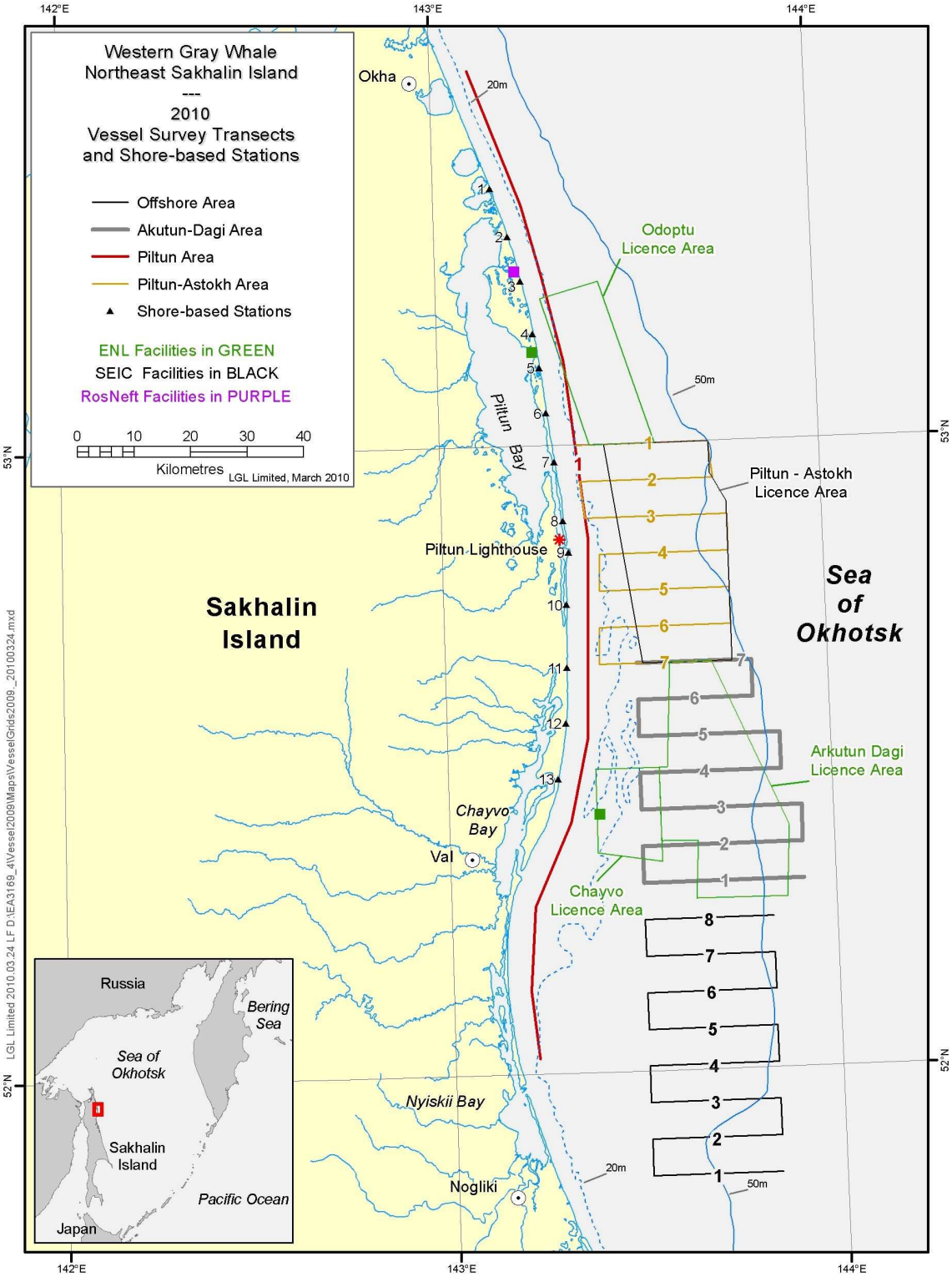

Figure 1 Systematic vessel-based gray whale survey transects in the Piltun and Offshore feeding areas, and in the Arkutun-Dagi and Piltun-Astokh license areas. The locations of the thirteen shore-based survey stations are also shown.

The surveys were performed from 13 permanent stations that have been used since 2004 (Figure 1). The survey route in the northern section was approximately 70 km long, with eight stations, and the southern section was approximately 40 km long with five stations. The stations were situated in elevated areas of the coast, and separated by approximately 8-10 km to reduce the probability of recounting the same whales in areas between neighboring stations. The distances between stations varied because selection of the station locations was constrained by the terrain relief (the highest points on shore with the best view of the offshore waters were chosen). Due to strong erosive forces along the coast, exact station locations and station heights can change from year to year. Consequently, station heights were measured in most years by a geodesic survey team. Details of the station height measurement protocols are described below in section 2.4. Measurements were conducted in 2004 when the shore-based distribution stations were first established, in 2005 at station 13 that replaced a station destroyed by fall storms, in 2006 at 4 stations (8, 9, 10 and 13) that were moved due to erosion from winter storms, in 2008 at the northern eight stations, and in 2009 at all thirteen stations. Table 1 provides geographic coordinates and other characteristics for all 13 stations measured in 2010.

Table 1 Location of Onshore Monitoring Stations in 2009 and their characteristics.

Site	Station number	Latitude (N)	Longitude (E)	Elevation above sea level (*m*)	Observation height[1](*m*)	Distance between Stations (*km*)	
Odoptu-Piltun section	1	53.41249	143.15274	10.1	11.9	1-2	9.08
	2	53.33517	143.19597	16.5	18.3	2-3	8.25
	3	53.26345	143.22717	28.0	29.8	3-4	9.53
	4	53.17961	143.25584	12.2	14.0	4-5	6.15
	5	53.12498	143.27012	7.2	9.0	5-6	8.12
	6	53.05245	143.28461	7.3	9.1	6-7	8.77
	7	52.97434	143.30208	6.2	8.0	7-8	10.03
	8	52.88049	143.31970	3.3	5.1	8-9	5.7
Astokh-Chayvo section	9	52,83012	143.33297	4.4	6.2	9-10	9,3
	10	52.74660	143.32285	5.2	7.0	10-11	11,2
	11	52.64637	143.31812	7.0	8.8	11-12	9.8
	12	52.55821	143.31059	9.0	10.8	12-13	9.6
	13	52.47003	143.28668	7.3	9.1		

Notes:
[1]*observation height is the actual eye height from which the observations are made. It is calculated as the measured station height above sea level plus the observer's eye height from the ground (assumed to be 1.8 m)*

2.3 FIELD PROTOCOLS

2.3.1 Vessel Surveys

Two types of marine mammal monitoring surveys were conducted from the vessel: opportunistic and systematic. All observations were made from the bridge, which has an elevation of 8.25 m above sea level. The observer eye height was assumed to be 1.65 m, which resulted in an effective observation height of 10 m. Surveys were conducted by alternating scans by eye and binoculars (Fujinon 7x50 FMTRC-SX 7°30' binoculars with reticle scale and built-in compass) that were each about two minutes long. The observers used the binoculars when a marine mammal sighting was made to determine the species, evaluate their behavior, and estimate the number of animals in the group.

The ship's GPS system was used to determine the exact position of the vessel during the surveys, and the ship's gyrocompass was used to determine the true bearing to a marine mammal sighting. The clock face bearing to a sighting was also recorded in order to be backwards compatible with 2002-2005 surveys. The distance to a sighting was recorded based on the binocular reticle scale. The MMO adjusted the position of the binoculars so that the top reticle line appeared to rest on the horizon when looking out to sea. The MMO lined up the top reticle on the shoreline when looking west from the Piltun feeding area transect. The MMO then counted the reticle lines starting at the top and going down to the location of the marine mammal. Occasionally when the marine mammal was sighted within 500 m of the vessel, the distance was estimated by eye.

For each marine mammal sighting, the date and time, the species, the numbers of animals, the behaviour, direction of movement, activity pattern (e.g., swimming, diving, breaching, fluking, feeding, playing), the distance from the vessel, and azimuth to the marine mammal, the position and heading of the vessel, and the weather and visibility were recorded immediately on a datasheet. The datasheets were entered into a computer database at the end of each working day.

Opportunistic surveys

The primary objective of the opportunistic surveys was to record marine mammal sightings while the vessel was in transit or conducting other research activities, and to advise on measures to be taken to avoid any potential impact between the vessel and marine mammals in the area. During the opportunistic surveys, observers monitored for the presence of marine mammals from the bridge each day during daylight conditions (weather permitting). These surveys were mainly conducted by one observer, with a second observer present if the sole MMO on watch determined that additional

assistance was needed when, for example, passing through large groups of marine mammals such as Northern Fur Seals near Cape Terpenya.

Systematic surveys

Two MMOs were on watch at all times. Each MMO was responsible for scanning one half of the survey area and to ten degrees on the other side of the vessel trackline. Thus each MMO scanned out to the horizon through an arc of 100 degrees from abeam the vessel to 10 degrees past the vessel trackline.

Systematic surveys were performed at a vessel speed of 10 knots on the Piltun transect and 11 knots in the other survey areas, and conducted only in conditions of good visibility (at least 1.5 km along the transect line or 50% of the horizon was visible) and smooth seas (not more than sea state three on the Beaufort scale).

Because some of the systematic vessel-based surveys take place in or in close proximity to known WGW feeding areas, specific procedures have been developed to minimize any potential impact with gray whales and other marine mammals.

2.3.2 Shore-Based Surveys

Shore-based surveys of WGWs (and other marine mammals) were performed by two survey teams – north and south – at the designated observation stations for each team on coordinated routes run concurrently.

Due to the poor condition of the roads in the study area (and sometimes the lack of roads), all-terrain vehicles were used to perform the shore-based surveys, i.e., 4WD Toyota Land Cruisers 100. The use of vehicles allowed the groups to efficiently move along the shoreline from one survey section to another, which substantially reduced the time interval between surveys from adjacent stations and therefore minimized double counting of WGWs due to their movements along the coast.

Coordination of survey efforts between the northern and southern shore-based teams was conducted as follows. The two team leads called each other in the morning to discuss weather conditions and to decide if the survey could be conducted. The north team started the survey from the northernmost station (station 1) and moved to the southernmost station (station 8). A full survey, covering all 8 stations along the 70 km route requires about 7 hours. The southern team worked the route from south to north, i.e., from station 13 to station 9. The 40 km full survey route of the south team took about 5 hours to complete.

The work of both teams was coordinated by radio so that the survey time at the neighboring stations on each side of the Piltun Bay mouth (stations 8 and 9) was synchronized so that both teams began surveys at these stations at precisely the same time.

On days when the team leads made a decision that a full survey could not be started in the morning due to unfavorable weather conditions or sea state, but where conditions later improved during the day so that a partial survey (one or more stations) could be conducted, the following partial survey protocol was used:

- Both teams made a decision independently of the other team about carrying out a partial survey, and which stations to survey.
- There was no need for the teams to synchronize their partial surveys at stations 8 and 9.
- The number of stations to be surveyed was determined by the available time remaining in the day, which ensured that the team could return safely to the base camp.
- Consecutive stations were selected.
- Stations were selected so that survey effort throughout the season was balanced, i.e., stations that had been sampled less often were given priority for the partial survey.
- The selected stations could be surveyed in whatever order (i.e., north to south, or south to north) that seemed the most efficient to the survey team, provided the stations were surveyed consecutively.

The shore-based whale surveys were conducted using a continuous scan of the nearshore waters surrounding an observation station. Scans were conducted at a constant rate of 10 degrees per minutes. The surveys were performed during daylight hours, using Fujinon 7x50 binoculars, with a 7°30' field of view, a built-in compass and range finding reticles. Surveys were not performed or were terminated under the following conditions:

- wave conditions rated at sea state 4 or higher on the Beaufort scale;
- wind speed of 10 m/sec or higher;
- heavy precipitation (rain, hail, snow);
- fog;
- other environmental conditions (or their combination) that reduced the visibility and prevented observers from detecting whales beyond 2 km from the survey station;

All the surveys were performed according to the following protocol:

- the direction in which the scans were conducted (i.e., from north to south or south to north) matched the direction in which the surveys were conducted, thereby minimizing the time interval between scans of areas between adjacent stations;
- all team members participated in the surveys – two continuously scanned the survey area through binoculars, while the third recorded whale sightings. The team members rotated roles from station to station so that each team member acted as both an observer and a data recorder throughout a survey;
- scans were performed from a standing position, using a rest for the binoculars, at a constant rate of 10° per minute;
- all marine mammal sightings, as well as all vessels, were recorded;
- the distances and bearings to the marine mammals sighted and to other targets (e.g. vessels) were determined according to readings of the built-in compass and reticle scale of the binoculars;
- for each marine mammal sighting, the time of the sighting, the species, the number of animals, cow-calf pairs, the direction of movement of the animals, behaviors, the bearing to the sighting, the reticle scale distance and the initials of the first MMO to observe the sighting were recorded;
- environmental conditions and the scan start and end time were also recorded;
- important details not included in the record columns were entered as notes.

Upon completion of each survey, all data recorded on the datasheets were transferred to an electronic database (Microsoft Excel worksheets) later that day. The electronic database was sent to LGL Sakhalin who prepared daily dot maps of WGW sightings.

2.4 STATION HEIGHT MEASUREMENT

The height of the shore-based observation stations was measured using the modified altitude calculation method that was developed by Bailey and Lusseau (2004). First, two points (A and B) were selected at the water line near the station (Figure 2 "Top-Down View") and the distance (d) between them was measured. A theodolite placed at the station location was then used to measure the vertical angles to the points A and B (Figure 2, "Side View" α and β, respectively) and the horizontal angle between the points (Figure 2 "Top-Down View" γ). The height of the theodolite's eyepiece from the water level (h_t) was calculated using the following formula:

$$h_t = \frac{d}{\sqrt{\left(\frac{1}{\cos^2\alpha}\right)+\left(\frac{1}{\cos^2\beta}\right)-\left(\frac{2\cos\gamma}{\cos\alpha\cos\beta}\right)}}$$

The station height was then calculated as $h = h_t - h_{eye} + h_{tide}$, where:

h_{eye} is the height of the theodolite's eyepiece from the ground, and

h_{tide}.is the tide height at the time of the measurement.

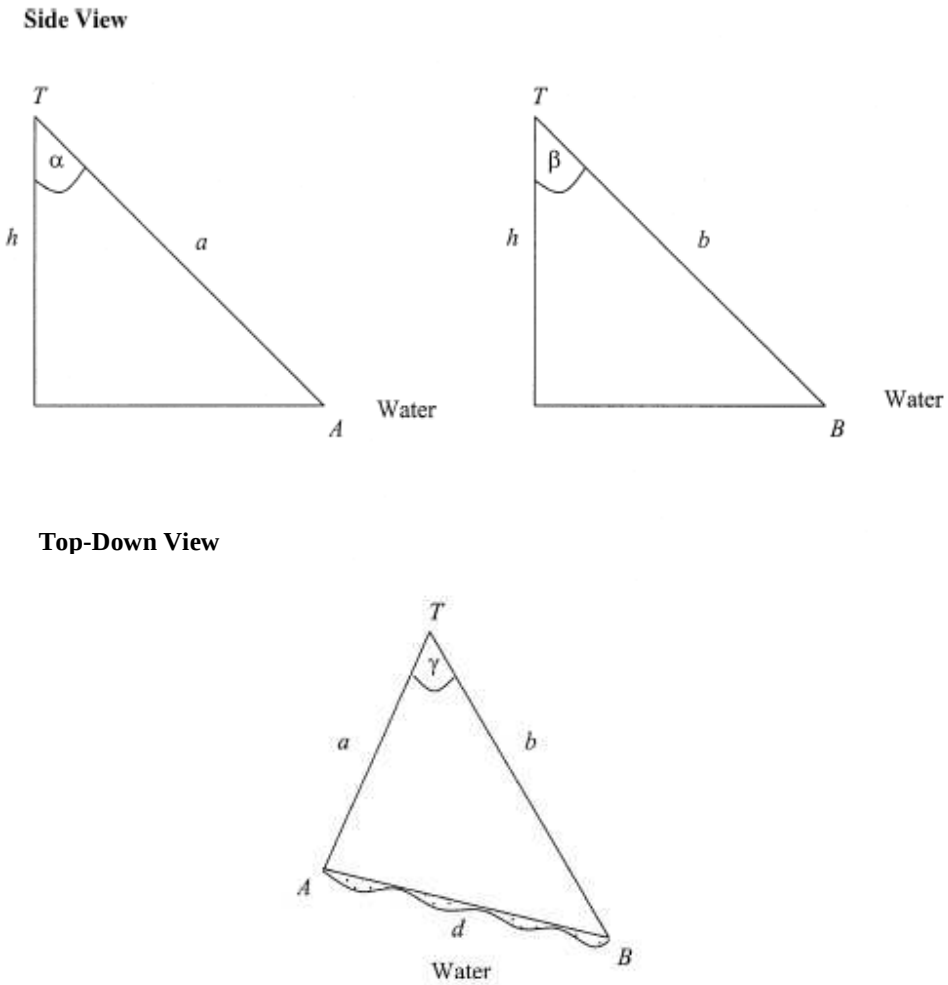

Figure 2 Schematic for determining theodolite altitude (T is the position of the theodolite).

2.5 DATA ANALYSIS AND MAPPING

Calculation of WGW sighting locations and data summaries of the systematic surveys were performed using Microsoft Excel. The current database contains data from all available systematic aerial, vessel and shore-based distribution surveys and is expanded each year with the new data collected. Information on

WGW relative abundance and distribution is obtained by estimating WGW densities using the method outlined in the section Density Analysis below. Calculation of WGW densities made it possible to combine data collected from different observer platforms. All WGW density maps were produced using the geographic information system ArcGIS v 10.0 (ESRI 2010).

2.5.1 Calculating Whale Coordinates, Sighting Depths and Sighting Distances from Shore for Vessel and Shore-Based Surveys

During the vessel-based and shore-based surveys, the distance to the whales was determined from the reticle scale of the binoculars. The bearing was ascertained from the built-in compass (shore-based surveys) or the ship's gyroscopic compass (vessel surveys).

When a whale or blow was sighted with the binoculars, divisions on the reticle scale were counted as described above in the Field Protocols section. The number of divisions recorded for each sighting was then converted to distance. Prior to 2008, the distance was determined solely using the methods developed by Lerczak and Hobbs (1998), using the following formulas:

When the reticles were lined up with the real or imaginary horizon:

$$\alpha = \arctan\left(\frac{\sqrt{2hR_E + h^2}}{R_E}\right) \cong \frac{\sqrt{2hR_E + h^2}}{R_E}$$

$$\beta = \frac{\pi}{2} - \alpha - \theta$$

$$H = \alpha R_E \cong \sqrt{2hR_E}$$

$$D_0 = (R_E + h)\cos\beta - \sqrt{(R_E + h)^2 \cos^2\beta - \left(2hR_E + h^2\right)}$$

$$\delta = \arcsin\left(\sin\beta \frac{D_0}{R_E}\right) \cong \sin\beta \frac{D_0}{R_E}$$

$$D = \delta R_E \cong \sqrt{D_0^2 = h^2}$$

where:

α - the angle between a horizontal line (90°) and the horizon;

β - the angle between the Observer and the target;

δ - the arc between the Observer and the target;

θ - the angle between the horizon and the target object;

h - the elevation of the Observer; A correction for sea level depending on the high or low tidal phase was included in the elevation for shore-based sightings.

R_E - = radius of the Earth $\left(6.371\times10^6 \text{ м}\right)$;

D_0 - straight-line distance to the object;

D - the distance between the Observer and the target on the Earth's surface;

When the reticles were lined up with the shoreline:

$$\gamma = \frac{L}{R_E}$$

$$L_0 = \sqrt{R_E^2 + \left(R_E + h\right)^2 - 2R_E\left(R_E + h\right)}$$

$$\beta = \arccos\left(\frac{2hR_E + h^2 + L_0^2}{2\left(R_E + h\right)L_0}\right) - \theta$$

$$D_0 = (R_E + h)\cos\beta - \sqrt{\left(R_E + h\right)^2 \cos^2\beta - \left(2hR_E + h^2\right)}$$

$$\delta = \arcsin\left(\sin\beta\frac{D_0}{R_E}\right) \cong \sin\beta\frac{D_0}{R_E}$$

$$D = \delta R_E \cong \sqrt{D_0^2 = h^2}$$

where:

γ- the arc between the shoreline and the Observer;

L – the distance to the shoreline along the Earth's surface;

L0 – the line-of-sight distance to the shoreline

β *- the angle between the Observer and the target;*

δ *- the arc between the Observer and the target;*

θ *- the angle between the horizon and the target object;*

h - the elevation of the Observer; A correction for sea level depending on the high or low tidal phase was included in the elevation for shore-based sightings.

R_E *- = radius of the Earth* $\left(6.371\times10^6 \text{ м}\right)$*;*

The accuracy of the distance estimates was increased by correcting the estimated values to account for the effects of light refraction following a procedure developed by Leaper and Gordon (2001). Because the Lerczak and Hobbs (1998) approach assumes that light travels in straight lines, it does not account for the bending of these lines due to refraction by the atmosphere. As a result, the perceived angles between the observer and the target (β) and between the target and the horizon (θ) are decreased, which results in underestimation of the distance from the observer to the target. Leaper and Gordon (2001) adjust for refraction via an expression that takes into account air temperature, air pressure and the vertical gradient in air temperature between the target and the observer to calculate the 'radius of curvature' (*r*) of the refracted ray. As air temperature and pressure were not measured prior to 2008, representative default values of 20ºC and 1000 millibar respectively were used for the purpose of estimating the refraction correction and updating the distance estimates for those years. Since 2008, air temperature and pressure have been measured directly and these measurements have been used in the refraction correction calculations. The refraction corrected angles (α_c, θ_c) for the distance calculation formulas shown above were calculated as (Kinzey and Gerrodette 2003):

$$\alpha_c = \arctan\sqrt{2h\left(\frac{1}{R_E} - \frac{1}{r}\right)}, \text{ and}$$

$$\theta_c \approx \theta + \frac{D}{2r}$$

Because the true distance (*D*) to the target in this equation was unknown, it was initially approximated using the uncorrected (for refraction) distance (D_a) to calculate θ_c, then substituting θ_c for θ to calculate a new D_a and iteratively repeating this process until D_a converged to the corrected value D_c.

Next, given the estimated distance to the whales or pods and the bearing to the animals from an observer with known coordinates and elevation, the coordinates of each whale sighting were calculated as outlined in Yermolayev and Zoteyev (1988) with minor adjustments as described below.

$$\varphi_2 = \varphi_1 + \cos K \times S/(1853 \times 60)$$
$$\lambda_2 = \lambda_1 + \sin K \times \sec\varphi_{cp} \times S/(1853 \times 60)$$

where Φ_2 and λ_2 - latitude and longitude coordinates of the animal's location, respectively (in decimal degrees)

ϕ_1 and λ_1 - latitude and longitude coordinates, respectively, of the observer's location (in decimal degrees)

K - bearing to the animal (in degrees);

S - distance to the animals (in meters);

ϕ_{cp} - average latitude, computed by the formula below:

$$\varphi_{cp} = \frac{\varphi_1 + \varphi_2}{2}$$

The depth and distance to shore for each gray whale sighting was determined using ArcGIS v10.0 (ESRI 2010). Each calculated sighting location was overlaid in the GIS with 1 m bathymetry to determine each sighting's depth. The ArcGIS Near tool was used to measure the perpendicular distance to shore from each whale sighting location.

2.6 DENSITY ANALYSIS

Western gray whale abundance and distribution data collected from the vessel-based and shore-based systematic surveys have been analyzed to produce estimates of whale densities at a 1 km^2 resolution. The density analysis methods were developed by LGL Limited in consultation with Trent McDonald, a statistician with WEST Inc., and the University of St. Andrews, developers of the Distance Sampling software (Thomas *et al.* 2006). The study area was divided into a grid of 1.0 x 1.0 km cells, with a WGW density (WGW/ km^2) estimated for each cell that was sampled during each survey from a vessel transect or shore station. The density estimates from each survey within each grid cell can then be averaged over selected time periods. Average density estimates correct for the possible double counting of WGWs from different vessel transects or shore stations by incorporating each survey's effort (area of the grid cell that was surveyed) into the calculation of the average WGW density estimate for that grid cell.

Gray whale sightings from systematic vessel-based and shore-based surveys were corrected for two types of visibility bias that typically result in an underestimation of animal abundance (Marsh and Sinclair 1989):

1. Availability bias: This is the probability that WGWs were available to be seen on the surface of the water during a particular survey based on the amount of time an area of water is observed during a survey (dependent on the size of the area in view, and vessel survey speed or binocular scanning rate at shore-based stations), and WGW surface-respiration-dive cycle behavior (Würsig *et al.* 2002, 2003; Gailey *et al.* 2004, 2005, 2006, 2007, 2008, 2009, 2010).

2. Perception bias: This is the probability that an observer perceives an available WGW. Distance sampling methodology (Buckland *et al.* 2001; Buckland *et al.* 2004) was used to analyze the effects of distance and other factors (e.g. sea state and WGW group size) on the probability of detecting an available gray whale.

Vessel surveys

Program Distance v5.0 (Thomas *et al.* 2006) was used to model a detection function for the vessel-based surveys that provided an estimate of detection probability for perpendicular distances of gray whale sightings made from a transect. The detection probability was then used in the calculation of WGW densities as described below. The systematic vessel sightings offshore of the Piltun survey line and in the other survey areas were truncated at a perpendicular distance from a transect line that corresponded to a detection probability of approximately 0.10 (Buckland *et al.* 2001). The detection function used to correct vessel survey observations toward the shore (i.e., to the west) from the Piltun transect was truncated at a shorter distance that was determined by visual inspection of these sightings because the detection by vessel-based surveyors of WGW in shallow waters sharply decreased in this area due to difficulties in detecting whale blows against the light coloured shore background, and the fact that whale blows are typically smaller in shallower waters. Accordingly, no WGW estimates for the nearshore area were made based on vessel survey data. The perpendicular truncation distance from a transect was used to delineate the effort (i.e., the area surveyed) from that transect.

Gray whale sightings made during systematic vessel surveys were excluded from the density estimates under the following conditions:

- Sightings were beyond the truncation distance from a transect.
- Sightings were made when the vessel was “off effort” on the connectors between east-west transects in the Offshore, Arkutun-Dagi and Piltun-Astokh survey areas.
- Sightings were made while “on effort”, but were located beyond the end of a transect line. The locations and group sizes of these sightings may be shown on the density maps for informational purposes.

Shore-based surveys

The shore-based detection function was assumed to be flat (i.e. the detection probability did not decrease with increasing distance from the observation station) for up to a maximum of 8 km radial distance. This detection function was based on an analysis conducted by the University of St. Andrews (Rexstad and Borchers 2007). The model they fitted included both shore-based and ship-based sightings in a joint analysis to estimate parameters of a shore-based detection function. An important assumption of their analysis was that the detectability of whales from the ship did not depend on distance from shore. In addition, the effects on the shore-based detection function of variables other than distance were not considered.

The binoculars' 0.1 reticle mark was used as a truncation distance for the shore-based detection function because there is substantial error in estimating the distance to whale sightings recorded beyond this distance (i.e., there is a long distance from the 0.1 reticle mark to the horizon), and associated uncertainty in assigning these sightings to specific grid cells. The actual distance corresponding to the 0.1 reticle mark depends on the height of the shore station with respect to sea level at the time of the observation. The predicted tide height at the time of a survey at each shore station was used to adjust the station height when the 0.1 reticle distance was calculated. The 0.1 reticle distance ranged from approximately 3.2 km to 12.8 km (Table 2). At stations that were high enough for the 0.1 reticle distance to exceed 8 km (stations 2 and 3), the actual values were shortened to equal the maximum distance of 8 km that was determined for the shore-based flat detection function (see above).

Table 2 Vehicle scan survey shore stations truncation distance. Gray whale sightings beyond the indicated truncation distance for a shore station and tide height are excluded from the WGW density analysis. The 0.1 reticle radial distance from each shore station, to a maximum of 8 km distance is shown for three tide heights: low tide height of -1.5 m, no tide, and high tide height of 1.5 m. The truncation distance is used to calculate effort for each survey from each shore station based on that station's height in 2010 and the tide height at the time of the survey. For stations 2 and 3 in the northern part of the Piltun feeding area with high enough elevation to make the 0.1 reticle mark correspond to a distance greater than the maximum truncation distance of 8 km, the truncation distance is set to 8000m with the actual 0.1 reticle distance shown in brackets.

Station	Station Height (m)	WGW Truncation Distance (m) at Tide Height of -1.5 m	WGW Truncation Distance (m) at Tide Height of 0 m	WGW Truncation Distance (m) at Tide Height of 1.5 m
1	10.1	6997	6459	5895
2	16.5	8000 (9063)	8000 (8604)	8000 (8131)
3	28.0	8000 (12208)	8000 (11829)	8000 (11442)
4	12.1	7698	7191	6662
5	7.2	5943	5350	4719
6	7.3	5956	5363	4733
7	6.2	5539	4920	4257
8	3.3	4293	3575	2778
9	4.4	4815	4144	3411
10	5.2	5120	4473	3772
11	7.0	5855	5257	4619
12	9.0	6619	6062	5476
13	7.3	5967	5375	4746

A WGW density was estimated for each grid cell that was sampled during a particular survey of a vessel transect or shore station by summing that survey's corrected (by the availability and detection probabilities) WGW sightings in the grid cell, and then dividing by the area that was surveyed in the grid cell. The surveyed area in each grid cell was determined by buffering each vessel transect and each shore station by the truncation distance for that transect or station, and overlaying each buffer onto the grid of 1.0 x 1.0 km cells in ArcGIS. The area of each grid cell that was covered by each buffer was then calculated and used as the grid cell surveyed area (Figure 3).

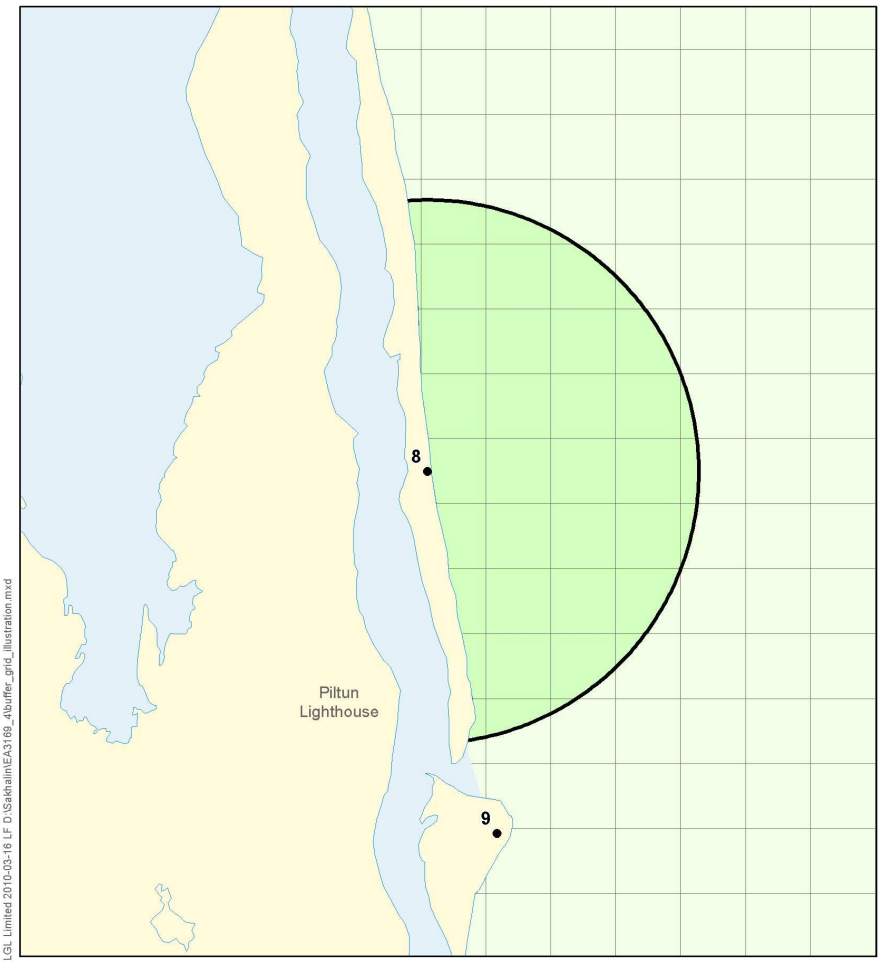

Figure 3 An example of the surveyed area for station 8 is shown as the black semicircle outline. The green grid cells show the overlap of the area surveyed by the station with the 1 km by 1 km grid cells used in the density analysis. The area of each green grid cell represents the survey effort by station 8 in that cell. As can be seen in the figure, all grid cells at the periphery of the station's surveyed area and the cells adjacent to the shoreline have an area that is less than 1 square kilometer.

Gray whale sightings beyond the truncation distances described above were excluded from the density analysis. In addition, density estimates were not calculated for grid cells with less than 0.1 km^2 area surveyed for shore-based surveys and less than 0.25 km^2 surveyed for vessel-based surveys because the small surveyed area caused a high bias in density estimates. The thresholds for the surveyed areas were determined by examining scatter plots of estimated densities against surveyed grid cell area for each survey type. Further analyses may be performed in the future to refine these thresholds.

The estimated densities from each survey were used to create WGW density surface maps by month and for the entire field season that depict the WGW spatial distribution and abundance at a resolution of 1.0 km^2 for most of the northeast Sakhalin Island coastline. The estimated average density in each 1.0 km^2 grid cell was calculated by taking a weighted average of the WGW density estimated by each survey that sampled that grid cell, with weights positively correlated with the amount of area that was surveyed in the grid cell.

The density analysis methodolgy continues to evolve and improve to reduce errors and uncertainty as methods are refined and additional survey data become available for estimation of the correction factors that are used in the analysis. Future work may examine the accuracy of parameters entering the density analysis, such as, for example, the correction factor for detection probability, or the positive bias in density estimates that can occur in grid cells with an area considerably less than 1 square km.

The results of the data collected in 2010 and comparison of the data with those collected in previous years is described and discussed in Volume II, Chapter 1 of the Western Gray Whale Joint Research and Monitoring Report. The density maps presented in the results for the vessel surveys include sightings that were made during the survey, but beyond the end of the systematic survey transects, and that consequently needed to be excluded from the density analysis described above. These sightings appear on the maps as circles indicative of the number of whales sighted at locations outside the designated survey grid. These observations were made primarily during the Offshore surveys to the northeast of the designated survey area. Some WGWs were also observed in the Piltun feeding area beyond the shoreward end of the Piltun-Astokh transects.

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2.8 LITERATURE CITED

Bailey, H. and D. Lusseau, 2004. Increasing the Precision of Theodolite Tracking: Modified Technique to Calculate the Altitude of Land-Based Observation Sites. Marine Mammal Science, 20(4):880-885, October 2004.

Blokhin, S.A., N.V. Doroshenko and I.P. Marchenko. 2003. The abundance, distribution, and movement patterns of gray whales (*Eschrichtius robustus*) in coastal waters off the northeast Sakhalin Island coast in 2002 based on the aerial survey data. Report by TINRO Centre, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website]

Blokhin, S.A., Doroshenko, N. and S. Yazvenko. 2004. Distribution, relative abundance, and movement patterns of western gray whales (*Eschrichtius robustus*) in coastal waters of northeastern Sakhalin Island, Russia, in June-December 2003 based on aerial survey data. Report by TINRO-Center for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 166 p. [available on the Sakhalin Energy Investment Company website.]

Blokhin, S.A., S.B. Yazvenko, V.L. Vladimirov and S.I. Lagerev. 2002. Abundance, distribution and behavior of gray whale *(Eschrichtius robustus)* based on the aerial surveys on the northeast Sakhalin shelf, summer and fall 2001. Marine mammals of Holarctic (Abstracts of reports of the 2nd Int'1 conf. - Baikal, Russia, 10-15 September 2002) - p. 36-38

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling. Oxford University Press. New York.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2004. Advanced Distance Sampling. Oxford University Press. New York.

ESRI 2010. ArcGIS software products. Environmental Systems Research Institute Redlands, CA.

Gailey, G., O. Sychenko, and B. Würsig. 2004. Western gray whale behavior and movement patterns: shore-based observations off Sakhalin Island, July-September 2003, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2005. Western gray whale behavior and movement patterns: shore-based observations off Sakhalin Island, July-September 2004, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2006. Western gray whale behavior, movement, and occurrence patterns off Sakhalin Island, 2005, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2007. Western gray whale behavior, movement, and occurrence patterns off Sakhalin Island, 2006. Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2008. Patterns of western gray whale behavior, movement and occurrence patterns off Sakhalin Island, 2007. Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2009. Patterns of western gray whale behaviour movement and occurrence off Sakhalin Island, 2008. Report for Sakhalin Energy Investment Company and Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia.

Gailey, G., O. Sychenko, and B. Würsig. 2010. chapter 5 *in*: Western gray whale research and monitoring program in 2009, Sakhalin Island, Russia. Volume II results and discussion.

Kinzey, D. and T. Gerrodette. 2003. Distance measurements using binoculars from ships at sea: accuracy, precision and effects of refraction. Journal of Cetacean Research & Management 5: 159-171.

Krebs, C.J. 1994. Ecology: The experimental analysis of distribution and abundance, 4th edition. Addison-Wesley Education Publishers, Inc., Menlo Park, California. 801 pp.

Leaper, R. and J. Gordon. 2001. Application of photogrammetric methods for locating and tracking cetacean movements at sea. Journal of Cetacean Research & Management 3:131-141.

Lerczak, J.A. and R.C.Hobbs. 1998. Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys // Mar. Mamm. Sci., 14 – p. 590-599.

Marsh, H. and D. F. Sinclair. 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management 53(4):1017-1024.

Rexstad, E. and D. Borchers. 2007. Memorandum: Western gray whale detection function and gradient. University of St. Andrews. Scotland.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2006. Distance 5.0. Release 1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/.

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, V.L. Vladimirov, N.V.Doroshenko, M.K.Maminov. 2005. Distribution and abundance of gray whales of the Okhotsk-Korean population in northeastern Sakhalin waters in July-November, 2004 // Report by VNIRO, Moscow and TINRO-Centre, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia – 199 p. [available on the Sakhalin Energy Investment Company website]

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, M.K. Maminov, S.P. Starodymov, E.P. Shvetsov. 2006. Distribution and abundance of gray whales of the Okhotsk-Korean population off northeastern Sakhalin, June-November, 2005 // Report by VNIRO, Moscow and TINRO-Centre, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia – 194 p. [available on the Sakhalin Energy Investment Company website]

Würsig, B., G. Gailey, T. McDonald, R. Nielson, J.G. Ortega-Ortiz, P. Wainwright, M. Jenkerson, O. Sychenko, K. Tarasyan, and N. Brown. 2002. Western gray whale occurrence patterns and behavior: Shore-based observations off Sakhalin Island, August-September 2001. Prepared by LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. Yuzhno-Sakhalinsk, Russian Federation.

Würsig, B, G. Gailey, O. Sychenko, and H. Petersen. 2003. Western gray whale occurrence patterns and behavior: shore-based observations off Sakhalin Island, August-September 2002. Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Yazvenko, S., T. MacDonald, S.K. Meier, S. Blokhin, S.R. Johnson, V. Vladimirov, S. Lagerev, M. Maminov, E. Razlivalov and M. Newcomer. 2002. Aerial marine mammal monitoring during the 2001 3-d seismic survey of Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia. Report by LGL Limited environmental research associates, Sidney, BC, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia. 163 pp.

Yermolayev, G.G. and Zoteyev, E.S. 1988. Fundamentals of marine navigation. Ed. by G.G. Yermolayev. 5th Ed. Moscow: Transport, p. 106-107.

CHAPTER 3

PHOTOGRAPHIC IDENTIFICATION OF THE WESTERN GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*) OFFSHORE NORTHEASTERN SAKHALIN ISLAND AND SOUTHEASTERN SHORE OF KAMCHATKA PENINSULA, 2010

METHODS AND ANALYSES[1]

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by

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REPORT
ON THE RESEARCH PROJECT

PHOTOGRAPHIC IDENTIFICATION OF THE WESTERN GRAY WHALE (Eschrichtius robustus) OFFSHORE NORTHEASTERN SAKHALIN ISLAND AND SOUTHEASTERN SHORE OF KAMCHATKA PENINSULA, 2010

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CHAPTER 3: PHOTO IDENTIFICATION

3.1 INTRODUCTION

Photo-ID has proven to be a useful and low-impact technique for monitoring wild populations of many species of marine mammals. Individuals can be passively "tracked" over space and time by photographically "capturing" then subsequently "re-capturing" the same whale while recording the location and time the photographs were taken. This technique is seen as a minimally intrusive method for monitoring because no physical device needs to be attached, nor biological samples taken from the animal. When incorporated into a long-term monitoring program, photo-ID can be a valuable method to help answer many ecological questions about the population dynamics of marine mammals. For example, photo-ID has been used successfully to identify migration routes for populations of large whales such as right whales, humpback whales and eastern gray whales (Best *et al.* 1993; Darling *et al.* 1996; Craig and Herman 1997; Salden *et al.* 1999), as well as feeding ranges, and interannual changes in whale distribution (Calambokidis *et al.* 2002; Clapham *et al.* 1993). For small or isolated populations, including WGWs, photo-ID can be used to assess population size, and monitor variation and trends over time (Whitehead *et al.* 1997; Cerchio 1998; Stevick *et al.* 2001; Bradford 2003; Weller *et al.* 2003, 2004; Calambokidis and Barlow 2004, Cooke *et al.* 2008). Finally, photo-ID is an effective method of examining health indicators of individual whales as well as the overall health of groups or populations (Pettis *et al.* 2004; Bradford *et al.* 2005).

Photo-ID research for the purpose of studying population dynamics, behavior, and other aspects of marine mammal biology began being actively used in the 1970's. The use of digital cameras in the last decade has made it substantially easier to obtain high-quality photographs of cetaceans and manage related data on the location and conditions under which they were taken. Furthermore, digital photography allows researchers to check the quality of the pictures in real time.

Photo identification (photo-ID) is also a valuable tool in gray whale studies (Darling 1984; Würsig *et al.* 1999, Calambokidis *et al.* 2002; Yakovlev and Tyurneva 2005 a,b,c; 2006), because individual gray whales are quite distinguishable on the basis of the markings on their sides, backs and flukes. The main objective of this photo-ID study is to assess the status of the western gray whale (WGW) population, including its reproduction, survival rate and physical condition. In addition, these gray whale photo-ID

efforts can provide data on habitat usage and possible presence of important habitats on the Sakhalin shelf and in other regions, such as offshore southeast Kamchatka.

The main objectives of the photo-ID study of WGWs are to:

- assess WGW abundance and annual return rates on the northeast Sakhalin Shelf and offshore southeast Kamchatka;
- investigate intra- and inter- year site fidelity and movements of individual whales within and among the Piltun and Offshore feeding areas, offshore south eastern Kamchatka and within the Sea of Okhotsk
- determine the stability of individual communities and groups;
- assess the number, status, habitat use, and the observed dates of separation of cow/calf pairs.
- assess physical status and health indicators of individual whales; and
- assess WGW population demographics and structure.

3.2 STUDY AREAS

3.2.1 Northeast Sakhalin Shelf

The study area covers the entire northeast coast of Sakhalin Island, including the nearshore Piltun feeding area and the Offshore feeding area further away from the coast (see Chapter 1, Figures 1 and 2). Photo-ID effort was concentrated in these two feeding areas, but whales were also photographed opportunistically if encountered elsewhere (e.g., north of Okha in 2010 and in other areas in earlier years).

The Sakhalin study area is described in detail in Chapter 1 ("Study Areas" section).

Whales photographed along the northeast coast of Sakhalin Island are included in the KOGW catalogue.

3.2.2 East Kamchatka Shelf

Photo-ID studies were also conducted along the eastern coast of Kamchatka Peninsula in 2004 at Khalaktyrsky Beach south of Cape Nalycheva (53°11’ N, 159°42’ E), and starting in 2006 in two locations that included Olga Bay (54°34’ N, 160°57’ E), and Vestnik Bay (51°28’ N, 157°34’ E) (see Chapter 1, Figure 1). These two areas are located at a distance of about 600 km with mainly rocky shores in between,

which are likely unsuitable for the feeding of gray whales. The shorelines of the two bays resemble the shore of Piltun Bay, with slightly curving sandy beaches. These beaches are ~23 km long in Vestnik Bay (shoreline direction of 80º-260º), ~25 km long in Khalaktyrsky Beach (shoreline direction 65º-245º), and ~35 km long in Olga Bay (shoreline direction 90º-270º). All three bays have small rivers flowing into them and the depths usually range from 5 to 20 meters. In all three locations described above, the northern part of each bay has a cape extending into the sea (Cape Olga, Cape Nalycheva, Cape Zholty). Whales photographed along the eastern coast of Kamchatka are included in the KAMGW catalogue.

3.2.3 Other Areas

In 2008, reconnaissance surveys were conducted in locations where gray whales had been observed over the past 20-30 years, including the northern part of the Sea of Okhotsk, the western shores of Kamchatka, and along the northern part of the Kurile Island chain. These surveys were conducted between the two stages of the *Akademik Oparin*'s research itinerary from July 24 to August 23, 2008 as part of a joint expedition by the Pacific Ocean Institute of Bio-Organic Chemistry [TIBOKh DVO RAN] and the IBM DVO RAN. Whales photographed in the areas described here are included in the NOGW catalogue.

3.3 HISTORY OF WESTERN GRAY WHALE PHOTO-ID

3.3.1 Sakhalin Island Shelf

Photo-ID studies of WGWs in this area are currently carried out by two teams of researchers. The Russian-US photo-ID team has been active in the nearshore Piltun feeding area since 1997, with a pilot program conducted in 1994 (Würsig *et al.* 1999; Weller *et al.* 2000, 2001, 2003, 2008). Specialists from the Institute of Marine Biology (IBM) of the Far East Branch of the Russian Academy of Science (DVO RAN) (henceforth "IBM team") have been working in both (Piltun and Offshore) feeding areas every year since 2002 (Yakovlev and Tyurneva 2003, 2004, 2005 a,b,c, 2006, 2008; Yakovlev *et al.* 2007, 2009b).

The Russian-US team and the IBM team have established that the majority of identified gray whales return to Sakhalin feeding areas each year and that a high degree of seasonal attachment to these areas is displayed by most of the identified individuals. It has also been recorded that some individual whales visit the area irregularly, i.e., they tend to skip seasons. The absence of those individuals in the coastal waters of the Piltun area during certain years may be partly explained by their presence in the Offshore feeding area or offshore southeast Kamchatka during the same year, although the number of observed

and photo-identified whales in this area has varied substantially from year to year. For example, more whales were observed in the Offshore area in 2002-2003 than in 2004-2005, with the number of whale observations again increasing in 2006 and 2007 (Yakovlev and Tyurneva 2003, 2004, 2005, 2006, 2008; Blokhin *et al.* 2003, 2004; Maminov 2003; Yakovlev *et al.* 2007; Tyurneva *et al.* 2008). Western gray whales observed offshore Sakhalin have also been encountered off Kamchatka within the same year, and in different years (Yakovlev and Tyurneva 2003, 2004, 2005 a,b,c, 2006, 2008, 2009, 2010; Yakovlev *et al.* 2007, 2009a,b)..

3.3.2 East Kamchatka Shelf

Over the past few decades, researchers have become increasingly aware of a wide distribution of gray whales in the coastal waters off southeast Kamchatka during the summer, autumn and early winter months (Blokhin *et al.* 1985; Vladimirov 1994; Vertyankin *et al.* 2004; Tyurneva *et al.* 2007b, 2010). According to Blokhin (1996), no WGWs were sighted along the coast of western Kamchatka over many years of both systematic and pilot observations. Yet, in August 2000, a small gray whale was seen entering the Bolshaya River (52°08’ N, 156°27’ E) (Nikulin *et al.* 2004). According to vessel-based surveys conducted on an annual basis by the Kamchatka Regional Fisheries Management Agency (Kamchatrybvod), gray whales have been sighted in the coastal waters to the southeast of the tip of the peninsula since 1979 Since the mid 1980s, solitary whales began to be observed during the summer months near the southeast coast of Kamchatka (Blokhin *et al.* 1985; Vladimirov 1994; Tyurneva *et al.* 2007; Tyurneva *et al.* 2008). Information on gray whale encounters in the coastal waters of the southern Russian Far East are given in Maminov and Blokhin's work of 2004.

In 2004, three gray whales were sighted and photographed during scheduled counts at Khalaktyrsky Beach offshore of the eastern part of the Kamchatka Peninsula (Yakovlev et al. 2007). During the first comparison of these photographs with the available 2002-2005 WGW catalogue of photo-identified whales offshore northeast Sakhalin no matches were found. However, in the following years, two of these individuals were identified offshore Sakhalin (Tyurneva *et al.* 2006, 2010).

In 2006, the IBM photo ID laboratory received for processing gray whale photographs collected in the north of the Sea of Okhotsk in Kekurny Bay dated July 13, 2006, and in Babushkin Bay dated July 28, 2006. As a result three whales were identified and assigned Catalogue ID numbers NOGW# (Vladimirov et al. 2007). In 2007, one of these whales was also sighted in both Piltun and Olga Bay and was assigned

the appropriate catalogue numbers. A second whale was identified in Olga Bay and has been encountered there on a regular basis in the summer feeding season since 2007.

From 2006 onwards, efforts were made to gather photo-ID data in Vestnik Bay and Olga Bay, Kamchatka, in the hope of confirming whether the whales belonged to the eastern or western populations. According to the 2004 and 2006-2008 photo-ID data, 116+2 temporary gray whales were identified in the surveyed areas offshore southeast Kamchatka, 61+1 of which are also registered in the WGW catalogues of northeast Sakhalin maintained at the IBM DVO RAN, i.e. had been previously sighted off the coast of Sakhalin.

Available data suggest that spatial movements between feeding areas on an inter- and intra-annual basis are linked to prey availability (Tyurneva et al. 2006, 2010a; Yakovlev et al. 2009a). It was also determined that within the same season whales could feed both at offshore Sakhalin and Kamchatka, i.e. they perform large-scale intra-annual movements.

The cases when gray whales use different feeding areas in subsequent years are considered inter-annual movements. Twenty-one of the whales photographed in 2009 only on the Kamchatka shelf were recorded in past years in the Sakhalin Catalogue.

Half of the whales seen in Olga bay (Kamchatka) in 2008 were seen at Sakhalin before. Ten whales seen near Sakhalin in 2008 were registered in Kamchatka in 2007. Out of the 37 gray whales registered offshore southeast Kamchatka in 2007, 20 were seen near Sakhalin in previous years. Five out of 13 gray whales seen in Kamchatka in 2006 were also seen near Sakhalin in previous or subsequent years.

3.3.3 Other Areas

There have been frequent sightings of gray whales in the coastal waters around the Commander Islands that are located approximately 200 km east of Kamchatka. Similar to the WGWs offshore Kamchatka, the appearance of gray whales near Bering Island (Commander Islands) at a remote distance from the mainland is apparently becoming a regular occurrence (Mamaev 2002; Vertyankin *et al.* 2004; Tyurneva et al. 2010b).

In 2008 a gray whale previously (in 2007) seen in Olga bay (Kamchatka) was photographed in Zakatny bay of Shikotan island (Kuril Islands). Later in 2008 this whale was seen in Olga bay again (Chapter 1, Figure 1), off Medny Island (Komandor Islands), and off Karaginsky Island (northeast Kamchatka). On July

8, 2008 four gray whales not registered anywhere before were photographed near Karaginsky island (north-east Kamchatka) due to the limited data and a lack of evidence of feeding, it is hard to determine if these locations are potential feeding areas. It could be that these are cases of whales traveling in search of areas with sufficient forage.

3.3.4 Movements of Western Gray Whales within and between Seasons

The discovery of the Offshore feeding area in 2001 gave the IBM research team an opportunity to gather evidence on whale movement between the two (Piltun and Offshore) feeding areas off Sakhalin Island. Observations of solitary gray whales within the range of the Offshore area were reported (Sobolevsky 2000; Miyashita *et al.* 2001) and it is quite likely; that the Offshore area was used as a feeding ground by gray whales before 2001. However, whale sightings in the Offshore area prior to 2001 were sporadic and counts were infrequent (see Chapter 1 of this report). Photo-ID of gray whales in the Offshore area was initiated in 2002 (Yakovlev and Tyurneva 2003) and showed that some of the individuals observed in this area were also observed in the Piltun feeding area during the same year. Additional photo-ID work in subsequent years confirmed the existence of intra- and interannual interchange of whales between the Piltun and Offshore feeding areas (Yakovlev and Tyurneva 2004, 2005a,b,c, 2006, 2008; Tyurneva *et al.* 2008; Yakovlev et al., 2009).

Since 2005, a number of WGWs from the IBM Sakhalin catalogue have been recorded near the coast of the eastern Kamchatka Peninsula (Yakovlev et al. 2009, Tyurneva et al. 2010a,b,c). To reach Sakhalin from Olga Bay, the whales could have swam a direct (i.e., straight line) route of ~ 1500 km or a coastal route of ~2800 km (Chapter 1, Figure 1). This is not a trivial distance, given that the entire route from eastern Sakhalin to the (still unknown but presumed) wintering grounds in the South China Sea may span ~4500 km. Gray whales have also been recorded in the northern Sea of Okhotsk, near the city of Magadan (~830 km from the Piltun feeding area following a direct route across the Sea of Okhotsk, or ~1800 km following a coastal route); at least some of these whales were observed offshore Sakhalin during the same summer season (Tyurneva et al. 2008, 2010).

3.3.5 Physical Condition

Seasonal fluctuations in blubber fat reserves in baleen whales are normal after winter periods of fasting and during migration (Perryman and Lynn 2002), and cows can be substantially thinner during years in which they are nursing calves (Pettis *et al.* 2004; Weller *et al.* 2004). Photo-ID methods can be used to detect these normal fluctuations, as well as abnormal changes in physical condition due to disease or

starvation (Thompson and Hammond 1992; Pettis *et al.* 2004), and make it possible to look at the relationship between birth rate and physical condition at both the individual and population levels.

From 1999 to 2003, the Russian-US photo-ID team noted that a variable number of identified whales (4-51.7%) displayed one or more of the features of skinny whales (see Physical condition Assessment section below; Weller *et al.* 2000, 2007). Their numbers peaked in 2000 and reached their lowest level in 2003. Some of the whales classified as skinny during one feeding season regained their weight the next year, whereas other whales that were not classified as skinny during one year were classified as skinny during the next year (Weller *et al.* 2004).

In 2005 and 2007, individual whales were observed by the IBM team over an extended period of time, i.e. over most of the feeding season. The physical condition in some underweight whales was observed to improve over the course of the feeding season (Yakovlev and Tyurneva 2006; Yakovlev *et al.* 2007). Improvement in the whales' physical condition was also recorded throughout the field seasons of 2008 and 2009 when the number of sightings of underweight whales decreased over the course of the season (Yakovelev *et al.* 2009b; Tyurneva et al, 2010b).

3.3.6 Skin Condition

Visual assessment of health-indicators has been used to monitor the overall health of individuals, which is then extrapolated to the entire population. Photographically capturing each individual allows researchers to visually assess changes in the appearance of the animal over time. Photographs were used to assess skin conditions, including skin sloughing and white patches (blotches), and barnacle load on the skin surface. The presence of atypical skin or physical conditions was established using visual assessment of the photographs. This type of visual monitoring has been done for a variety of species including humpback whales and right whales as well (Gulland et. al, 2008; Pettis et. al. 2004).

Individuals expressing changes in skin condition over time (e.g. from one season to the next) were visually monitored through multiple photo sessions whenever possible during the season. Repeat encounters allowed the researchers to track the progression/regression of the condition throughout the season. Photographs of affected animals were also compared inter-annually. Extra attention was given to examining photographs and sighting histories from whales returning every year with observed skin abnormalities.

The progression of white patches or blotches in the skin surface has been puzzling and their origins are still unknown (Tombach Wright et. al. 2007). This white to grey discoloration of the skin frequently changes from one year to the next in patch size and total body area affected. In cases where this has been observed, the individuals have been flagged and photographic visual comparisons through time have been conducted to monitor the progression of the condition (Yakovlev et al., 2009a).

3.4 FIELD METHODOLOGY

3.4.1 Northeast Sakhalin Shelf

The field procedure for the photo-ID work used by the IBM team since 2002 is based on recommendations for photo-ID work of marine mammals, set forth in the International Whaling Commission Special Publication No. 12 (Hammond *et al.* 1990). The research vessel *Akademik Oparin* was the base ship for the photo-ID effort, with the actual work conducted from a 4.8 m long Zodiac boat when the weather and schedule for other research permitted this. The work was suspended if weather conditions became unfavorable for photo-ID (fog; high, wind-driven waves greater than 3; wind speeds of more than 10 m/sec; heavy rain; high seas; or poor light) or posed a safety risk.

On specified photo-ID days, when conditions permitted, the Zodiac was deployed from the base ship whenever gray whales were sighted. When the research vessel approached within approximately 2 km of a group of gray whales, it was brought to a full halt. After a safety briefing, the Zodiac was launched from the base ship and the photo-ID "mission" was commenced. Observers positioned high on the bridge of the base ship continued visual observations of marine mammals. This sighting information and data on whale movements were provided via VHF to the photo-ID team aboard the zodiac to ensure the most efficient and safest approach to the whales. This was particularly important in the Offshore feeding area where the distances between groups of whales or individuals were usually greater and the whales' movements were less predictable because of the greater diving depth.

The mission was completed when the Zodiac returned back to the base ship. There could be multiple missions in any given day (during the daylight period, from dawn to dusk), and the Zodiac could travel among multiple solitary individuals or groups of whales during each of these missions. Every arrival at a new solitary individual or group of whales is called a "sighting", thus there could be several sightings per mission. A "sighting" is defined as the observation and photographing of a solitary individual or a group of two or more whales swimming in direct proximity to each other (within 10 body lengths) with

coordinated dive and surfacing times and directions of movement relative to other individuals in the group.

The Zodiac was outfitted with a 40 HP four-stroke Mercury outboard motor, a digital depth finder, a portable global positioning system (GPS) navigator and all safety equipment required by established project safety protocols. The research team consisted of a boat driver, a data recorder, a digital video camera operator and a digital camera photographer. In the Piltun area, the base ship sailed in parallel with the shoreline at the required safety distance to offer the Zodiac crew whatever assistance it might need. In the Offshore area, the base vessel would remain at least 1 km from the whales and within visual sight of the Zodiac.

After sighting whales, the Zodiac driver slowed to idling speed in order to establish the base number and behavior of whale(s) in the target group prior to approach, and to locate any other groups of whales in this area. IWC guidelines for small vessel operations around cetaceans were followed (Carlson, 2008; IWC, 1996). Extra caution was taken when operating around cow calf pairs. The boat moved away if an obvious change in whale behavior was observed upon or after approach or during the photo-ID session, and a new subject was targeted. Contact with a group of whales was maintained until all presumed individuals in the group had been photographed, if possible. However, no more than one hour was spent with a group, regardless of the number of aspects photographed, to minimize disturbance to the animals over an extended time period. The Zodiac slowly withdrew from the group of whales once the session was completed. These procedures were repeated each time an additional solitary whale or whale group was sighted and photographed. A sighting number was given to each of these encounters. Sighting numbers were assigned sequentially starting with 1 on each photo-ID day.

The following parameters were recorded on data sheets for each sighting: the camera frames and video recording counter numbers in reference to the identified whales, the Zodiac position (as determined by GPS), the depth (using digital depth finder), the temperature (at sea surface) and the distance to the subject whale(s), and its course according to compass readings. The whales' position (determined by the GPS), the time, behavior, number of whales in the area[1], direction of their movement, the presence of other groups of gray whales, killer whales and passing vessels, and airplanes or helicopters in the observation area were also noted.

[1] Group size estimates were based on a consensus of the observers aboard the Zodiac and were later confirmed in the laboratory via photo-matching.

The presence of mud plumes, both at whale feeding sites near the boat and when no whales were visible was recorded. In addition, secondary indicators of whale feeding, such as circling or diving birds or schooling fish, were documented. If whale foraging was observed (as confirmed by mud plumes or assumed from typical movements and behavior), GPS positions of the whales were recorded and communicated to the base ship via VHF radio so that benthic samples could be taken at these WGW feeding sites at a later time at whale foraging locations after the whales left their feeding grounds (see also Chapter 4 of this volume).

A Nikon D2X digital camera with a fixed 300 mm f/4 telephoto lens or a Nikkor 80-400 mm zoom lens with image stabilizer (IS) was used for photography. The use of a high-quality digital camera provided the possibility of rapid data acquisition and reduced the time spent on image processing and archiving at the end of the survey season. The photographs were recorded at a high resolution setting in RAW format (NEF).

An attempt was made to photograph all aspects (head, back flanks, and flukes) of each whale. A whale was photographed in sequence, from head to fluke on both the right and left sides, and the dorsal and ventral fluke surfaces. Priority was given to photographing the right and left sides of each whale, as fluking frequency varies with individual behavior and foraging depth. Preference was given to photographing the right sides (flanks) of the subject animal as right sides have been arbitrarily chosen among gray whale researchers as a baseline identifier. Matchable right side photographs are required for an individual whale to be included in the photographic identification catalogues. A matchable quality photograph for photo-identification of gray whales is any photograph of the appropriate region of the body (aspect), which can readily be identified as belonging to a particular individual whale when compared to other photos of the same target region of that same whale.

Traditionally the right and left flanks were examined for standard recognition purposes in photo-identification of gray whales. The ventral surface of the flukes is an additional aspect in most gray whale catalogues (Weller *et al.* 2002; Calambokidis *et al.* 2002; Yakovlev and Tyurneva 2006). Since the likelihood of repeated recognition of an individual (*via* matching) increases as more information for that individual is collected in a catalogue, a fourth aspect – the dorsal fluke surface – was added as supplemental information for the IBM identification process (Yakovlev et al., 2009). The dorsal fluke surface of an individual whale can often be displayed even in shallow feeding areas, when deeper diving may not be feasible. The method of adding aspects to improve recognition accuracy, especially during

the early years of data collection and catalogue preparation, has been successfully used with other marine mammal species (McConkey 1999; Bannister 2000; Glockner-Ferrari and Ferrari 2000).

Digital photography has allowed for sequentially photographing individuals from first surfacing (blow) to dive (flukes) to create a "full series" of photographs for each individual that offers nearly complete coverage of an animal and serves as a matching aid in side-to-fluke matches within a series. While the best photos of the four main aspects are still maintained for any catalogue, the full series for an individual is very useful as a supplement to help match non-ideal photos back to the best photos in the catalogues. All identified photographs of the individual, including the full series, are labeled and maintained within the database.

Video footage was recorded using a Sony HDR-HC7E digital video camera. Video footage was important for recording whale behavior and was particularly useful for documenting the physical condition of the whales (e.g., protruding scapulae and depressions behind the blowhole) that are often difficult to distinguish on still photographs due to lighting limitations, exposure, and position of the whale in the picture. Video also assists with identification of cow-calf pairs and unaccompanied calves by providing behavioral information about the individuals (e.g. play behavior, length of close contact between individuals). The use of video in cow-calf pair and unaccompanied calf identification is described in more detail in section 3.5.6 below.

After each photo-ID mission was completed, the Zodiac returned to the base ship. All the digital images were loaded into a notebook computer and a backup external hard disk from the camera memory cards and were archived on DVD. The information recorded on data sheets was entered into Microsoft Access and archived in Microsoft Excel. All data were recorded on waterproof data sheets and entered into a laptop computer at the end of each photo-ID mission.

Backup copies were made and also archived on external disks and DVD. All digital data were stored on three different digital media at all times. All archived data DVDs were also duplicated and the backups were stored at various offsite locations whenever possible.

3.4.2 Field Studies of the East Kamchatka Peninsula

In 2006, photo-ID effort was conducted in Olga Bay, Kronotsky Bay, Kamchatka Peninsula (Figure 1) using vessel-based field procedures similar to those used in the Sakhalin offshore surveys. In subsequent years, starting in 2007, photo-ID surveys were conducted from Zodiacs launched from shore.

Prior to the start of large-scale surveys in 2008, the Kamchatka team members were trained to work with the whales during photo-ID surveys in order to adhere to the same methodology that was proven in the Sakhalin Island surveys and was used as the basis. Starting in 2008 two inflatable boats were used in the surveys: the main boat, from which the photo-ID surveys were conducted, and an auxiliary (backup) boat to ensure operational safety. Moreover, for safety purposes, one expedition member was left behind at the base camp and called both boats operating offshore on the radio every 30 minutes. Achilles boats (4.2 m) with Yamaha-30 two-stroke outboard motors were used. The two-stroke motors were chosen because of their lighter weight and ease of handling and because they much simpler, easier to repair in the field and did not require certified maintenance technicians. Both boats had safety equipment, including an extra low-power motor. Before the boats were launched, the team conducted a safety and mission briefing. While they were in motion the boats maintained a distance of 400 to 800 meters between each other, and the team members observed the water surface and looked for whales. When gray whales were spotted, the support boat stayed in place and conducted visual observations to minimize anthropogenic impact on the whales. The main boat approached a solitary whale or group of whales to determine the number of animals, their natural behavior, and the directions of their movement. Water depths and temperatures were recorded prior to photo-ID. If possible initially the right flank of the animal was photographed, followed by the left flank and then the dorsal and ventral fluke surfaces. The boat maneuvered cautiously in order to minimize impact on the whales in accordance with International Whaling Commission requirements (IWC, 1996) for small craft operations near Cetaceans. The duration of these missions reached 11 hours in good weather when the team was in the boat all light day. In most cases the boats initially headed to the most distant habitat of the gray whales, 3-4 km offshore the mouth of the Kronotskaya River , which is just beyond thewhales foraging grounds. This trip took about 1 hour and 20 minutes. The boats then proceedproceeded towards shore and photo-ID work was initated when whales were observed. This procedure is used in order to position the boats closer to the base station in the event of bad weather or the end of the work day. If the photo-ID team was unable to cover the entire whale feeding area in one day, then at twilight the work was halted and the boats returned to their base station. If there was good weather the following day, the photo-ID work was initiated in the area where the previous day's survey had ended, with a slight overlap of the area from the day before.

During the survey the coordinates (GPS), time of the survey, depth of the location, weather, distance to the whales, information on sighted whales, and other information were entered on paper forms. The recorded information was entered in an MS Excel database onshore at the base camp.

A Canon 40D digital camera with a zoon lens (75-300 mm) and an image stabilizer was used for the whale photographic survey. The photographs were shot at the highest resolution in JPEG format. RAW format was tried but was found to be time- and space-consuming and did not offer noticeable advantages during matching. All the digital photos of the whales were transferred to a computer and then backed up to an external disk and DVD disks (at least 3 digital media).

3.5 DATA PROCESSING AND ANALYSIS

3.5.1 Databases and Software Used

Since 2005, a Microsoft Access database was used to store the field data and the IMatch database was used to store whale photographs along with the matching data. At the end of the matching process, data from these two sources were combined into a Microsoft Access database that was used to generate tables and figures for the reports. When necessary, digital photographs of whales were edited (enhanced) using Adobe Photoshop. The best photographs of gray whales for each sighting were printed with a color printer Epson Aculaser C1100 on high-quality paper, and compiled into a pre-catalogue portfolio. Adobe Illustrator was used to compose the WGW pre-catalogues. The databases are backed up according to the established protocol.

3.5.2 Photo ID Analysis

To recognize individual whales by their distinguishing marks on their sides and flukes, researchers used standard photo-recognition methods described in Special Edition No. 12 of the International Whaling Commission (Hammond *et al.* 1990), with modifications that were developed by other specialists conducting similar gray whale studies (Calambokidis *et al.* 2002; Weller *et al.* 2004).

Whale body pigmentation pattern was the primary feature used to distinguish individuals, with scars and barnacle patches supplementing the matching process. Whale knuckle height, spacing and ratios were also considered as a final check to compare matches (Calambokidis et al. 1999; S. Swartz & M.L. Jones pers. comm. 2007). A “match” was made when two separate sightings of the same individual could be confirmed by reviewing photographs or video footage (typically photographs). A confident

match was not made unless the images were considered to be of good or excellent quality. Poor quality images were used only for supplemental information or were digitally archived for potential future use.

All of the images for every individual taken at each sighting were stored in a searchable database. The best photos of each sighting were combined into a pre-catalogue. The pre-catalogue was then used to create the annual catalogue by selecting the best photos of every available aspect (right side, left side, dorsal fluke, ventral fluke) for each whale that was identified within a field season.

The "master catalogue" contains the best photos of every available aspect of each whale obtained during all years of the study; it is updated on an annual basis with new or better photos from the current year. All new individuals (including calves) that have been photographed for the first time are also added to the master catalogue.

The following whale body areas (aspects) were selected to create the catalogues (in order of priority): right (RS) and left (LS) sides of the body, and ventral (VF) and dorsal (DF) fluke surfaces. Use of all four aspects has proven useful for creating catalogue pages for whales seen for the first time (new individuals) and for updating the images in the master catalogue with (1) additional aspects that were not photographed during the earlier years and (2) photographs showing any changes in body markings that had occurred during subsequent study years, such as the appearance or disappearance of scars and camouflaging (masking) of natural pigmentation by barnacle spots.

3.5.3 Processing the Photographs

The photographs for each sighting in each daily mission were reviewed in sequence, beginning with the first sighting of the first mission of the season. Each sighting's photographs were first examined to identify and group images of each individual whale that was photographed. Confident left-to-right side matches were established based on the following criteria:

1. the whale was photographed as a solitary individual;

or

2. sequences of the left and right side for a single sighting had the same flukes; and

3. as a final check to assist with right to left matches, the height, spacing and ratios of whale knuckles along the dorsal side of the tail stem were considered (Calambokidis et al. 1999; S. Swartz and M.L. Jones 2007, private message).

Side-to-fluke matches were considered to be reliable when taken in sequential order in real time, and when pictures of the body parts of a whale in successive photographs greatly overlapped. Digital photography greatly assisted during the side-to-fluke matching process. Special attention was devoted to identifying whales with various deviations from the "physiological norm," including: (1) classifying whales with deviations in body physical conditions (BC) into categories; and (2) distinguishing whales with obvious sloughing of skin or anomalous skin conditions.

All photographs were tagged with additional descriptions, such as whale identification, aspect, and physical condition. The data were then entered into a database that stores all available photographs. This database contains the full sighting history for each individual for the season once all the photographs for the field season have been processed.

3.5.4 Assigning Identification Numbers and Updating the Annual and Master Catalogues

After all of the season's photographs were grouped by individual and sighting, the best photos were compared to the available catalogue images collected during previous years. Existing identification numbers were then assigned to animals found to be identified in the past. In the event of a discovery of a new whale, and if high-quality photographs of the right side of the individual were available, the whale would be assigned a new identification number. Whales identified only by a left side photo or flukes, or by a right side photo of poor quality received temporary identification numbers (TEMPNo.) for subsequent identification. Such whales are not placed in the master catalogue, but included in the temporary whale catalogue and mentioned in the annual report as "Temporary Whales". Temporary whales remained as such until a good quality (matchable) right-side photograph of the animal is obtained. The whale was then "promoted" to the Master Catalogue and given a personal identification number after a good photograph of the whale's right flank is obtained. Temporary identification numbers are used for reference and allow the whale's sighting history to be preserved.

Once matching was completed, a permanent identification number (KOGW#) was assigned to each individual whale and the final annual catalogue was created with each individual's best photos for the current year and that whale's identification number. After the annual catalogue is completed, new information and photographs obtained during the current season are added to the master catalogue and catalogue information is updated in the database.

3.5.5 Regional Catalogues

When photo-ID data were obtained from areas other than the Sakhalin Coast, a regional catalogue was compiled for each area using identification numbers specific to that area, e.g., KamGW# for whales recorded off Kamchatka and NOGW# for whales recorded in the northern part of the Sea of Okhotsk, in contrast with KOGW# for whales recorded offshore Sakhalin Island. If the same whale was found in different regions, then it was assigned a two- or three-part ID indicating the areas in which it had been seen (such as KOGW159 = KamGW034 = NOGW003).

3.5.6 Cow and Calf Identification

A "calf" was defined as an individual up to one year old (current year's offspring) as established by a set of criteria, such as their small body size (about one-third a mature adult) and demonstrating a close association with a particular adult whale (Wells and Scott 1990; Weller *et al.* 2004).

In 2009 we began developing a systematic process to rank the significance of cow-calf pair identification criteria and grade the reliability of the identification of existing pairs and unaccompanied calves. This system is still being refined.

Cows were identified by their close or immediate proximity to calves. The following criteria were used to identify nursing females:

1. The female was encountered next to the same calf two or more times in a season and stayed close to the calf.
2. The female had been counted with the calf (calves) in past years.
3. It is known that in the past year, the female was sighted in the summer-fall feeding area without a calf.
4. The female itself has a noticeable weight deficiency.
5. The accuracy of identification of the foraging female has been confirmed by other research teams.

The following degrees of certainty were used to assess the reliability of the identification of cows for the identified calves:

I - high degree of certainty (complete certainty)

This degree is assigned if Criteria 1 or 5 are met and/or if other criteria are met if a given animal has been sighted in past years.

II - medium degree of certainty (certainty)

This degree will be assigned if a female has been encountered with a calf only once and other teams of researchers did not encounter this pair as long as criteria 2, 3, and 4 are met.

III - low degree of certainty (insufficient certainty)

This degree will be assigned if criteria 1, 2, and 5 are not met, i.e. if a whale was encountered once with a calf and was not known as a foraging female in past years.

Thus, the entry "**III** 3, 4" means that a whale was encountered with a calf only once during a season, had not been encountered with calves in past years, and had a physical condition deficiency.The entry "**II** 2, 3, 4" means that the whale was sighted with a calf only once in that season, was known as a nursing female in past years, had not been encountered with a calf in the preceding year, and had a physical condition deficiency.

The calf identification process was based on a set of morphological and behavioral criteria that were evaluated by photographs, video footage and photo-ID field notes. To date, it consists of the following elements: grades of the reliability of identification (A – certain, B – highly probable , C – likely) and calf identification criteria (numbered). Calf identification reliability grades are assigned based on sets of different criteria. For example, grade A with criteria 1, 2, 4 indicates that the new whale was certainly a calf (?) and seen in shallow waters (1), it looked like a calf (2) and the whale was observed once in close association with a cow and without other adults nearby, but after that was seen in groups with other known calves (4).

Grade A was assigned if any 3 of the following conditions were met:

1. the whale is not in the catalogue and was observed only in shallow waters.
2. the whale looks like a calf (has a short round rostrum, is smaller than an adult, is well-nourished, has no “donut”-shaped barnacle spots).
3. the whale was observed two or more times in close (intimate) association with a full size adult whale that was presumed to be a cow.

4. the whale was observed once in close (intimate) association with a full size adult whale presumed to be a cow and without other adults nearby, but after that was seen in groups with other known calves.

Grade B was assigned if any 3 of the following conditions were met:

1. the whale is not in the catalogue and was observed only in shallow waters.

2. the whale looks like a calf (has a short round rostrum, is smaller than an adult, is well-nourished, and has no "donut"-shaped barnacle spots).

3. the whale was observed once in close association with a full size adult whale presumed to be a cow and with other adults nearby, but after that was seen in groups with other known calves.

4. the whale was observed once in close association with a full size adult whale presumed to be a cow and was not encountered after that.

Grade C was assigned if any 3 of the following conditions were met:

1. the whale was not in the catalogue and was observed only in the shallow waters.

2. the whale looks like a calf (has a short round rostrum, is well nourished, and has no "donut"-shaped barnacle spots).

3. the whale was observed once near a full size adult whale presumed to be a cow and without other adults nearby, but didn't show close association.

4. the whale was observed without a cow, but was seen near other cow-calf pairs.

5. the whale was observed without a cow, but was seen in groups with other known calves.

D Additional criteria:

1. smaller blow compared with that of adult whales.

2. playful behaviour.

3. calf or cow/calf identification is confirmed by the behaviour studies team.

Notes:

* *Criteria D1 and D2 are used to improve the certainty of the identification, but do not affect the assigned grade.*

** *If a calf identification that received grade B or C also had criterion D3, then the grade is raised to an A. If the behaviour team thinks that the whale is a calf, but can't define its cow, then a C grade is raised to B.*

Not all of the above criteria are present at all times, and the weight given to the different criteria is subjective, therefore the degree of certainty in the conclusion regarding the calf identification varied from case to case. Calves that met certain criteria, but did not satisfy other criteria of the certainty required to be assigned a grade A or B, were recorded as possible, i.e. assigned grade C.

During late August-September, calves are weaned from their cows, and towards the end of the season solitary, unassociated small gray whales may be recorded. These may include recently weaned calves or yearlings. Distinguishing between the two is difficult. The only definitive criterion in identifying a yearling is a record of it as a calf in the previous year, although factors such as the presence of vibrissae, size, spout height, rostrum shape, behavior, and absence of barnacle spots in the form of rings, and other additional attributes can be used to support the classification.

3.5.7 Physical Condition Assessment

A hierarchical system for classifying the degree of emaciation of whales was developed based on the classification system of the US-Russian photo-ID team (Weller *et al.* 2001). A whale was considered to have a deficient physical condition if it exhibited one or more of the following symptoms:

- an obvious subdermal protrusion of the scapulae from the body with associated thoracic depressions at the anterior and posterior insertions of the pectoral flipper;
- the presence of noticeable depressions around the blowhole and head with a post-cranial "hump" on the dorsal surface;
- a pronounced ridge of lumbar and caudal vertebrae along the spine giving the body a bell shape (frontal view) with bulging along the lateral flanks; and
- the presence of protruding ribs and vertebrae along the dorsal surface and/or lateral flanks or ribcage.

If any one or more of the above criteria were observed in photographs or video data, the subject animal was given a classification based on the physical condition at the time of that sighting. The final classification given to a subject animal was the highest-class number (most skinny) associated with that animal based on the analysis of available photographs for that sighting. The physical condition (BC) classes for whales were defined as follows:

class 0: standard physical condition whale showed none of the four criteria listed above;

class I: whale exhibited up to two of the four criteria listed above to a mild degree;

class II: whale exhibited more than two criteria listed above to a mild degree or up to two of the four criteria to a moderate degree;

class III: (a) whale exhibited more than two of the four criteria listed above to a moderate degree or any of the four criteria listed above to an extreme degree, but exhibited no more than two criteria in total; and

class IV: whale exhibited more than two of the four criteria listed above to an extreme degree.

The subjective terms of "mild," "moderate" and "extreme" above were agreed upon within the IBM photo-ID team by comparison of photographic and video samples. For calculations of the percentage of underweight whales relative to the total number of observed animals, only classes II to IV were used. The physical condition of class I closely resembles that of class 0 and hence the difference was considered biologically insignificant (Yakovlev and Tyurneva 2003), Tyurneva et al., 2007b).

If an animal was observed with a higher physical condition class (i.e., the whale was skinnier) during the sightings early in the season, and the physical condition class improved in subsequent sightings, we used the latest available classification of that whale during the season for the purpose of calculating the total number of underweight whales.

3.5.8 Skin Condition Assessment

While visually reviewing the photographs of individual whales throughout the season, special attention was given to individuals showing any sort of skin abnormalities. Thus far, three types of conditions have been photographed and monitored 1) skin sloughing, 2) pigmentation alteration in the form of white-grey patches of skin appearing where previously normal skin existed. and 3) wounds and scars.

Skin sloughing has been tracked for a number of individuals, although it is not observed every year (Yakovlev and Tyurneva, 2005-d). In some years, photographic examples of the entire sloughing process have been taken (2003, 2007). In these cases, the sloughing was observed to progress in stages over a few days starting at the dorsal ridge (*m1* or molting stage), then downwards on the body toward the ventral surface (*m2* stage), until all dead or damaged skin was sloughed and the whale was observed with no sign of skin sloughing days later (*m3* stage).

White patches on the skin are visually assessed (Tombach Wright et al., 2007). All skin changes are recorded to track the progression of physical condition and monitor any changes.

3.5.9 Whale Movements between Feeding Areas and Kamchatka

The current study used the sighting histories of the individual gray whales that were photographed during the field season to provide an overall assessment of the whales' seasonal and daily movements in both the Piltun and Offshore feeding areas, as well as their movement between these areas.
These data can be used to assess inter-annual movements between known feeding areas and remote regions (Yakovlev et al. 2009; Tyurneva et al, 2010d).

In 2010, bad weather conditions didn't allow the vessel team to obtain data on all cow-calf pairs that were present in the Piltun feeding area. Data from the shore-based behavioral team were more complete and were used to supplement the cow-calf information of the 2010 season.

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3.7 LITERATURE CITED

Bannister, J.L. 2000. Southern right whales off western Australia. *In*: Individual Recognition of Cetaceans: Use of Photo-ID and Other Techniques to Estimate Population Parameters. P.S. Hammond, S.A. Mizroch, and G.P. Donovan (Eds). Int. Whal. Comm. Special Issue 12. Cambridge. pp. 279-288.

Best, P., R. Payne, V. Rowntree, J.T. Palazzo and M. Do Carmo Both. 1993. Long-range movements of south Atlantac right whales *Eubalaena australis.* Mar. Mamm. Sci. 9(3): 227-234.

Blokhin, S.A., M.K. Maminov and G.M. Kosygin. 1985. On the Korean-Okhotsk Gray Whale Population. International Whaling Commission Report N 35, pp. 375-376.

Blokhin, C.A. 1996. Distribution, abundance and behaviour of the American and Asian gray whale populations (*Eschrichtius robustus*) in regions of their summer distribution along the Far East coast. Izvestiya of the Pacific Research and Fisheries Centre, Vol. 21, pp. 36-53.

Bradford, A.L. 2003. Population assessment of western north Pacific gray whales (*Eschrichtius robustus*). M.Sc. Thesis, School of Aquatic and Fishery Sciences, University of Washington, 115 p.

Bradford, A.L., D.W. Weller, A.M. Burdin, Yu.V. Ivashchenko and R.L. Brownell, Jr. 2005. Skin sloughingof gray whales *(Eschrichtius robustus)* in the Sea of Ohotsk. Abstract of 16 th Biennial Conference on the Biology of Marine Mammals, San Diego, USA. December 12-16, 2005. P. 42.

Bradford, A. L., Weller D. W., Burdin A.M. and R. L. Brownell, Jr. 2010. Using barnacle and pigmentation characteristics to identify gray whale calves on their feeding grounds. Marine Mammals Science, DOI: 10.1111/j.1748-7692.2010.00413.x

Calambokidis, J. and J. Barlow. 2004. Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Mar. Mamm. Sci. 20(1): 63-85.

Calambokidis, J., J.D. Darling, V. Deecke, P. Gearin, M. Gosho, W. Megill, C.M. Tombach, D. Goley, C. Toropova and B. Gisborne. 2002. Abundance, range and movements of a feeding aggregation of gray whales (*Eschrichtius robustus*) from California to southeastern Alaska in 1998. J. Cetacean Res. Manage. 4(3):267- 276.

Carlson, C. 2008. A Review of Whale Watch Guidelines and Regulations Around the World. Report to the IWC (International Whaling Commission). Bar Harbour, Maine.149pp.

Cerchio, S. 1998. Estimates of humpback whale abundance off Kauai, 1989 to 1993: evaluation biases associated with sampling the Hawaiian Islands breeding assemblage. Mar. Ecol. Prog. Ser. 1755: 23-34.

Clapham, P.J., L.S. Baraff, C.A. Carlson, M.A. Christian, D.K. Matilla, C.A. Mayo, M.A. Murphy and S. Pittman. 1993. Seasonal occurrence and annual return of humpback whales, Megaptera novaeangliae, in the southern Gulf of Maine. Canadian Journal of Zoology. 71, 440-443.

Clapham, P.J., L.S. Baraff, C.A. Carlson, M.A. Christian, D.K. Matilla, C.A. Mayo, M.A. Murphy and S. Pittman. 1993. Seasonal occurrence and annual return of humpback whales, *Megaptera novaeangliae*, in the southern Gulf of Maine. Canadian Journal of Zoology. Vol. 71, P. 440-443.

Cooke, J.G., A.L. Bradford, D.W. Weller, A.M. Burdin, and R.L. Brownell, Jr. 2008. Population assessment of western gray whales based on data from Piltun, Sakhalin Island. Paper RW2008-12, presented at the Wide Range Workshop, Tokyo, 18 pp.

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2006. Population assessment of western gray whales in 2006. Paper SC/60/BRG11 presented to the IWC Scientific Committee, 2006. 10 pp.

Craig, A.S. and L.M. Herman. 1997. Sex differences in site fidelity and migration of humpback whales (*Megaptera novaeangliae*) to the Hawaiian Islands. Canadian Journal of Zoology. 75: 1923-1933.

Darling, J.D. 1984. Gray Whales off Vancouver Island, British Columbia. *In*: The Gray Whale *Eschrichtius robustus*. M.L. Jones, S.L. Swartz, S.Leatherwood (Eds). Academic Press, Inc. pp 276-287.

Darling, J.D., J. Calambokidis, K.C. Balcomb, P. Bloedel, K. Flynn, A. Mochizuki, K. Mori, F. Sto, H. Suganuma and M. Yamaguchi. 1996. Movement of a humpback whale (*Megaptera novaeangliae*) from Japan to British Columbia and return. Mar. Mamm. Sci. 12(2):281-287.

Glockner-Ferrari, D.A. and M.J. Ferrari. 2000. Reproduction in the Humpback Whale (*Megaptera novaeangliae*) in Hawaiian waters, 1975-1988: the life history, reproductive rates and behavior of known individuals identified through surface and underwater photography. *In:* Individual Recognition of Cetaceans: Use of Photo-ID and Other Techniques to Estimate Population Parameters. P.S. Hammond, S.A. Mizroch, and G.P. Donovan (Eds). Int. Whal. Comm. Special Issue 12. Cambridge. pp. 161-169.

Gulland, F., MD., Nutter, F.B., Dixon, K., Calambokidis, J., Schorr, G., Barlow, J., Rowles, T., Wilkin, S., Spradlin, T, Gage, L., Mulsow, J., Reichmuth, C., Moore, M., Smith, J., Folkens, P., Hanser, S.F., Jang, S., and C.S. Baker. 2008. Health Assessment, Antibiotic Treatment, and Behavioral Responses to Herding Efforts of a Cow-Calf Pair of Humpback Whales (*Megaptera novaeangliae*) in the Sacramento River Delta, California. Aquatic Mammals. 34(2): 182-192.s

Hammond, P.S., S.A. Mizroch and G.P. Donovan. 1990. Individual recognition of cetaceans: use of Photo-ID and other techniques to estimate population parameters. Report of the Int. Whal.Comm.Special Issue 12. 440 p.

IWC (International Whaling Commission). 1996. General Principles for Whalewatching: Agreed general principles to minimize the risks of adverse impacts of whalewatching on cetaceans.

Jones M.L. and S.L. Swartz. 2002. Gray whale *Eschrishtius robustus*. In book: Encyclopedia of Marine Mammals. Eds. W.F. Perrin, Wursig B. and J.G.M. Thewissen. Academic Press, P. 524 - 536.

Mamaev, V.G. 2002. Nearshore sightings of cetaceans off the Kommander Islands In: Marine Mammals of Holarctic. Collection of scientific papers of International Conference, Baikal, Russia, 10-15 September, 2002. P.168-170.

Maminov, M.K. and Blokhin, S.A. 2004. Gray whale (Eschrishtius robustus) in coastal watersof southern Far East. In: Marine Mammals of the Holarctic. Collection of scientific papers of International Conference, Koktebel, Ukraina, 2004. P. 362-368.

McConkey, S.D. 1999. Photographic Identification of the New Zealand sea lion: a new technique. New Zealand J. of Mar. and Fresh. Res. 33(1):63-66.

Miyashita, T., S. Nishiwaki, V.A. Vladimirov and N.V. Doroshenko. 2001. Paper SC/53/RMP5 presented to the IWC Scientific Committee, July 2001 (unpublished). 12 pp.

Nikulin, V.S., A.M. Burdin, V.N. Burkanov, V.V. Vertyankin, V.V. Fomin and A.M. Mironova. 2004. Observations of large cetaceans in the Kamchatka region (1994-2003). In: The conservation of biodiversity of Kamchatka and adjacent waters. The collection of papers 5-th scientific conference, 14-22 November 2004. Petropavlovsk-Kamchatskii, Russia, pp. 226-229.

Perryman, W.L. and M.S. Lynn. 2002. Evaluation of nutritive condition and reproductive status of migrating gray whales (*Eschrichtius robustus*) based on analysis of photogrammetric data. J. Cetacean Res. Manage. 4:155-164.

Pettis, H.M., R.M. Rolland, P.K. Hamilton, S. Brault, A.R. Knowlton and S.D. Kraus. 2004. Visual health assessment of North Atlantic right whales (*Eubalaena glacialis*) using photographs. Can. J. Zool. 82:8-19.

Reeves, R.R., T.D. Smith, E.A. Josephson. 2008 Observations of western gray whales by ship-based whalers in the19th Century. International Whaling Commission, Scientific Committee. World Whaling History. SC/60/BRG7 , 19 pp.

Salden, D.R., L.M. Herman, M. Yamaguchi and F. Sato. 1999. Multiple visits of individual humpback whales (*Megaptera novaeangliae*) between the Hawaiian and Japanese winter grounds. Can. J. Zool. 77:504-508.

Sobolevsky, E.I. 2000. Marine mammal studies offshore northeast Sakhalin, 1999. Unpublished contract report by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, for

Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 149 p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Stevick, P.T., P.J. Palsboll, T.D. Smith, M.V. Bravington and P.S. Hammond. 2001. Errors in identification using natural markings: rates, sources, and effects on capture-recapture estimates of abundance. Can. J. of Fish. and Aquat. Sci. 58(9): 1861-1870.

Swartz, S.L., Taylor, B.L. and Rugh, D.J. 2006. Gray whale *Eschrichtius robustus* population and stock identity. Mammal Review. Vol. 36. N 1. P. 66-84.

Thompson, P.M. and P.S. Hammond. 1992. The use of photography to monitor dermal disease in wild bottlenose dolphins (*Tursiops truncatus*). Ambio 21:135-137.

Tombach Wright. Ch., Tyurneva, O.Yu. and Yakovlev, Yu.M. 2007. Anomalous skin conditions observed on western gray whales *Eschrichtius robustus* in northeastern Sakhalin, Russia, 2002-2006. Abstract of 17th Biennial Conference on the Biology of Marine Mammals, Cape Town, South Africa. November 29 – December 3, 2007.

Tyurneva, O.Yu. and Yakovlev, Yu. M. 2005. Skin sloughing of gray whales (*Eschrichtius robustus*) in the Sea of Ohotsk. Abstract of 16 th Biennial Conference on the Biology of Marine Mammals, San Diego, USA. December 12-16, 2005. P. 286-287.

Tyurneva, O.Yu., M.K. Maminov, E.P. Shvetsov, V.I. Fadeev, N.I. Selin and Yu.M. Yakovlev. 2006. Seasonal movements of gray whales (*Eschrichtius robustus*) between feeding areas on the northeast shelf of Sakhalin Island. In the book: Marine Mammals in the Holarctic. Collection of scientific papers of International Conference Saint-Peterburg, September 10-14, 2006. P. 530-535.

Tyurneva O.Yu., V. Vertyankin, Yu. M. Yakovlev, V.A. Vladimirov and V.N. Burkanov. 2007a. Occurrence of gray whales (*Eschrichtius robustus*) of endangered western population at east coast of Kamchatka Peninsula. In: The changing North Pacific: previous pattern, future projections, and ecosystem impact. 16 annual meeting PICES, 26 October – 5 November, 2007, Victoria, Canada. p. 153.

Tyurneva, O.Yu., Yakovlev, Yu.M., Tombach Wright, Ch. 2007 b. Application of photodentification to study body condition of western gray whales (*Eschrichtius robustus*) in northeastern Sakhalin, 2003–2006, 17th Biennial Conf. on the Biology of Marine Mammals. November 29-December 3, 2007, Cape Town, South Africa, 2007.

Tyurneva O.Yu., Fadeev V.I., Yakovlev Yu. M., V. Vertyankin V.A. 2008. Changes in the movement and distribution of western gray whales between known feeding areas in 2002-2007. Beyong observations to achieving understanding and forecasting in a changing North Pacific: forward to the future. Proceeding PICES Seventeenth Annual meeting, October 24 – November 2, 2008, Dalian, People's Republic of China. p. 120.

Tyurneva, O.Yu., V. Vertyankin, V.V., Yakovlev, Yu. M. and Selin, N.I., 2010 a. The peculiarities of foraging migrations of the Korean–Okhotsk gray whale (*Eschrichtius robustus*) population in Russian waters of the Far Eastern seas. Russian Journal of Marine Biology, 2010, Vol. 36 N 2, p. 117-124.

Tyurneva, O. Yu., Yakovlev,Yu.M., Vertyankin, V. V., Gailey, G., Sychenko, O. and Muir, J. E. 2010 b. Discovering a new feeding area for calf-cow pairs of western gray whales on the southeast shelf of Kamchatka in 2009 and their utilization of different feeding regions within one season. In the book of abstract "North Pacific Ecosystems Today, and Challenges in Understanding and Forecasting Change" International Conference PICES-2010 (North Pacific Marine Science Organization) October 22 – 31, 2010. Portland, OR, U.S.A. p. 184.

Tyurneva, O. Yu., Yakovlev, Yu. M., Vertyankin, V. V., Gailey, G., Sychenko, O. and Muir, J. E. 2010 c. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeast Sakhalin Island and southeast Kamchatka peninsula (Russia), 2009. The article SC/62/BRG submitted to the IWC 62 Scientific Committee Meeting, Agadir, Morocco, June 2010. 12 pp.

Tyurneva, O. Yu., Yakovlev, Yu. M., Vertyankin, V. V., Gailey, G., Sychenko, O. and Muir, J. E. 2010 d. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeast Sakhalin Island

and southeast Kamchatka peninsula (Russia), 2009. The article SC/62/BRG submitted to the IWC 62 Scientific Committee Meeting , Agadir, Morocco, June 2010. 12 pp.

Vertyankin, V.V., V.C. Nikulin, A.M. Bednykh and A.P. Kononov. 2004. Sighting of gray whales (Eschrichtius robustus) near southern Kamchatka. In the book: Marine Mammals in the Holarctic. Collection of scientific papers of International Conference Koktebel, Krimea, Ukraine, October 11-17, 2004. P. 126-128.

Vertyankin V.V., Vladimirov V.A., Tyurneva O.Yu. , Yakovlev Yu.M., Andreev A.V. and Burkanov V.N. 2007. Sighting of gray whales *(Eshrichtius robustus)* offshore eastern Kamchatka and in the northern Sea of Okhotsk, 2006. Scientific Committee Papers International Whaling Commission, 59 annual meeting, Anchorage, USA, 2007. electronic version SC/59/WP6, 8 pp.

Vladimirov, V.L. 1994. The modern distribution and abundance of whales in the seas of the Far East. Russian Journal of Marine Biology. Vol. 20, N 1, pp. 3-13.

Weller, D.W. and R.L. Brownell Jr. 2000. *Eschrichtius robustus* (Asian or Northwest Pacific stock). *In:* Hilton-Tayler (comp.) 2000 IUCN Red List of Threatened Species. IUCN/SSC, Gland, Switzerland and Cambridge, UK.

Weller, D.W., B.G. Würsig, A.M. Burdin, S. Reeve and A.L. Bradford. 2000. Gray whales summering off Sakhalin Island, Far East Russia: June-October 1999. A joint U.S.-Russian scientific investigation. Unpublished contract report by Texas A&M University, College Station, TX and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 69 pp. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Weller, D.W., B. Würsig and A.M. Burdin. 2001. Gray whales off Sakhalin Island, Russia: June-September 2000. A joint U.S.-Russian scientific investigation. Unpublished contract report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Petropavlosk-Kamchatkii, Russia, for Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 24 p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Weller, D.W., A.L. Bradford, A.M. Burdin, T. Miyashita, T. Kariya, A.M. Trushin, S.A. MacLean, V.A. Vladimirov and N.V. Doroshenko. 2002. Photographic recaptures of western gray whales in the Sea of Okhotsk. Report SC/54/BRG presented to the Int. Whal. Comm. Scientific Committee, 13, 8 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, G.A. Tsidulko, Y.V. Ivashchenko and R.L. Brownell Jr. 2003. Gray whales off Sakhalin Island, Russia: June-September 2001. A joint U.S.-Russian scientific investigation. Unpublished contract report by Texas A&M University, College Station, TX, Kamchatka Institute of Ecology and Nature Management, RAS, Petropavlovsk-Kamchatskii, Russia, and National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, USA for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 75 p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Weller, D.W., A.M. Burdin, A.L. Bradford, Y.V. Ivashchenko, G.A. Tsidulko, A.R. Lang and R.L. Brownell Jr. 2004. Western gray whales off Sakhalin Island, Russia: A Joint Russia-U.S. Scientific Investigation July-September 2003. Unpublished report for International Fund for Animal Welfare and International Whaling Commission by Southwest Fisheries Science Center, La Jolla, CA, Kamchatka Branch of Pacific Institute of Geography, Petropavlovsk, Russia, and the Alaska Sealife Center, Seward, AK. 41 p.

Weller, D.W., A.M Burdin, A.L. Bradford, Y.V. Ivashchenko, G.A. Tsidulko, A.R. Lang and R.L. Brownell Jr. 2005. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2004. Document SC/57/BRG1, Scientific Committee, International Whaling Commission, Cambridge, UK.

Weller, D.W., Burdin, A.M., Bradford, A.L., Lang, A.R., Tsidulko, G.A., Kim, H.W. and Brownell, R.L. Jr. 2006. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2005. Document SC/58/BRG3, Scientific Committee, International Whaling Commission, Cambridge, UK.

Weller, D.W, A.M., Bradford, A.L., Lang, H.W. Kim, N. Krukove, G.A. Tsidulko, A.M. Burdin and R.L. Brownell Jr. 2007. Status of western gray whales off northeastern Sakhalin Island, in 2006. Document SC/59/BRG19, Scientific Committee, International Whaling Commission, Cambridge, UK.

Weller, D.W., Bradford, A.L., Lang, A.R., Kim, H.W., Sidorenko, M., Tsidlko, G.A., Burdin, A.M. and R.L. Brownell Jr., 2008. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2007. Document SC/60/BRG3, Scientific Committee, International Whaling Commission, Cambridge, UK.

Wells, R.S. and M.D. Scott. 1990. Estimating bottlenose dolphin population parameters from individual identification and capture-release techniques. *In:* Individual Recognition of Cetaceans: Use of Photo-ID and Other Techniques to Estimate Population Parameters. P.S. Hammond, S.A. Mizroch, and G.P Donovan (Eds). Int. Whal. Comm. Special Issue 12. Cambridge. pp.407-415.

Whitehead, H., J. Christal and S. Dufault. 1997. Past and distant whaling and the rapid decline of sperm whales off the Galapagos Islands. Cons. Biol. 11(6): 1387-1396.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L. Bradford, S.A. Blokhin and R.L. Brownell Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Unpublished contract Report by Texas A&M University, College Station, TX and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited and Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia. 101 p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Yakovlev, Y.M. and O.Y. Tyurneva. 2003. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) population in 2002. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 27p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Yakovlev, Y.M. and O.Y. Tyurneva. 2004. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) population along the northeast coast of Sakhalin Island, Russia, 2003. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 52p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Yakovlev, Yu.M. and O.Y. Tyurneva. 2005a. A Note on Photo-Identification of the Western Gray Whales *(Eschrichtius robustus)* offshore NE Sakhalin, Russia, 2002-2004. Report SC/57/BRG9 presented to the Int. Whal. Comm. Scientific Committee, Ulsan, Korea, June 2005, (unpublished), 3pp.

Yakovlev, Yu.M. and O.Y. Tyurneva. 2005b. Photo-identification of the western gray whale (*Eschrichtius robustus)* Offshore NE Sakhalin, Russia, 2002-2004. Abstract of 14 Annual Meeting North Pacific Marine Science Organization (PICES), Vladivostok, September 29 - October 9, 2005. S3-2353, P. 35.

Yakovlev, Y.M. and O.Y. Tyurneva. 2005c. Photographic identification of gray whales (*Eschrichtius robustus*) of the Korean-Okhotsk population on the northeast shelf of Sakhalin Island, Russia, 2004. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 75p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Yakovlev, Yu.M. and Tyurneva, O.Yu. 2005 d. Skin sloughing of gray whales *Eschrichtius robustus* in the Sea of Okhotsk, 16th Biennial Conf. on the Biology of Marine Mammals. December 12-16, 2005, San Diego, California, 2005, p. 286.

Yakovlev, Y.M. and O.Yu. Tyurneva. 2006. Photographic identification of the Okhotsk-Korean gray whale (*Eschrichtius robustus*) along northeast Sakhalin Island, Russia, 2005. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 75p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com].

Yakovlev, Y.M., Tyurneva O.Yu. and V.V. Vertyankin. 2007. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island and southeastern Kamchatka, Russia, 2006. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 99 стр. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Yakovlev, Y.M. and O.Yu. Tyurneva. 2008. Photographic identification of the Korean- Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island, 2007. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 116p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Yakovlev, Y.M., Tyurneva O.Yu. and V.V. Vertyankin. 2009a. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island and southeastern shore of Kamchatka peninsula, 2008. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 160p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Yakovlev, Yu.M. Tyurneva, O.Yu. and Tombach Wright, Ch. 2009b. Seasonal movements of western gray whales *Eschrichtius robustus* between the feeding areas on the northeast coast of Sakhalin Island (Russia) in 2002 – 2006. Asian Fisheries Science. Vol. 22, N 1, P. 191-202. Available online at www.asianfisheriessociety.org

Yakovlev, Yu.M., Tyurneva, O.Yu., Vertyankin, V.V., Gailey, G., Sychenko, O., Muir, J. and Tombach Wright, Ch. 2010. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin Island and southeastern shore of Kamchatka peninsula, 2010. Final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, Chapter 3, pp. 63-111. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

CHAPTER 4

BENTHOS STUDIES IN FEEDING GROUNDS OF THE OKHOTSK-KOREAN GRAY WHALE POPULATION, 2010

METHODS AND ANALYSES[1]

Photo taken by Y.M. Yakovlev

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REPORT
ON THE RESEARCH PROJECT

BENTHOS STUDIES IN FEEDING GROUNDS OF THE OKHOTSK-KOREAN GRAY WHALE POPULATION IN 2010

METHODS AND ANALYSES

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CHAPTER 4: BENTHOS STUDIES

4.1 INTRODUCTION

Studies of benthic food resources are essential for understanding the ecology of the western gray whale (*Eschrichtius robustus*). By linking changes in their distribution and behavior to temporal and spatial changes in gray whale food resources, we gain information needed for the adaptive management of stressor mitigation and conservation. Specifically, we have a limited understanding of the factors that regulate or influence biological production (growth) of forage benthos on the northeast Sakhalin shelf, and we do not adequately understand the link between distributions of prey and the spatial or seasonal distribution and behaviour of whales. It is essential, therefore, to improve our knowledge of such trophodynamics (i.e., ecological relationships between predator and prey) including the biotic and abiotic factors shaping them. This knowledge can be used to elucidate potential impacts on the gray whale population from industrial activities, and give direction for mitigative measures designed to lessen them.

Benthos studies have been conducted annually since 2001 offshore of northeast Sakhalin Island. Research has focused on historical gray whale feeding areas such as the nearshore Piltun area seaward of Piltun Lagoon, an Intermediate area south of the Piltun area grid that includes the nearshore Chayvo subarea (i.e. a subarea of the Intermediate area), and on other areas where whales were observed feeding, such as the Offshore feeding area and feeding points (see Figure 3). To date, the benthic studies have resulted in an extensive dataset of the distribution, abundance and temporal-spatial dynamic of gray whale food resources.

The benthic program began in 2001 with a pilot study of 10 diving transects in the northeastern Sakhalin coastal zone from Niyskiy Bay in the south to Tront Bay in the north, including four transects in the area offshore of Piltun Lagoon. The resulting data demonstrated that, at depths of 5 to 15 m, the area is characterized by high abundance of gray whale prey, primarily amphipods and isopods (Fadeev 2002). A proposal was therefore developed in 2002 for a comprehensive study of benthos in four main areas (Figure 3): (i) the Piltun area, which extends from Odoptu Bay in the north to the southerly limit of Piltun Lagoon in the south, (ii) the Intermediate area located nearshore directly south of the Piltun feeding area grid, which includes a relatively small region later called the Chayvo subarea (not recognized as distinct area prior to 2006) (iii) the Offshore feeding area, located in the deeper waters to the southeast

of Chayvo Bay where large concentrations of feeding gray whales were observed in September 2001, and (iv) reference areas offshore from the Piltun area, which served as analytical controls where gray whales had not been observed feeding (this reference area was only sampled in 2002). Geographically, the Intermediate area (including the Chayvo subarea) is a southward extension of the Piltun area; therefore, it is currently considered part of the Piltun feeding area in distribution studies despite being considered separately for benthic studies (see Chapter 1). Regular grid samples of benthos, epibenthos and zooplankton were taken in the Piltun and Offshore feeding areas annually (in 2002-2010), in the Intermediate area in 2002, 2007-2009 and in the reference area only in 2002. In addition to the grid sampling, yearly samples were taken at locations where gray whales had been seen feeding; these additional sample locations are hereafter referred to as gray whale feeding points.

In 2006, feeding gray whales were sighted regularly by shore- and vessel-based observers in the nearshore waters of Chayvo Bay (within the Intermediate area) (see Fig. 3), thus we decided to sample the benthos, epibenthos and plankton in this small area to investigate upon what the whales were feeding. This area is referred to as the "Chayvo feeding subarea", and has been sampled annually since 2006.

The data obtained on the benthos composition and distribution indicated that in the Offshore feeding area, the dominant gray whale prey species were ampeliscid amphipods (Fadeev 2003, 2007). Ampeliscid amphipods are the most widespread and best-known food item in eastern gray whale feeding locations (Zimushko and Lenskaya 1970; Blokhin and Pavlyuchkov 1999; Bogoslovskaya 1996; Zenkovich 1937; Kusakin *et al.* 2001; Jones and Swartz 2002; Nerini 1984; Oliver *et al.* 1983, 1984). In comparison, the feeding grounds of the Piltun Area were dominated by epibenthic amphipods *Monoporeia affinis* that differ from ampeliscid amphipods in both ecology and their diet (Sobolevsky *et al.* 2000; Fadeev 2007).

The primary objective of this ongoing study is to quantify the distribution and status of benthos along the grid in the Piltun and Offshore feeding areas, and at the locations where whales were observed to be feeding during the field season (feeding points), in order to increase our understanding of gray whale distribution and movement in relation to prey availability. To achieve the key objectives of the study, benthic and sediment samples were analyzed to:

- obtain general information on the species composition and abundance (colony density and biomass) of individual taxonomic groups and common species of benthos from analysis of macrobenthos collected from the Piltun and Offshore areas;
- compare the benthos distribution and abundance in the Piltun and Offshore feeding areas among all years of the study;
- determine the composition, density and biomass of macrobenthos at specific gray whale feeding points;
- assess size distributions of the common species of amphipods and isopods using morphometric analysis;
- assess the influence of hydrology and particle size distribution of sediments on the production and composition of macrobenthos in the gray whale feeding areas and at gray whale feeding points;
- assess the concentrations of high-priority pollutants – petroleum hydrocarbons, heavy metals and organochlorine pesticides – in the seafloor of gray whale feeding areas.

From 2006-2008, the source of particulate organic material (POM), which is assumed to be used by key WGW prey species (e.g., amphipods) as food was investigated using stable isotope (13C and 15N) and fatty acid marker analyses (Fadeev 2009). According to literature sources, filter- and seston-feeding benthos like amphipods constitute the majority of food resources for the Eastern gray whales (Zimushko and Lenskaya 1970; Thornson 1984; Dunham and Duffus 2002). Available data on food sources of the EGWs include direct observation, i.e., stomach contents of harvested whales (Zenkovich 1934, 1937; Zimushko and Lenskaya 1970; Rice and Wolman 1971; Bogoslovskaya *et al.* 1981; Blokhin 1984; Litovka and Blokhin 2009) and diver's studies of feeding excavations of whales (Oliver and Slattery 1985; Nelson *et al.* 1994). This direct evidence is lacking for WGWs. Most whaling of WGWs took place during the migration, and their stomachs were usually empty (Andrews 1914). However, there is a growing body of data linking the distribution of feeding western gray whales with the distribution of potential prey, mainly the species of amphipods (Fadeev 2002-2009). Knowledge of the trophodynamics of prey organisms and the role of sources of particulate organic matter (POM) that support the production of these organisms is important to understand WGW ecology. Natural ratios of stable isotopes of carbon and nitrogen have been widely used to investigate the sources and flows of organic matter in a variety of marine, fresh water and terrestrial ecosystems (De Niro and Epstein 1978, Minagawa and Wada 1984; Fry 2006). These methods can be complemented by the use of trophic fatty acid markers (TFAM) that differ according to source of organic carbon. To determine the role of various sources of POM in the trophodynamics of benthic communities in northeastern Sakhalin waters, isotope ratios and fatty acids

from Piltun and Offshore whale feeding areas were compared to samples from the mouth and from within Piltun Lagoon (Fadeev 2009). Based on this analysis it was concluded that (i) amphipods and isopods in the Piltun and Offshore feeding areas feed mainly on diatom phytoplankton, or on organisms feeding on diatom phytoplankton, of which plankton Piltun Lagoon is only a minor source, (ii) bacteria attached to suspended sediment exported from Piltun Lagoon into Piltun feeding ground do not provide a significant part of the food resource for amphipods and (iii) the gray whales' main food supply (i.e., abundant species of amphipods and isopods) is mainly dependant on diatom phytoplankton.

The following chapter describes the methodology and analytical approach of the benthic studies conducted in the Sakhalin area during August–September 2010 by scientists of the Marine Biology Institute of the Far East Branch of the Russian Academy of Sciences on the research vessel Akademik Oparin.

4.2 MATERIALS AND METHODS

4.2.1 Survey Areas

In 2010, regular grid benthic samples were taken in the Piltun feeding area, the Intermediate area, the Chayvo feeding subarea, the Offshore feeding area and from gray whale feeding points. The sampling design and site selection for each year is partly based on results from previous years.

4.2.2 Background to 2010 Survey Design and Site Selection

The sampling locations in 2010 was based on previous survey years and selected as follows:

1. Grab samples were continued to be taken in the two main gray whale feeding areas, i.e., Piltun feeding area and Offshore feeding area, to gather data on the benthic distribution and abundance and to document any changes compared with previous years.

2. Since 2006, whales were regularly seen feeding in nearshore waters of the Chayvo Bay subarea. Sampling at several locations in this small subarea (30 km^2) was therefore initiated in 2006, repeated in 2007–2010.

3. In 2002, thirteen stations at depths ranging from 8 to 24 m were sampled in the Intermediate area. Because the biomass of potential gray whale prey species was low in this area and very few whales were observed, no benthic sampling was conducted there from 2003–2006. The same 13 sample locations from 2002 were repeated in 2007 (i.e., they were not randomly selected within their grid cells) in order to analyze any changes in benthos composition, density and biomass that might have occurred over the 5-year period. Benthic sampling in the Intermediate area was again conducted in 2008 (3 stations) and 2009–2010 (12 stations).

4. In 2004–2005, whales were observed feeding in unusually deep waters (>15 m) in the northern part of the Piltun feeding area. Sampling at these feeding sites determined that whales may have been feeding on concentrations of sand lance. Feeding points were recorded and samples were collected in this general area in 2006–2008. Several samples were also collected in the locations of 2004-2005 feeding points when whales were not seen to be feeding there. Sampling in 2006–2008 showed a progressive and substantial decrease in the frequency of occurrence of sand lance at these sites. Gray whales were still observed in this area, however, in lower numbers than in 2004-2005 (Fadeev, 2009). In contrast, in 2009 there were no observations of feeding gray whales in this area; therefore, no sampling was conducted. In 2010 benthic samples were collected in this area at two gray whale feeding points.

The sampling effort (station locations, type of sampling and numbers of samples) is presented in Tables 1 and 2.

4.2.3 Details of Grab Sample Collections

Two key gray whale feeding areas that were studied annually since 2002 were again sampled in 2010: (1) Piltun Feeding Area (coastal zone from Odoptu Bay to southern Piltun Lagoon) and (2) Offshore Feeding Area (30–45 km offshore from the middle of Chayvo Bay to southern Niyskiy Bay). The Chayvo feeding subarea, a small local area in the vicinity of Chayvo Bay, about 40 km south from the Piltun lagoon mouth, was studied every year since 2006 and again sampled in 2010. The entire grid of the Intermediate area, sampled in 2002, 2007, 2008 and 2009, was also sampled in 2010. A consistent approach was used in planning the locations of benthos stations in these areas, as described in more detail below.

Piltun Feeding Area

During planning of the benthic studies in 2002, the nearshore waters of the Piltun feeding area were divided into 60 sectors of equal area, comprising five blocks corresponding to the 2001 aerial survey sectors (Yazvenko *et al.* 2002). The total area of the Piltun sampling grid is approximately 1000 km^2 (Figure 1). Within each sector, the locations of the sampling stations were determined based on random number table (60 stations). A new set of 60 randomly chosen locations, one per sector, were selected each year from 2002–2006. In 2007, the same 60 sampling locations of 2002 were repeated (i.e., not selected randomly). Randomly chosen locations were again selected in 2008 and 2009-2010.

Data from previous years showed the sections of the Piltun area with the highest prey biomass were at depths <15 m. In 2002, shallow water samples were collected from the base vessel (The Nevelskoy) with the draft of only 2 m.

In 2003, and 2007-2008, benthos trawl samples were taken from a Zodiac, using a small (1:3 size replica) variant of Sigsby trawl along three transects at depths of 3–15 m. The coordinates of the trawling start and end points were recorded by GPS. In 2004–2008 , shallow water samples (3–12 m) were collected by divers close to the diving transects of 2001 and Zodiac transect of 2003. In 2009, a Petersen grab was used to take benthic samples in water depths of 3–12 m. Because the sample area of a Petersen grab is ~0.025 m^2 compared to 0.2 m^2 of the Van Veen grab, a few locations were sampled using both types of equipment in order to compare the results. However, these data are not included in this report.

Since 2007, benthos samples were taken every year in the Piltun area to study the size distribution and assess the growth rates of common amphipod and isopod species throughout the season. For this purpose, benthic samples were collected at the start and end of the expedition at several locations in the Piltun area where acoustic buoys were deployed and retrieved where these locations also had a high prey biomass. Expedition dates varied slightly from year to year, typically starting in July or early August and ending in late September or early October. In 2009–2010, 11 such stations were taken twice during the season in the Piltun area at the locations of acoustic buoys (water depths 10-11 m) to assess prey biomass and growth rates in these locations. These stations were opportunistically selected, because it was a rare and valuable occasion when the Oparin was inside the 20m isobath, and the vessel visited each location twice during the season.

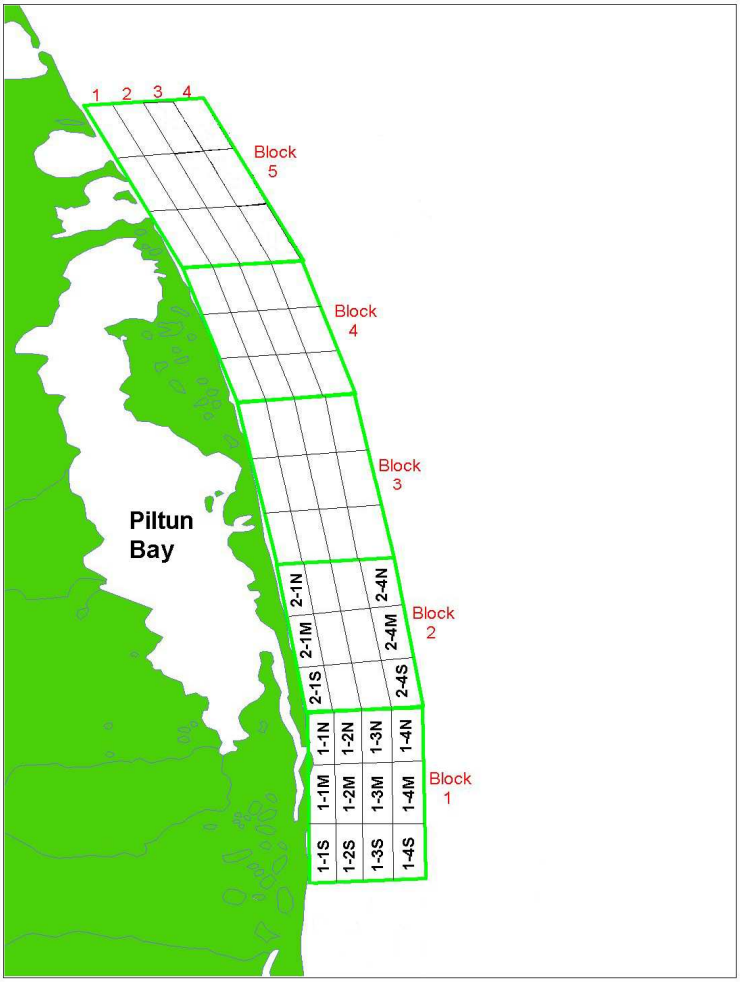

Figure 1 Benthic sampling grid of the Piltun Feeding Area (> 1000 km^2). Each year benthic and sediment samples were taken from one location in each sector, totaling 60 locations.

Table 1 Benthic samples collected from *Akademik Oparin* in August–September 2010.

Area	van Veen Grab	Epibenthic net	Bongo plankton net
	Stations/samples	samples	samples
Piltun area	76/228	0	0
Intermediate area	12/36	0	0
Chayvo area	7/21	0	0
Offshore area	48/144	0	0
Feeding points	15/45	30	60
Total	158/474	30	60

Table 2 Stations, including feeding points, diving surveys and grid location, by depth in Piltun area for 2002–2010.

Depth Range, m	Number of Stations								
	2010	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**
1 - 5	0	0	12*	14*	5*	6*	6*	0	0
6 -10	9	10	19*	18*	6*	7*	7*	10	6
11-15	21	27	33	20	16	15	6	19	25
16-20	13	11	8	18	14	12	13	7	16
21-25	16	26	15	17	14	27	14	12	20
26-30	14	19	10	14	13	15	13	10	11
31-35	9	3	6	3	3	5	5	5	2
Total	**82**	**96**	**103**	**104**	**74**	**87**	**64**	**63**	**80**

*Note: * denotes diving collections.*

Offshore Feeding Area

The sampling grid of the Offshore survey area was initially divided into 36 sectors (four rows of 9 cells), each ~50 km^2 in size (Figure 2), following the 2001 aerial survey grid (Yazvenko *et al.* 2002). The individual sectors in the Offshore area are larger than those in the Piltun area. In 2002 and 2003, one location was randomly selected within each grid cell to make a total of 36 sampling stations. In 2003, feeding gray whales were observed beyond the eastern boundary of the Offshore sampling grid (Maminov 2004), therefore the sampling grid was extended by 3 more cells to the east, for a total of 48 sectors (with a total area of over 2000 km^2). A set of 48 randomly chosen locations, one per sector, was selected in this extended grid each year from 2004–2006. In 2007, the same 48 sampling locations of 2002 were repeated. Randomly chosen locations were again sampled in 2008–2010.

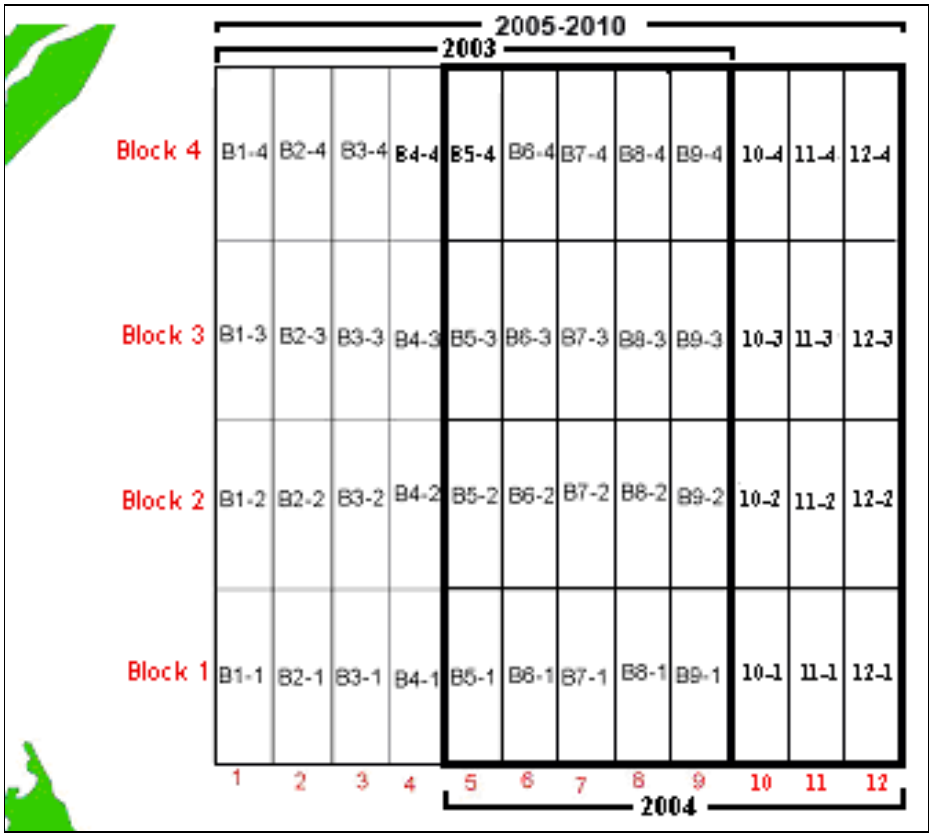

Figure 2 Benthic sampling grid in the Offshore Feeding Area (~2000 km^2). The area includes a total of 48 sectors in twelve lines oriented parallel to the coast. Lines 10, 11, and 12 have been sampled since 2005.

Intermediate Area

Stations of the Intermediate area are located south of the Piltun area and cover waters from Chayvo Bay to the western boundary of the Offshore area (Figure 3). Bottom grab samples were collected at 15 stations in 2007-2008 and at 13 stations in 2002, at depths from 8 to 24 m, with an average collection depth of 18.1±1.1 m. In 2009 and 2010, 36 samples were collected from 12 stations using a Van Veen grab.

Chayvo Feeding Subarea

Benthic sampling in this small area (~30 km^2) in the nearshore waters of Chayvo Bay started in 2006. This area is located ~40 km south from the mouth of Piltun lagoon. Based on photo-ID data, a total of 7 locations were established and sampled for benthos (Van Veen grab), epibenthos (epibenthos net) and plankton (Bongo net). In 2007–2010, the same locations were sampled again, non-randomly, to analyze any changes in the composition and abundance of gray whale prey species.

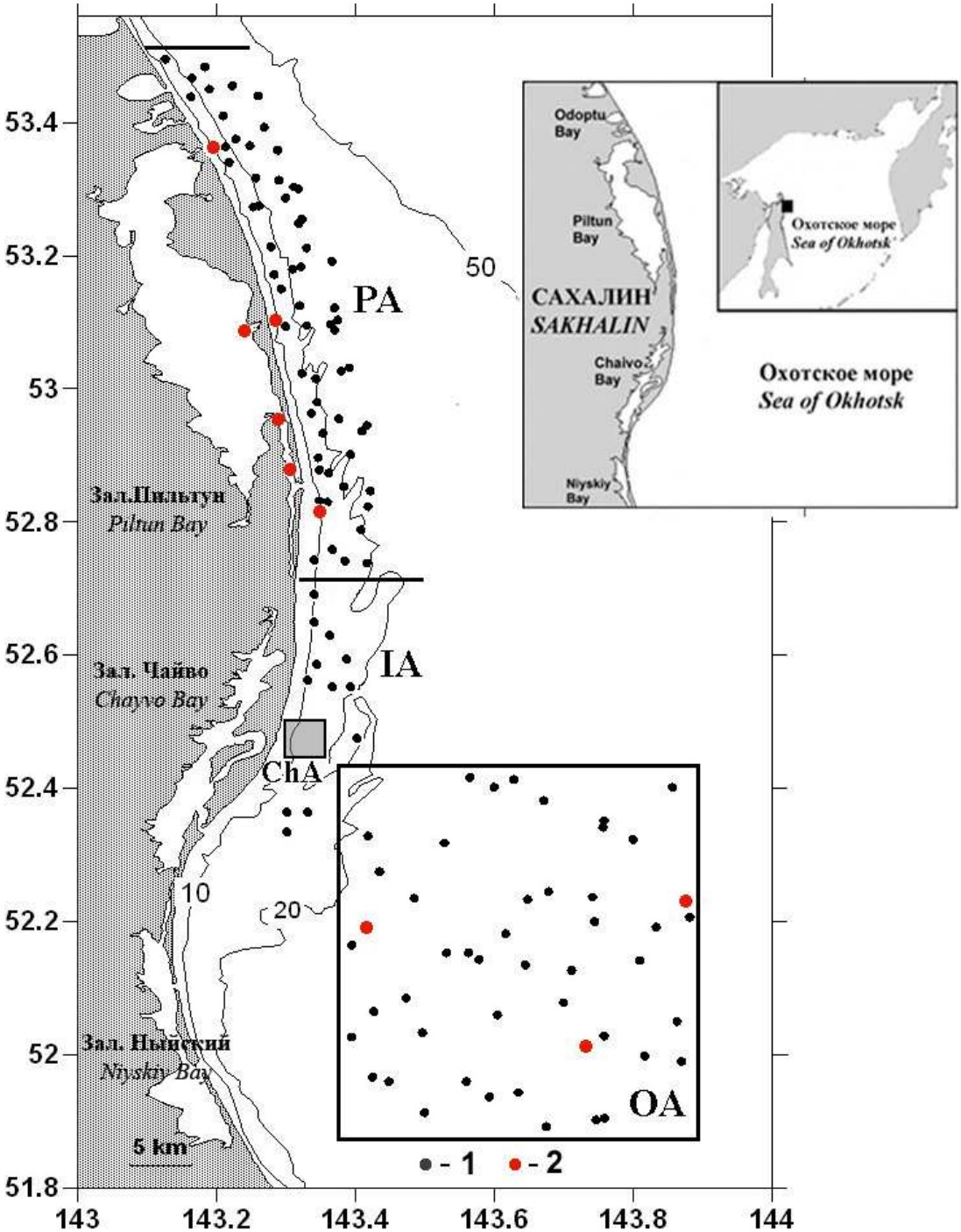

Figure 3 Locations of bottom grab sample stations in 2010. PA – Piltun Feeding Area, IA – Intermediate Area, OA – Offshore Feeding Area, ChA – Chayvo Subarea; 1 – benthic station. 2 – station for collection of animals and sediments for analysis of isotope and molecular biomarkers in 2006-2008.

Gray Whale Feeding Sites

Similar to previous years, we sampled the benthos (Van Veen grab), epibenthos (epibenthos net) and plankton (Bongo net) at locations where gray whales were observed feeding to determine what prey species gray whales may have been targeting. The locations where these samples were taken are provided in the Volume II (Results and Discussion) of this report.

4.3 FIELD SAMPLING PROTOCOLS

All benthos samples taken from the expedition vessel were obtained using a Van Veen bottom grab sampler (grab area 0.2 m^2, weight 57 kg). Each randomly selected point within a certain grid cell ("station") was sampled once during the field season, with three replicate samples taken at each station. The three replicate samples were collected in rapid succession while the vessel was drifting. The distance between the samples varied with the speed of drift from 10-150 m, with an optimal distance around 50 m. The three samples were processed and analyzed for their content separately but then their results pooled for statistical analysis to represent a combined "station". The micro- and mesoscale distributions of forage macrobenthos were studied at three stations in 2007 and 2008, and one station in 2009 by taking 10 consecutive bottom grab samples along a transect as the vessel drifted in the Piltun and Chayvo areas. Before the start of grab sampling, an underwater video recording was made of the water column and the sediment surface at each station to obtain information on plankton in the water column and of epibenthos in the water layers near the seafloor. The location at each station was determined by GPSMAP 76C, and the water depth was recorded, along with the water surface and bottom temperatures and salinities. Water temperature and salinity were recorded using a MultiLine P4 hydrologic probe (Germany) at depths to 20 m, and a Veleport SV EXTRA probe (England) at depths greater than 20 m; this probe included sensors for pressure, temperature, electrical conductivity, and dissolved oxygen concentration.

Sampling at gray whale feeding points was conducted at locations were feeding whales were observed during a photo-ID mission. Upon completion of the photo-ID mission, and only after the Zodiac and the whales had vacated the area in question, the vessel would return to the previously recorded GPS coordinates to obtain benthic prey samples using a Van Veen bottom grab sampler. In order to determine the presence of other possible food sources, an epibenthic net with an area of 0.25 m^2 was used to collect samples of epibenthos and a double Bongo net (0.1 m^2) was used for plankton collection.

Aboard the ship, all of the macrobenthos samples were washed through a sequence of three sieves: 5 mm (to remove coarse bottom fractions and large animals, such as sand dollars and molluscs), followed by 1 mm, and 0.5 mm sieve sizes, and fixed with 4% formalin. After 10 days, all the benthos and epibenthos samples were transferred to 75% ethanol. The washed (non-fixed) benthos samples were photographed with an Olympus C-1060 digital camera.

To analyze the particle size distribution and the concentrations of petroleum hydrocarbons and heavy metals in sediments, surface sediment samples were taken using a Teflon pipe sampler when these samples were collected with both Van Veen and Petersen grabs. The samples were placed in plastic bags and dishes and kept in a cooler until analysis at an onshore laboratory.

4.4 LABORATORY ANALYSES

4.4.1 Analyses of Particle Size Distribution of Bottom Sediments

Particle size distributions of bottom sediments was analyzed by the Shelf Problems Laboratory of Far East State University (DVGU) using two Russian standard methods, screen and aerometric, to determine percentages of the following size fractions (in mm): greater than 10; 10–5; 5–2; 2–1; 1–0.5; 0.5–0.25; 0.25–0.1; 0.1–0.05; 0.05–0.01; 0.01–0.005, and less than 0.005 (Petelin 1967). The methods are summarized as follows:

The moisture content (W) and specific gravity of the sediment samples were determined by standard method (Petelin 1967). Then, the sediment sample was dried and sifted through a series of mesh sizes of 10, 5, 2 and 1 mm. The sediment fractions remaining on the screens and the fraction passing through the 1 mm screen were weighed. The sediment sample was transferred to a 1000 cm^3 flask, which was then filled with distilled water (approx. 300 ml). The sediment–water mixture was allowed to stand for one day, after which 1 cm^3 of 25% ammonia solution was added to the sample flask and boiled for 1 hour before cooling to room temperature. The suspension was poured into a 1-liter glass cylinder through a 0.1 mm sieve. The soil particles retained on the 0.1 mm sieve were dried, sifted through a set of screens with mesh sizes 0.5, 0.25, and 0.1 mm, and then weighed separately. The remaining suspension was agitated for one minute until all sediment was stirred up from the bottom of the cylinder. An aerometer was introduced, and readings were taken one minute after agitation stopped (for the –0.05 mm fraction), after 30 minutes (for the –0.01 mm fraction), and after 3 hours (for the –0.005 mm fraction).

Sediment groups and types were determined according to the classification presented in Table 3.

Table 3 Sediment Classification System (Bezrukov and Lisitsyn 1960; Shepard 1976).

Sediment group	Types of sediments	Abbreviation in text	Predominant particle size, mm	Md, mm*
Coarsely clastic (psephites)	Pebbles	Peb	>10	
Coarsely clastic (psephites)	Gravel: coarse medium fine	 Grc Grm Grf	 10-5 5-2 2-1	
Sandy (psammites)	Sand: coarse medium fine	 Sc Sm Sf	 1-0.5 0.5-0.25 0.25-0.1	 1-0.5 0.5-0.25 0.25-0.1
Silt (silts)	Coarse silts Fine silt silt	Ac Af	0.1-0.05 0.05-0.01	0.1-0.05 0.05-0.01
Clay (pelites)	Coarse pelite	Pec	<0.01	0.01-0.005

Notes:
"Md, mm" is the median diameter of the soil particles in mm. Numbers in the column are the range of values for the given type of sediment.

4.4.2 Analysis of the Concentrations of Heavy Metals, Petroleum Hydrocarbons and Organochlorine Pesticides in Bottom Sediments

Heavy Metals

The concentrations of iron, zinc, chromium, copper and lead were measured using a Nippon Jarrell-Ash AA-855 atomic absorption spectrophotometer. A single-slot burner was used as the atomizer, with an acetylene-air gas mixture. A deuterium lamp was used for background correction. The test sensitivity (µg/ml) was 2 for iron; 0.02 for zinc; 0.005 for copper; and 0.02 for chromium. Aluminum and barium concentrations were measured with an acetylene-nitrous oxide gas mixture. The test sensitivity was 2 µg/ml for aluminum and 1 µg/ml for barium. Cadmium, lead and arsenic concentrations were determined on a Hitachi 170-70 atomic absorption spectrophotometer with a graphite-tube atomizer. Zeeman effect background correction was used. The test sensitivity (µg/ml) was: 0.0002 for cadmium; 0.005 for lead; and 0.02 for arsenic. Mercury concentrations were determined by the flameless atomic absorption method using a Hiranuma Hg-1 microanalyzer. The test sensitivity was 0,0001 µg/ml.

The samples were prepared for atomic absorption analysis by the accepted Russian methods, namely the procedures developed by the Azov Fishery Research Institute (RD-15-229-91 – Cd; RD-15-241-91 – Cu; RD-15-227-91 – As; RD-15-231-91 – Pb; RD-15-228-91 – Cr; RD-15-232-91 – Hg) as follows: samples of bottom sediments were dried at 105°C. One gram of the specimen, weighed with accuracy to within 0.01 g, was transferred to a glass beaker, and 10 ml of concentrated HNO_3 was added. The beaker was kept at room temperature for 24 hours, after which 5 ml of bidistilled H_2O was added, and the beaker was heated at 120°C for three hours (during which the beaker was covered with watch glass). Then, 3 ml of concentrated $HClO_4$ was added to the cooled solution, and the mixture was heated at 180°C until HCl vapor appeared. The residue was filtered and brought up to a volume of 25 ml with bidistilled H_2O in a measuring flask. Acid-soluble forms of the heavy metals (with the exception of mercury) were determined in the mineralization product.

Samples were prepared as follows for mercury assay: 1 g of a carefully homogenized specimen with natural moisture content was treated with 50% sulfuric acid and 6% potassium permanganate, with subsequent reduction of mercury with stannous chloride, according to the procedure "Determination of Total Mercury in Bottom Sediments by the Flameless Atomic Absorption Method," RD-15-226-91 developed by the Azov Fishery Research Institute.

The laboratory glassware used in the decomposition process was washed with diluted nitric acid and rinsed three times with bidistilled water.

The concentrations of zinc, copper, chromium, iron, barium, cadmium, lead, arsenic and aluminium (C, µg/g) were computed by the formula:

$C = X \cdot V/P$, where

X – concentration of the target element in the final sample solution, µg/ml;

P – sample weight, g (dry);

V – final sample solution volume, ml.

The mercury concentration in the sample (C, µg/g dry mass) was computed by the formula:

$C = X/P$, where

X – the mercury concentration in the assay sample (µg/l);

P – dry weight of the sample, g.

Upon arrival of the bottom sediment samples, they were checked for possible contamination (e.g., broken seal of the packaging) and the acceptability of the transfer conditions, and were checked for adequate sample size, after which the sample labels were checked against the accompanying documents. The sample characteristics were logged. The samples were prepared for analysis according to the procedures described above. Standard solutions of heavy (= toxic) metals were prepared from reference specimens of metals listed in the State Registry of Measures which had passed GSORM official tests.

Every spectrophotometer used had passed initial calibration according to the manufacturer's instructions. Before the analyses of bottom sediment samples, three-point calibration of the instruments was performed, and the linearity of response factors for each of the metals to be measured was checked. The relative standard deviations for the initial calibration and the subsequent calibrations were within limits of 3-5%. Three blank samples were prepared for each procedure for sample preparation for atomic absorption assays of metals.

Organochlorine pesticides

The sediments were dried at 70°C and analyzed for content of chlorinated hydrocarbons (*p,p´*-DDT, *p,p´*-DDD and *p,p´*-DDE, and α- and γ-isomers of HCCH). Chlorinated hydrocarbons were analyzed by gas-liquid chromatography according to the standard procedures of the Russian Meteorological Service (Methodological Guidelines 1996) on an LSM-8 chromatograph with a glass column (1 m × 3 mm, stationary phase SE–30, column temperature 220°C, detector temperature 250°C).

The method is based on extracting chlorinated hydrocarbons with a mixture of organic solvents (acetone-hexane), isolating the extracts with sulfuric acid and an aqueous solution of sodium sulfite in the presence of tetrabutyl ammonium (TBA) sulfate, and subsequent determination of the chlorinated hydrocarbons in the concentrated extract by gas-liquid chromatography. The substances are identified according to the retention time relative to DDE. The quantities of the substances are calculated according to the respective peak heights. When polychlorinated biphenyls (PCBs) are present in a sample, they are separated from the organochlorine pesticides (OCP) by alkaline dehydrochlorination (in an alcohol solution).

The minimum detectable quantity of DDT, DDD and DDE is 0.3-0.5 ng/g of dry bottom sediment; α-HCCH and γ-HCCH, 0.1 ng/g of dry bottom sediment.

Petroleum hydrocarbons

The sediments were dried at 70°C and analyzed for the total (gross) concentration of petroleum hydrocarbons. Petroleum hydrocarbons were extracted with n-hexane, and the content of them was determined by IR spectrophotometry according to the standard procedures of the Russian Meteorological Service (Methodological Guidelines 1996).

The method is based on extracting petroleum hydrocarbons from bottom sediment samples with a basic ethanol solution, with transfer of the component under analysis to hexane, removal of extraneous compounds by sorption onto aluminium oxide, replacement of the solvent with carbon tetrachloride, and subsequent measurement of the concentration of petroleum hydrocarbons by IR spectrophotometry. The minimum detectable quantity of petroleum hydrocarbons is 0.5 µg/g of dry bottom sediment.

4.4.3 Analysis of Benthos Samples

The macrobenthos content of sediment samples was examined to determine species composition and quantitative characteristics (biomass and count for each species and for individual taxonomic groups, and total biomass and count of macrobenthos in the sample). All animals were sorted. Large organisms were counted visually, and small ones were counted with the use of an MBS-10 binocular microscope. The wet weight of large benthic organisms was determined with a VLKT-100 electronic scale accurate to 10 mg, while the wet weight of small organisms was determined on a torsion scale accurate to 1 mg. Before weighing, the organisms were dried on filter paper for one minute.

Biomass per square meter of seafloor was calculated based on the capture area of the sampler and rounded to the nearest 0.01 g. The density of organisms per square meter was calculated and rounded to the nearest integer number. For colonial animals (Hydroidea, Bryozoa, Spongia), the number of individual colonies was counted; when it was not possible to determine the number of colonies clearly (e.g., because of fragmentation or aggregation of colonies), the number was indicated by a question mark "?" in the table. Taxonomic identification of the sample collections was done by qualified taxonomists[1] who had many years of experience with the relevant animal group. If the species was represented only by juvenile individuals (i.e., young without clear taxonomic features) so that it was

[1] The following colleagues from IBM DVO RAN and ZIN RAN took part in taxonomic identification of the major macrobenthos groups: L. L. Demchenko (amphipods), M. V. Malyutina, Ph.D. (isopods), G. M. Kamenev, Ph.D. (bivalve molluscs), V. V. Gul'bin, Ph.D. (gastropods), I.L. Alalikina (polychaetes), S. F. Chaplygina, Ph.D. (hydrozoa), V. N. Romanov, Ph.D. (ascidians), A. V. Chernyshov, Ph.D. (nemertini).

difficult to identify the species, the designation *sp. juv.* was used for the taxon name. The rate of occurrence (frequency) of species in sandy bottom sediments was assessed by determining the species frequency (P, %), which is the percentage ratio of the number of quantitative samples containing the species to the total number of quantitative samples taken in the area. This parameter partly reflects the availability of the prey to consumer species, such as the gray whale.

4.4.4 Statistical Analyses Approach

The primary basis for the statistical analysis was a data matrix in the form of a list of benthic groups or species for each station, with quantitative characteristics (abundance, biomass) of the groups or species. Unidimensional statistical parameters were estimated using Statistica 7.0 software package (StatSoft, Inc. 2006; Borovikov, 2001). Statistical parameters shown in the text and tables below are designated as following: M – mean, Sd – standard (mean square) deviation, SE – standard error, n – sample size, p – p-value. Critical p-value (alpha) for statistical tests is set at 5%.

Mean values of quantitative characteristics of the abundance of benthos were compared using Student's t-test and a single factor analysis of variance (ANOVA; Borovikov, 2001). Normality of the distribution of the quantitative characteristics was assessed using the Shapiro-Wilk test. Empirically, the quantitative characteristics of benthos abundance (number of individuals and biomass) typically do not follow a normal distribution (Shitikov et al. 2003). Therefore, to compare samplings using parametric criteria, the source data were transformed based on the shape of the empirical distribution (Elliott 1977).

The type of the benthos' distribution was determined using the dispersion index (Elliott, 1977): $I = \frac{\sigma^2}{\overline{x}}$, where σ^2 – dispersion of the density of the colony, and $\overline{x}$ – mean density of the colony. If I =1, then the distribution is random; I >1 indicates a tendency to the aggregated distribution, and I <1 – to the regular distribution. Statistical significance of I's divergence from 1 was tested using $d = \sqrt{2\chi^2} - \sqrt{2\nu - 1}$, where χ^2 – chi-square value, and ν – number of degrees of freedom. In case of a random distribution,*squareroot* (√x) or *double squareroot* (√√x) transformations were used, in case of aggregated distribution,*log* transformation was used (log x; if there were zero values log (x+1)).

The benthic communities were also described using multidimensional statistical analysis, including classification and ordination methods (Afifi and Eyzen 1982) using the statistical software package

Primer v5 (Clarke and Gorley 2001). Dendrograms were plotted using Ward's method with Bray–Curtis index:

$$S_{jk} = 100\left\{1 - \frac{\sum_{i=1}^{p}|y_{ij} - y_{ik}|}{\sum_{i=1}^{p}(y_{ij} + y_{ik})}\right\},$$

where $|y_{ij} - y_{ik}|$ absolute difference in abundance between the *i*-thspeciesand*j*-thand*k*–thspecies in the samples (Clarke and Green 1988; UNEP 1995). The significance of the differences between clusters was measured using R-statistic of the non-parametric single factor dispersion analysis (ANOSIM; Clarke and Warwick 2001).

Analysis of the lists of macrobenthos species (presence-absence of the species) in different areas and bathymetric levels was performed using the hierarchic cluster analysis (Sørensen similarity index, average linkage method) of the PAST software package (Hammer *et al.* 2001). The quality of the resulting clusters was tested using the normalized stress value (S) of the non-parametric multidimensional scaling (NMDS; Shitikov *et al.* 2003).

The entropy index of the sorting of sediments (H_s) was calculated based on the Shannon Diversity Index (H) using the formula: $H_s = -\sum p_i \times (\ln p_i)$: where p_i is the proportion of the i-th fraction in the sediment and n is the number of grain size fractions in the analysis. This measure is independent of the type of the particle-size distribution function of sediment and is determined solely by the number of the particle-size ranges in the analysis and the selected scale of fraction sizes. The normalized sorting index (H_s/H_{max}, where $H_{max} = \ln n$) ranges from 0 (completely sorted sediments) to 1 (completely unsorted sediments).

4.4.5 Mapping

Standard procedures for the SURFER 7 cartographic system (Surface Mapping System) were used to construct distribution maps of bottom-sediment and water-column parameters, pollutant concentrations, and indices of quantitative abundance of macrobenthos. The cartographic system was used only for illustrating the general nature of the parameter distributions in the study area. Therefore, the "simple planar surface" version of the polynomial regression method was used to calculate isolines. This method described in detail by Draper and Smith (1981) is good for identifying large-scale trends in spatial distribution of data. The procedure for obtaining, processing, and analyzing samples was consistent with generally accepted methods (Bilyard and Becker 1987).

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4.6 LITERATURE CITED

Andrews, R.C. 1914. Monographs of the Pacific Cetacea. I. The California gray whale (*Rhachianectes glaucus* Cope). Mem. Am. Mus. Nat. Hist. 1(5):227-87.

Afifi, A. and S. Eyzen. 1982. Statistical Analysis: Approach to Computer Use, Moscow, Mir, 488 pages.

Bezrukov, P.L. and A.P. Lisitsin. 1960. Classification of Sediments of Modern Bodies of Water // Proc. USSR Academy of Sciences Oceanology Institute, Vol. 32, pp. 3-15.

Bilyard, G.R. and S. Becker. 1987. Recommend protocols for sampling subtidal benthic macroinvertebrate assemblages in Puget Sound. US EPA.Washington, 1987. 30 p.

Blokhin, S.A. 1984. Investigations of gray whales taken in the Chukchi coastal waters, U.S.S.R. In: Jones, M. L., Swartz, S. L., and Leatherwood, S., eds., The Gray Whale: *Eschrichtius robustus*: New York, Academic Press, p.487-509.

Blokhin, S.A. and V.A. Pavlyuchkov. 1999. Feeding of Gray Whales of the California-Chukotka Population in Mechigmen Bay) // Bull. of TINRO, Vol. 126, p. 442-446.

Bogoslovskaya, L.S., L.M. Votrogov and T.M. Semenova. 1981. Feeding habits of the gray whales off the Chukotka Peninsula. Rep. Int. Whal. Comm. 31: 507-510.

Bogoslovskaya, L.C. 1996. The Gray Whale // Priroda, Issue 12. Pages 46-60.

Borovikov, V. 2001. STATISTICA: Art of analysis of data on a computer. For professionals. SPb: Piter. 656 P.

Clarke, K.R. and R.N. Gorley. 2001. PRIMER v5: User Manual/Tutorial. PRIMER-E: Plymouth. 91 P.

Clarke, K.R. and R.N. Green. 1988. Statistical design and analysis for a 'biological effects' study // Mar. Ecol. Prog. Ser. V. 46. No. 1-3. P. 213-226.

Clarke K.R., Warwick R.M. 2001. A further biodiversity index applicable to species list: variation in taxonomic distinctness // Mar. Ecol. Progr. Ser. Vol. 184. P. 265-278.

De Niro, M.J. and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. // Geochim et cosmochim. acta. V. 42, N 5. P. 495–506.

Draper, N. and H. Smith. 1981. Applied Regression Analysis. Wiley-Interscience. 709 p.

Dunham, J.S. and D.A. Duffus. 2002. Diet of gray whales (*Eschrichtius robustus*) in Clayoquot Sound, British Columbia, Canada. Marine Mammal Science 18: 419-437.

Elliott, J.M. 1977. Statistical analysis of samples of benthic invertebrates // Freshwater Biol. Ass., Sci. Publ., 1977. V. 25. 156 P.

Fadeev, V.I. 2002. SCUBA benthic research in the feeding area of the western gray whale in 2001. Unpublished final report by the Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Science, Vladivostok, Russia, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 113p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev, V.I. 2003. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2002. Unpublished contract report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 118 p. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev, V.I. 2004. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2003. Unpublished contract report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company

Limited, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev, V.I. 2005. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2004. Unpublished contract report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev, V.I. 2006. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2005. Unpublished contract report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev, V.I. 2007. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2006. Unpublished contract report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev V.I. 2007. Investigations of benthos and food resources in summer feeding areas of the Korean-Okhotsk population of the gray whale Eschrichtius robustus in 2001-2003 // Response of marine biota to environmental and climatic changes. Vladivostok: Dalnauka, 2007. P. 213-232.

Fadeev, V.I. 2008. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2007. Unpublished contract report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website http://www.sakhalinenergy.com]

Fadeev V.I. 2009. Benthos studies in feeding grounds of western gray whales off the northeast coast of Sakhalin Island (Russia), 2004-2008. // Paper SC/60/BRG24 presented to the IWC Scientific Committee, 2009. P. 1-9.

Fry, B. 2006. Stable isotope ecology. N.Y.:Springer. 308 p.

Hammer, O., Harper D.A.T. and P.D. Ryan. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9 pp. (http://palaeo-electronica.org/2001_1/past/issue1_01.htm)

Jones, M.L. and S.L. Swartz. 2002. Gray Whale (*Eschrichtius robustus*). Pp. 524-536 in The Encyclopedia of Marine Mammals, ed. by W.F. Perrin, B. Würsig, and J.G.M. Thewissen, Academic Press, San Diego, CA.

Kusakin, O.G., E.I. Sobolevsky, and S.A. Blokhin. 2001. A review of benthos investigations on the shelf of northeast Sakhalin. Draft Report by the Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, and the Pacific Research Institute of Fisheries and Oceanography (TINRO), State Comm. for Fish. and Oceanog., Vladivostok. P. 89.

Litovka D.I. and S.A. Blokhin. 2009. Investigations on Eastern Gray Whales Eschrichtius robustus (Lilljeborg, 1861), taken in Mechigmensky Bay, 2007-2008. Paper IWC/61/BRG5 presented to the International Whaling Commission (unpublished). 15 p.

Maminov, M.K. 2004. Distribution and relative abundance of gray whales of the Okhotsk- Korean population in northeastern Sakhalin waters in July-September, 2003 // Report by TINRO-Center, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia – 72 p. [available on the Sakhalin Energy Investment Company website].

Methodological Guidelines. 1996. Determination of Contaminants in Samples of Marine Bottom Sediments and Suspensions. RD 52.10.556-95. Federal Service of Russia for Hydrometeorology and Environmental Monitoring. Moscow. 50 pp.

Minagawa, M. and E. Wada E. 1984. Stepwise enrichment of 15N along food chains: Further evidence and relation between δ15N and animal age. Geochim. Cosmochim. Acta. V. 48. P. 1135-1140.

Nelson, C.H., R.L. Phillips, J. McRea Jr., J.H. Barber Jr., M.W. McLaughlin and J.L. Chin. 1994. Gray whale and Pacific walrus benthic feeding grounds and sea floor interaction in the Chukchi Sea. Technical report for Minerals Management Service, IA No. 14157, U.S. Geological Society, CA, U.S.A. 51 P. + Appendices.

Nerini, M. 1984. A review of gray whale feeding ecology. In the Gray Whale (*Eschrichtius robustus*). M.L. Jones, S.L. Swartz, Leatherwood S. (eds). Acad. Press, Inc., Orlando, Florida. P. 451-463.

Oliver J.S., and P.N. Slattery. 1985. Destruction and opportunity on the sea floor: effects of gray whale feeding. Ecology 66: 1965-1975.

Oliver, J.S., P.N. Slattery, M.A. Silberstein, and E.F. O'Connor. 1983. A comparison of gray whale feeding in the Bering Sea and Baja California // Fisheries Bull V. 81. P.:501-512.

Oliver, J.S., P.N. Slattery, M.A. Silberstein, and E.F. O'Connor. 1984. Gray whale feeding on dense ampeliscid amphipod communities near Bamfield, British Columbia // Canadian Journal of Zoology V. 62. P:41-49.

Petelin, V.P. 1967. Particle-size analysis of sea sediments. M.: Nauka. P. 36-58.

Rice, D.W. and A.A. Wolman. 1971. The Life History and Ecology of the Gray Whale (*Eschrichtius robustus*). American Society of Mammalogists, Special Publication No. 3, Stillwater, Oklahoma. viii+ 142 pp.

Shitikov V.K., Rosenberg G.S., Zinhenko T.D. Quantitative hydroecology: methods of system identification. Tolyatti: IEVB RAS, 2003.

Shepard, F.P. 1976. Marine Geology. Leningrad: Nedra. 488 pages

Sobolevsky, E.I., Y.M. Yakovlev, and O.G. Kusakin. 2000. Some Data on the Macrobenthos Composition in Gray Whale (*Eschrichtius gibbosus* Erxl., 1877) Forage Areas on the Northeastern Sakhalin Shelf // Ekologiya, 2000, № 2. Pages 144-146.

Statsoft Inc. Statistica 7; Tulsa, Statsoft. Inc. 2006.

Thornson, D.B. (ed.) 1984. Feeding ecology of Gray Whales (*Eschrichtius robustus*) in the Chirikof Basin, summer 1982. U.S. Dep. Commerce NOAA, OCSEAP Final Rep. 43: 209-460.

UNEP. 1995. Statistical analysis and interpretation of marine community data. Reference Methods for Marine Pollution Studies. UNEP. 1995. No 64. 54 p.

Yazvenko S., T. MacDonald, S.K. Meier, S. Blokhin, S.R. Johnson, V. Vladimirov, S. Lagerev, M. Maminov, E. Razlivalov, and M. Newcomer. 2002. Aerial marine mammal monitoring during the 2001 3-d seismic survey of Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia. Final Report by LGL Limited, Sidney, BC, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia. 163 p. Zenkovich, V.A. 1937. Feeding of Far East Whales// DAN USSR, Vol. 16 No. 4. Pages 231-234.

Zenkovich, B.A. 1934. Research data on cetacea of far eastern seas: Bulletin of the Far East Academy of Science, USSR, No. 10, 34 pp.

Zenkovich, B.A. 1937. More on the gray California whale (*Rhachianectes glaucus* Cope, 1864: Bulletin of the Far East Academy of Science, USSR, no. 23, 19 pp.

Zimushko, V.V. and S.A. Lenskaya. 1970. On the feeding of the gray whale (*Eschrichtius gibbosus* Erxl.) in the summer feeding areas. Ecologia 3:26-35. (in Russian).

CHAPTER 5

PATTERNS OF WESTERN GRAY WHALE BEHAVIOR, MOVEMENT, AND OCCURRENCE OFF SAKHALIN ISLAND, 2010

INTRODUCTION AND METHODS[8]

Photo taken from shore, G. Gailey

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CHAPTER 5: BEHAVIOR STUDIES

5.1 INTRODUCTION

Oil and gas development and operations offshore Sakhalin Island introduce a range of industrial activities in close proximity to areas where western gray whales are known to feed. To understand what extent these and other activities might result in disturbance, onshore behavioral surveys of western gray whales (WGWs) have been conducted every year since 2001 during the feeding season. Behavior studies provide important information on gray whale natural feeding, movement and respiration activities. Observations of behavioral responses to anthropogenic activities provide valuable information about the potential disturbance of whales due to activities that occur near or within their feeding habitat.

Observed changes in behavioral patterns can function as indicators of disturbance (natural or otherwise) that if significant enough could affect life functions, which could lead to population consequences, such as decreased survivability, growth rates, and reproduction (NRC 2005). For example, if significant adverse feeding conditions (due to either natural and/or anthropogenic causes) were observed in a given feeding season, those effects may affect survival of young during that year or affect reproduction the next year. If the disturbance was dramatic enough, it could affect adult survival, i.e. both vital rates in the NRC Population Consequences of Acoustic Disturbance (PCAD) model (NRC 2005). Therefore, marked behavioral changes due to anthropogenic activity would be a leading indicator of potential impacts on feeding activity that in turn could have population consequences.

In comparison, behavioral studies can identify population the level of effects more rapidly than other studies, such as photo-identification (photo-ID). For example, based on mark-recapture model fits using photo-ID data (post-analysis of data), detection of changes in demographic parameters, such as survival rates, reproductive success or population trends, would not be likely until at least three years of subsequent data have been collected and analyzed (Cooke, personal communication, 2009). Based on current analyses, it is also unclear how photo ID analysis could be used to distinguish between natural and anthropogenic effects.

A protective and management approach to designing mitigation measures is to identify and reduce behavioral effects caused by anthropogenic activities to low levels. When behavioral effects are minor, effects of behavioral change on life functions such as feeding should also be minor. In turn, if effects on feeding are minor, effects on adult survival or reproduction would be expected to be very small on a population level (NRC 2005). Therefore mitigation strategies designed to reduce potential behavioral effects from anthropogenic activity either in real time or in planning for future activities serves to limit the potential effects on the population.

The current behavioral research program on gray whales off Sakhalin has been ongoing since 2001, although observations have occurred there since 1997. The behavioral observation period typically starts no later than mid-July and continues through September, although there are slight variations in survey duration from year to year. Besides variations in start and end date, which, depending on year, can be adjusted to incorporate periods of planned industrial activities in the survey period, weather conditions also influence the period during which data can be gathered. In 2010, behavioral observations were initiated in early August and finished at the end of September. The relatively late onset of behavioral observations in 2010 was due to earlier behavioral monitoring and mitigation efforts for a 4-D seismic survey conducted by Sakhalin Energy approximately 20 km south of the present study area.

The main objectives of the behavior studies of WGWs are to:

- Evaluate spatial and temporal movement patterns of WGWs in relation to environmental, demographic, and potential anthropogenic activities.
- Ascertain baseline feeding and other behaviors, and assess behaviors that have the potential to be affected by anthropogenic activities.
- Evaluate inter and intra daily variation in nearshore relative abundance and geographic distribution patterns of western gray whales while providing additional information to the broader scale and less intensive distribution data collected in Chapter 2.
- Provide direct geographic and temporal indicators of how WGWs are utilizing their nearshore feeding habitat on a daily, seasonal, and annual basis to better understand their population, behavior, and spatial ecology.

5.2 METHODS

Behavioral surveys were conducted from onshore locations along the northeastern part of Sakhalin Island, Russia (Table 1). This region is known to have high concentrations of feeding WGWs, and is in

close proximity to existing and planned oil and gas developments. The use of onshore locations allows observations of behavioral patterns without disturbing the whales. Three primary observation methods were used: 1) scan sampling to obtain relative abundance estimates, distribution, and group-size information; 2) theodolite tracking of individuals or groups to describe spatial movements, orientations, speeds, and habitat use; and 3) focal follow observations to monitor surfacing-respiration-dive parameters and other surface-visible behaviors. These methods, along with the study area, are described in detail below.

5.3 STUDY AREA AND OBSERVATION STATIONS

Behavioral observations of WGWs were conducted at six geographic locations along the shore of the Piltun feeding area. These six stations have been used since 2004 and cover a 66-km stretch of coastline (**Error! Reference source not found.**). Two of the stations (2nd Station and Station 07) have been used since 2001, 1st Station and Odoptu Station were first used in 2002, and North Station and South Station were added in 2004. Each station was selected based on its height above sea level relative to the generally low dunes of the area (Table 1). In previous years, two behavioral teams conducted research at two adjacent stations on each available survey day to optimize sample size and obtain longer-term movement and respiration data on individuals (i.e. an individual traversing across two adjacent stations). However, in 2010, only one behavioral team conducted research at a single station on every good weather day. Observations took place at the southernmost station first and proceeded systematically from south to north. Data were collected at all six stations over a period of six favorable weather days. Thus, the reduction in teams decreased the amount of sampling at each station for the field season.

Table 1 Locations of six shore-based stations along the northeastern coast of Sakhalin Island, Russia. Station heights were measured in 2010.

Station Name	Latitude	Longitude	Height (m)
North Station	53° 18' 22.9"	143° 12' 35.3"	19.97
Odoptu Station	53° 12' 33.0"	143° 14' 51.4"	17.01
Station 07	53° 07' 30.0"	143° 16' 12.3"	7.68
2nd Station	53° 03' 09.1"	143° 17' 04.5"	9.44
1st Station	52° 58' 27.5"	143° 18' 06.6"	7.19
South Station	52° 53' 23.7"	143° 19' 05.5"	4.90

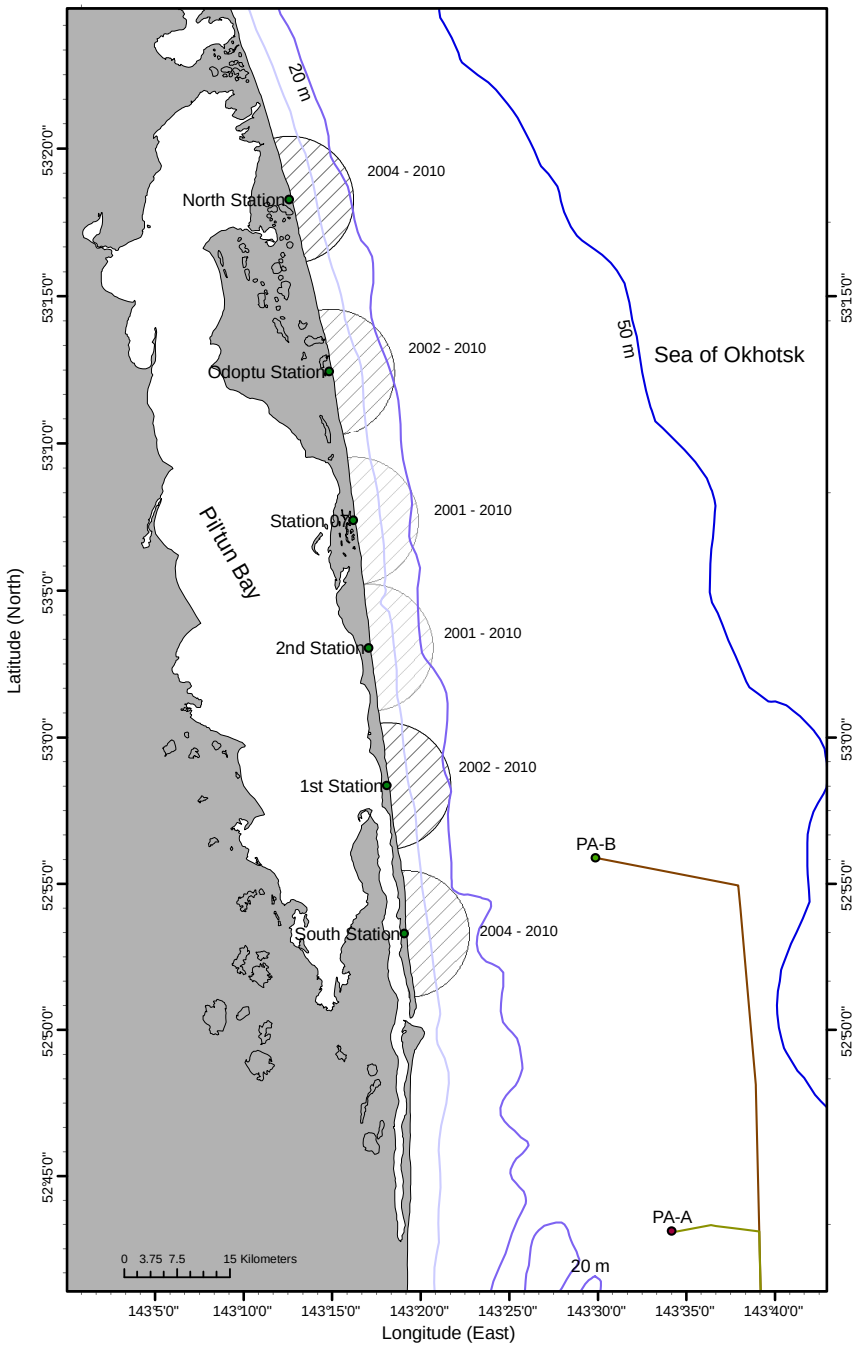

Figure 1 Geographic positions of six shore-based stations in the northeastern coastal region of Sakhalin Island, Russia. Semi-circular grids illustrate approximate viewable range (4 km) from each station. The 4-km range is used for focal follow and theodolite tracking information. Dates indicate years when data were collected at each station.

5.4 FIELD PROTOCOLS

5.4.1 Environmental Parameter Measurements

Environmental conditions can potentially influence the observational data being collected and therefore environmental data were recorded several times per day to ensure consistent and reliable data. Environmental conditions recorded included relative visibility, glare, sea state, wind speed, wind direction, cloud cover, and swell height (Tables 2 and 3). Hand-held weather stations (Kestrel 4500) were used at the observation station to automatically record atmospheric temperature, barometric pressure, wind speed, wind direction, humidity, and several other environmental parameters at 10-min intervals throughout each day of effort. Atmospheric temperature and pressure information were used to estimate a refraction correction for calculations of distance approximation (Leaper and Gordon 2001).

After each field day, the environmental data were downloaded to a computer and stored. If any of the above-mentioned environmental parameters hampered observations, then research effort was discontinued until conditions were acceptable. For scan sampling surveys, visibility conditions greater than 3 (i.e. obscured horizon) and/or Beaufort sea states > 3 were unacceptable for data collection/analyses. For focal follows and theodolite tracking, an obscured horizon (visibility code > 3) generally does not interfere with data collection and data were usually collected in these conditions. Given the animal's distance from the observation platform, theodolite tracking continued until Beaufort 5 conditions and visibility conditions < 5. If the animal was too far (> 2 km) in inclement weather conditions, then research effort was discontinued.

Table 2 Environmental parameters recorded.

Parameter	Units	Description	Estimation	Example
Station	Textual	Name of Observation Station	Computer	2nd Station
Date	Date	Date of environmental recording	Computer	12-Aug-09
Time	Time	Time of environmental recording	Computer	14:23:33
Beaufort	0-12	Beaufort scale to estimate sea state conditions	Observational	3
Visibility	1 - 5	Code to estimate visibility conditions	Observational	2
Temperature	° C	Atmospheric temperature at time of environmental recording	Weather Device	12.5
Pressure	mB	Atmospheric pressure at time of environmental recording	Weather Device	1008.5
Swell height	m	Estimated swell height at time of environmental recording	Observational	0.8
Wind Speed	km/h	Speed of wind at time of environmental recording	Weather Device	13.6
Wind Direction	Textual	Direction of the wind (N, E, S, W, NE, SSW, etc) at time of environmental recording	Weather Device	SSE
Glare	%	Percent of the observational area obscured by sun glare	Observational	10
Glare Angles	Numeric Bearings (0-360)	Magnetic bearing range from the beginning of the northern concentration of glare to the southern end of sun glare concentration that obscures observations	Observational	120-145
Cloud Cover	%	Percent of cloud coverage in the atmosphere	Observational	60
Tide	m	Predicted tide heights at time of observations. Not estimated in field.	Predicted	0.1

Table3. A) Beaufort and B) Visibility categories for environmental data recording.

(A)

Beaufort	Description	Sea conditions	Land conditions
0	Calm	Flat.	Calm. Smoke rises vertically.
1	Light air	Ripples without crests.	Wind motion visible in smoke.
2	Light breeze	Small wavelets. Crests of glassy appearance, not breaking	Wind felt on exposed skin. Leaves rustle.
3	Gentle breeze	Large wavelets. Crests begin to break; scattered whitecaps	Leaves and smaller twigs in constant motion.
4	Moderate breeze	Small waves with breaking crests. Fairly frequent white horses.	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	Moderate waves of some length. Many white horses. Small amounts of spray.	Branches of a moderate size move. Small trees begin to sway.

(B)

Visibility Code	Description	Conditions
1	Excellent	Clearly defined horizon line with no obstruction
2	Good	Little to no haze and/or rain with a relatively clear horizon line
3	Fair	Some haze and/or rain but the horizon is still visible for reticle estimation
4	Poor	No visible horizon due to fog and/or rain obstruction
5	No visiblity	No visible horizon due to fog and/or rain obstruction with visibility less than half the distance to the horizon and the observation point

5.5 SCAN SAMPLING

To monitor the relative number and distribution of WGWs in the study area, scan sampling methods were conducted hourly when focal behavior sessions were not being conducted. Two observers used hand-held binoculars (Fujinon FMTRC-SX 7x50) to progressively scan a predetermined section of the study area ranging from ~0° to 180° magnetic North (magnetic declination relative to true North was ~11.7° West in 2010). The scan direction was from north to south, meaning that each scan was initiated from the northern portion of the study area and proceeded to the southern portion. In 2001–2003, the area scanned was 140° (20° to 160°). This area was scanned in 15 min, so the scanning rate was 9.33°/min. In 2004–2008, the full 180° was scanned, with a scanning rate of 9.33°/min to be consistent with data collected in previous year. The resulting scan duration was 19.28 min. When an observer sighted a whale or group of whales, the number of whales, angular distance between the whale and the horizon (measured using binocular reticles), magnetic bearing, estimated distance from the station, and the observer who made the initial sighting were recorded. The *Pythagoras* software, developed by Gailey and Ortega-Ortiz (2002), was used to: 1) inform the observers of the approximate region they should be scanning for every 10° magnetic North, 2) provide a data entry form to record sighting information, and 3) calculate geographic position and visually display sightings in real-time.

5.6 THEODOLITE TRACKING

The spatial and temporal movement patterns of WGWs were monitored with Lietz/Sokkisha Model DT5 theodolites with 30-power monocular magnification and 5-sec precision. The theodolite tracking technique converts horizontal and vertical angles into geographic positions of latitude and longitude for each theodolite recording. The tracking of individuals over time provides information about the animals' relative speeds and orientations, which can then be analyzed alone or in relation to anthropogenic activity on the water (see Würsig *et al.* 1991, Gailey 2001, Gailey and Ortega-Ortiz 2002, and Gailey *et al.* 2004, for further description and mathematical calculations related to the use of theodolites). A theodolite tracking session was initiated when a single or a recognizable gray whale in a group could be identified and the individual was within a relatively close distance (4-5 km) from the station. Each individual was continually tracked until the animal was lost from sight, moved beyond the 4-5 km distance, or when environmental conditions hampered further tracking. For each theodolite recording, subsequently referred to as a fix, the date, time, and vertical and horizontal angles were stored in a Microsoft Access database with the relative distance, bearing referenced to true North, and geographic position calculated in real-time by the theodolite computer program *Pythagoras* (Gailey and Ortega-Ortiz 2002).

5.7 FOCAL BEHAVIOR OBSERVATIONS

Focal observations of behavior and respiration events (*sensu* Altmann 1974, Martin and Bateson 1993) were conducted on individual WGWs. A focal behavior session was initiated when all observers determined that a single whale could be monitored continuously and reliably enough so that respiration and critical behavioral events would not be missed. The reason for choosing a single or individually recognizable whale was that it was generally impossible to distinguish individuals within a group due to the low vantage points and distance from whales. A focal session was terminated if the whale moved out of the study area (~4-5 km distance from the observation station) or when the criteria for environmental conditions were exceeded (this is >3 Beaufort and/or > 3 Visibility code (see Table3. A)). At least one behavioral observer would follow individuals with the aid of hand-held binoculars (7x50). The observer verbally stated each behavioral event, and a computer operator recorded this into a laptop computer with *Pythagoras* (Gailey and Ortega-Ortiz, 2002). To minimize inter-observer variability, the behavioral observer's observations were periodically evaluated by other observers. In most focal follow sessions, behavior and respiration events were recorded simultaneously with spatial and temporal movements provided by theodolite tracking of the focal animal.

5.8 DATA ANALYSIS

5.8.1 Scan Data

Scan data provide information on the distribution and relative abundance of whales in the near shore Piltun feeding area. The number of whales and pods were analyzed using all scan data from the shore-based stations and were compared within and between each station. A fixed kernel method was used to analyze distribution patterns and evaluate if whales used some parts of the feeding area more frequently than other parts (Worton 1989). The number of whales/pods per station was evaluated for different periods during the day and for different seasons. Generally, 'summer' refers to June and July, and 'autumn' refers to August and September.

Whale sighting locations were calculated based on the observed height above sea level, geographic bearing, and distance to each sighting (see Lerczak and Hobbs 1998 for distance equations). In addition, a refraction index was used to correct for potential errors in line-of-sight estimation for distance approximation (Leaper and Gordon 2001). The refraction correction required known atmospheric temperature and pressure information which were recorded automatically at 10-min intervals by a hand-held environmental device at each observation station.

Observers at stations with higher elevations had a larger observation range and as such could see animals further from shore than observers at stations with lower heights. To standardize comparisons, a threshold distance of ≤ 6 km from the station was used in analyses that compared relative abundance between the stations. For analyses that included whale location information, such as distance from shore, a threshold of 10 km from the observation station was used. The rationale for using an increased distance threshold for these analyses was to include sightings further than 6 km from shore in the analyses.

The scan survey data were also analyzed to produce estimates of WGW densities at a 1 km^2 resolution. Since multiple scans are conducted at one station each good weather day and the number of scans varied in number among the different stations, density estimates were calculated to provide an effort corrected representation of the relative abundance of WGWs observed within the study area. To calculate the density estimates, the study area was divided into grid cells of 1.0 × 1.0 km and an average whale density was estimated for each cell. Each sighting was corrected for the probability that a gray whale was available at the surface during each survey ("availability bias") and the probability that a gray whale would be observed if it was available ("detection bias") (Marsh and Sinclair 1989). Different

combinations of the grid cell whale densities estimates for each behavioral scan survey were averaged within each grid cell to produce density surface maps at different temporal scales (e.g., monthly, seasonal) that depicted spatial distribution and abundance at a resolution of 1.0 km^2 for the behavior study area off the northeastern coast of Sakhalin Island. Further details in relation to density calculations are outlined in Chapter 2 of this volume.

5.8.2 Theodolite Data

Theodolite tracking information was evaluated in terms of each animal's relative speed, orientation, and displacement. Due to potential issues of over- or under-sampling, and to ensure that fixes within a single track were uncorrelated, each trackline was interpolated temporally, as suggested by Turchin (1998). The temporal component was based on evaluating the entire trackline dataset in terms of step lengths, turning angles, number of fixed data points and fix rate. A 90-sec interpolation criterion was based on an autocorrelation analysis performed on WGW movement patterns (see Würsig *et al.* 2002). Therefore the interpolation was conducted by starting at the first whale position in a track and then interpolating geographic positions 90-sec apart based on the actual fix data. The result of the interpolation procedure yielded tracklines with pairs of fix points (steps) separated by time intervals of ~90 sec. Due to the relatively low elevations of the observation stations, a distance threshold of 4 km from the station was used to obtain the most reliable data for analysis of speeds, orientations, and displacement (see Table 1, for station elevations and Würsig *et al.* 1991 for height-related errors).

For each interpolated trackline, the calculated leg speed, acceleration, linearity, reorientation rate, ranging index, and mean vector length were analyzed (Table 4). Leg speed is estimated by calculating the distance traveled between two sequential fixed points within a trackline divided by the time interval between these two points. Acceleration evaluates changes within leg speed to determine if an animal is generally increasing or decreasing speeds within a trackline. Linearity is an index of deviation from a straight line, calculated by dividing the net geographic distance between the first and last fix of a trackline by the cumulative distances along the track. Linearity values range between 0 and 1, with 0 indicating no net movement and 1 indicating a straight line (Batschelet 1980). Another directionality index, mean vector length (Cain 1989), was added as a movement variable due to its dependence on angular change within a trackline as opposed to distance values used in the linearity index. Mean vector length values ranged from 0 (great scatter) to 1 (all movements in the same direction) (Cain 1989). Reorientation rates represent a magnitude of bearing changes along a trackline. This rate was calculated

as the summation of absolute values of all bearing changes along a trackline divided by the entire duration of the trackline in minutes (Smultea and Würsig 1995).

A ranging index was included to measure the minimal diagonal area of the whale's track by incorporating its course and track duration (Jahoda *et al.* 2003). Furthermore, a "displacement" analysis was conducted to evaluate natural movement patterns among different behavioral states of WGWs. Displacement is defined as a straight-line distance an animal moved spatially from the start of the track (i.e., step 0) to the nth step. Confidence intervals for the displacement analysis were based on bootstrap methods. The bootstrap was conducted by randomly selecting (with replacement) i_n paths (where i_n was defined as the number of paths that have n moves), and calculating the mean squared displacement. After 1000 iterations of the bootstrap, the 95% confidence interval for each step was selected from the 26th and 975th values as the lower and upper limits, respectively. In other words, all tracks were initially included in the first step (step 0), and tracks were randomly selected with replacement to derive confidence intervals via bootstrap for that step. The procedure is repeated for each step in the analysis. Due to the nature of this analysis, all paths were used for low n steps (i.e. step 0), but as n increases, the number of paths decrease. The consequence of this is greater error bars at higher n steps (Turchin 1998).

5.8.3 Behavioral/Respiration Data

To evaluate potential behavioral changes, focal behavioral data were quantified by seven variables: 1) blow interval (times <60 s between subsequent exhalations per surfacing), 2) number of blows per surfacing, 3) surface time (duration the animal remains at or near the surface), 4) dive time (logged whenever a submerged whale did not blow for >60 s), 5) surface blow rate (mean number of exhalations per minute during a surfacing), 6) surface-dive blow rate (number of exhalations per minute averaged over the duration of a surfacing-dive cycle, using the dive previous to the surfacing) and 7) Time at Surface – percentage (0-100%) of the observation time a whale was observed at the surface (Table 4). The determination of a 60-s dive criterion was based on evaluating the bi-modal frequency distribution and survivorship analysis of all subsequent blows (regardless of time between blows), where the 60-s threshold was between the two (blows and dives) different distributions. One ~10.5-min long bin was randomly selected per behavioral observation session to address autocorrelation among bins and ensure independence of samples for analyses, and one mean was calculated for each of the six variables per 10-min bin (see next section).

Table 4 Description of the movement and respiration variables derived from track line and focal follow observations.

	Variable	Definition
Movement	Leg Speed	Distance traveled between two sequential fixed points within a trackline divided by the time interval between the two points
	Acceleration	Changes within leg speed to determine if an animal is generally increasing or decreasing speeds within a trackline
	Linearity	An index of deviation from a straight line, calculated by dividing the net geographic distance between the first and last fix of a trackline by the cumulative distances along the track
	Mean Vector Length	A directionality index r (Cain 1989) dependent on angular changes - range from 0 (great scatter) to 1 (all movements in the same direction)
	Reorientation Rate	Magnitude of bearing changes, calculated by the summation of absolute values of all bearing changes along a trackline divided by the entire duration of the trackline in minutes
	Ranging Index	Measure of the minimal diagonal area of the whale's track incorporating its course and track duration (Jahoda *et al.* 2003)
	Displacement	Straight-line distance an animal moved from the initial observation (step 0) to the nth step (step = 90 seconds) in the trackline
Respiration	Respiration Interval	Duration less than 60 s between subsequent exhalations per surfacing
	Dive Time	Any interval where exhalation period is greater than 60 s
	Surface Time	Duration the animal remains at or near the surface
	Number Blows/Surfacing	Total number of exhalations per surfacing
	Time at Surface	Percent of time animal was observed at the surface without diving
	Surface Blow Rate	Mean number of exhalations per minute during a surfacing
	Dive-Surface Blow Rate	Number of exhalations per minute averaged over the duration of a surfacing-dive cycle, using the dive previous to the surfacing

5.8.4 Theodolite and Focal Behavior Data Bins

Due to variation in duration between tracklines and focal follows, all data were binned into 10.5-minute intervals per tracking/focal follow session. Bins of 10.5 minutes were arbitrarily chosen in length as a compromise between allowing adequate time to acquire data upon which responses could be measured and the need to assess short-term behavioral responses. Similar length bins have been used in the past (Gailey *et al.*, 2007a,b) and proved adequate for meaningful analyses. "Binning" involved combining locations within intervals of time lasting approximately 10.5 min, and viewing the interval of time as the basic observation unit upon which responses and explanatory variables were measured. Each 10.5-minute interval of time was called a *bin*, and ended at an actual or interpolated geographic location. Due to non-constant track lengths, one or multiple bins were obtained for each track. For each bin, the

above-mentioned tracking and behavioral values of interest were calculated. Due to variation in the number of bins per tracking session, and to avoid pseudoreplication in analyses, one bin was randomly selected from each trackline or focal behavior session. Therefore, the sampling unit used for analyses was one bin representative per trackline or focal behavior session.

The behavioral state of WGWs was associated with each bin and classified as one of the following four levels: Feeding, Feeding/Traveling, Traveling, and Mixed. Classification of behavior into one of these four categories was based on field observations regarding a whale's predominant behavior at the time. Feeding behavior was characterized by non-directional movement where whale(s) generally remain in one localized area with consistent periods of diving. Traveling behavior was characterized as swimming in one general direction and often remaining at the surface without consistent dives. Feeding/Traveling behavior consisted of whale(s) swimming at relatively slow speeds with consistent periods of diving and having directional persistence in movement. Mixed behavior was any combination of transitional behaviors, other behaviors (such as socializing, resting, etc), or unrecognized/unknown behaviors comprising a portion of the bin.

5.8.5 Transformations

Histograms were evaluated for each of the response variables. Transformations for each non-normal distribution were performed to approximate normal distributions for analytical purposes. The distributions of linearity and mean vector length were highly skewed, non-normal in shape, and contained values that ranged from 0 to 1. The empirical logit transformation was applied to linearity and mean vector length. A small constant of 0.003 was subtracted from each observation to avoid division by zero when the original response was 1.0. The distributions of reorientation rate, range, respiration interval, dive time, blows per surfacing, and surface time were non-normal. Each of these variables were log-transformed. The square-root of leg speed and distance from shore were taken to provide an approximate normal distribution. The distribution of the number of whales and pods observed during scan were also non-normal and were log transformed (i.e., log(# whales/pods + 1).

The results of the behavioral analyses of movement, respiration, and abundance are outlined in part II (Results and Discussion) of this report.

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5.10 LITERATURE CITED

Altman, J. 1974. Observational study of behaviour, sampling methods. Behaviour 49:227-267.

Batschelet, E. 1980. Circular Statistics in Biology. Academic Press, New York, NY. 371pp.

Cain, M.L. 1989. The analysis of angular data in ecological field studies. Ecology(70): 1540-1543.

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2008. Population assessment of western gray whales in 2008. *In:* Report to the Western Gray Whale Advisory Panel. WGWAP 5. http://www.iucn.org/themes/marine/pdf/wgwap/WGWAP5.pdf

Gailey, G.A. 2001. Computer systems for photo-identification and theodolite tracking of cetaceans. M.S. thesis. Texas A&M University, College Station, TX. 125 pp.

Gailey, G.A. and J. Ortega-Ortiz. 2002. A note on a computer-based system for theodolite tracking of cetaceans. Journal of Cetacean Research & Management. 4(2): 213-218.

Gailey, G., O. Sychenko, and B. Würsig. 2004. Western gray whale behavior and movement patterns: shore-based observations off Sakhalin Island, July-September 2003, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., B. Würsig and T. McDonald. 2007a. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. Environmental Monitoring and Assessment.

Gailey, G., T. McDonald, R. Racca, O. Sychenko, A. Rutenko, and B. Würsig. 2007b. Influences of Underwater Sound and Nearshore Vessel Activity on Western Gray Whale Behavior during the Installation of a Concrete Gravity Based Structure off Sakhalin Island, Summer 2005. Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation. 150 pp.

Jahoda, M., C. Lafortuna, N. Biassoni, C. Almirante, A. Azzellino, S. Panigada, M. Zanardelli, and G. Nortarbartolo Di Sciara. 2003. Mediterranean fin whale's (*Balaenoptera Physalus*) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. Marine Mammal Science 19(1): 96-110.

Leaper, R. and J. Gorden. 2001. Application of photogrammetric methods for locating and tracking cetacean movements at sea. Journal of Cetacean Research & Management 3:131-141.

Lerczak, J.A. and R.C. Hobbs. 1998. Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. Marine Mammal Science 14:590-599.

Marsh, H. and Sinclair, D.F. 1989. Correcting for visibility bias in strip transect aerial surveys for aquatic fauna. *J. Wildl. Manage.* 53(4): 1017-24.

Martin, B., and P. Bateson. 1993. Measuring Behaviour. 2nd edition. Cambridge University Press, New York, NY.

NRC. 2005. Marine mammal populations and ocean noise: Determining when noise causes biologically significant effects. The National Academic Press. Washington, D.C. 126 pp.

Smultea, M.A. and Würsig, B. 1995. Behavioral reactions of bottlenose dolphins to the *Mega Borg* oil spill, Gulf of Mexico 1990. Aquatic Mammals 21(3):171-181.

Turchin, P. 1998. Quantitative Analysis of Movement. Sinauer Associates, Sunderland, Massachusetts. 396pp.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164-168.

Würsig, B., F. Cipriano, and M. Würsig. 1991. Dolphin movement patterns: information from radio and theodolite tracking studies. Pages 79-112 in K. Pryor and K. S. Norris, ed. Dolphin societies-discoveries and puzzles. University of California Press, Los Angeles, CA.

Würsig, B., G. Gailey, T. McDonald, R. Nielson, J.G. Ortega-Ortiz, P. Wainwright, M. Jenkerson, O. Sychenko, K. Tarasyan, and N. Brown. 2002. Western gray whale occurrence patterns and behavior: Shore-based observations off Sakhalin Island, August-September 2001. Prepared by LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. Yuzhno-Sakhalinsk, Russian Federation.