Classification: Unrestricted
Issue Purpose Approve for Use

BM Code: 17.03.07.03
April, 2013

# Sakhalin Energy Investment Company Ltd.

## WESTERN GRAY WHALE RESEARCH AND MONITIRING PROGRAM IN 2012, SAKHALIN ISLAND, RUSSIA.

## Tom 1. Methods.

**(Программа мониторинга охотско-корейской популяции серого кита у северо-восточного побережья острова Сахалин в 2012 году. Том 1. Методы.)**

**Document Number: 0000-S-90-04-T-0428-01-E**
**Revision 01**

## Document History

Filename 0000-S-90-04-T-0428-01-E

| Date | Issue | Custodian | Process Owner | Authoriser | Consulted | Distributed |
|---|---|---|---|---|---|---|
| Apr. 2013 | 01 | Larin Roman | Alexey Vladimirov | Richard Evans | | |
| | | 26.04.13 | 26.04.13. | 26-04-13 | | |

## Revision Details

| Rev | Location of Change | Brief Description of Change |
|---|---|---|
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# WESTERN GRAY WHALE RESEARCH AND MONITORING PROGRAM IN 2012, 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 2013

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# CHAPTER 1

## SAKHALIN GRAY WHALE RESEARCH AND MONITORING BACKGROUND


Photo taken by Y.M. Yakovlev


by
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March 2013


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# CHAPTER 1: RESEARCH AND MONITORING BACKGROUND

## 1.1 INTRODUCTION

Exxon Neftegas Limited (ENL), operator in the Sakhalin-1 consortium, and Sakhalin Energy Investment Company, operator in 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 gray whale (*Eschrichtius robustus*) Sakhalin congregation. Due to the critically endangered status of the gray whale, the Sakhalin feeding congregation 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 gray whale Sakhalin feeding congregation 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 gray whale Sakhalin feeding congregation ecology, and the research and monitoring programs that are being conducted.

## 1.2 ECOLOGY OF THE GRAY WHALE SAKHALIN FEEDING CONGREGATION

### *1.2.1 Population Status*

It was thought until very recently that there were 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 was 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. The wintering range for this population remained poorly understood. However, data obtained in recent years from satellite tagging of gray whales in the Sakhalin feeding congregation in 2010-2011 (Ilyashenko, 2012; Rozhnov et al., 2011) and comparative analysis of the available photo-ID catalogs of gray whales photographed in waters off the coasts of California, British Columbia, and Sakhalin have shown that a significant number of the animals that feed off the northeast Sakhalin coast during the summer and autumn migrate across the Sea of Okhotsk and the Bering Sea toward the shores of North America and as far south as California for the winter (Urban et al., 2012; Weller et al., 2012).

New genetic analyses of samples from gray whales in different regions of their West Pacific feeding range (Meschersky, 2011, 2012) performed in parallel with the above also indicate that the feeding congregation of whales residing off the Sakhalin coast during the summer-autumn season includes a substantial proportion of eastern gray whales; it is impossible to estimate just how many, however, due to a lack of information. The Scientific Committee of the International Whaling Commission (IWC) has acknowledged the uncertainty in regard to the true population status of East Sakhalin gray whales associated with the new scientific data and emphatically recommended putting maximum effort into more detailed study of the issue (Report…, 2012). Accordingly, we should for the time being refrain from further use of the term "Okhotsk-Korean (or western) population" for gray whales that gather off the Sakhalin coast and refer to them instead in a more neutral way as the "East Sakhalin feeding congregation."

The earlier gray whale populations in the western and eastern North Pacific were depleted by commercial whaling in the 19th and early- to mid- 20th centuries. As a result of strict conservation measures, the eastern population has recovered and is estimated at approximately 20,000 individuals (Laake *et al.* 2009; Punt and Wade 2010). The very existence of the western population, however, is in question; that population has probably never been large, and according to some estimates did not exceed 2,000–2,500 individuals even at its historical peak (Berzin 1974; Yablokov and Bogoslovskaya 1984). Hence it is quite likely that whaling brought that population to near extinction (Brownell and Chun 1977; Weller *et al.* 2002b). It is possible that the population had actually completely died out after 1950, and that the discovery of a pod of 20 feeding gray whales off northeastern Sakhalin near Piltun Bay on 10 September 1983 (Blokhin *et al.* 1985) was due to an influx of animals from the eastern population, which by that time had recovered fully from the deep depletion  of the abandoned western Pacific feeding range in the early 1900s (Ilyashenko, 2012).

The number of gray whales in Sakhalin waters during feeding season has increased gradually in recent years. Based on aerial survey data, the estimated population was 70-75 individuals by the late 1980's and 90-100 individuals in the late 1990's, reaching a level of approximately 120 individuals by 2004-2005, which recent research indicates is apparently close to the maximum trophic support capacity of the habitat (Vladimirov et al., 2012a, 2012b). The number of gray whales feeding in northeastern Sakhalin waters is currently estimated at approximately 130 (Tyurneva *et al.*, 2011, 2012; Vladimirov *et al.*, 2012a, 2012b).

The estimated annual mortality rate of the animals in this congregation as of 2008, based on 1994 to 2007 photo identification data, is 130 individuals (90% confidence interval 120-142), which indicates annual mortality of 22% (14-31%) for calves and 2.2% (1.3%-3.3%) for non-calves (Cooke *et al.* 2008). This population estimate is based on data collected on the Sakhalin shelf. Note, however, that some western gray whales, including yearlings that were seen the previous year with mothers nearshore Sakhalin Island, are later observed offshore eastern Kamchatka (Yakovlev and Tyurneva, 2008; Yakovlev *et al.* 2007, 2011, 2012; Vertyankin *et al*. 2007; Tyurneva *et al.* 2011, 2012). Thus, Cooke *et al.* (2008) likely underestimated the Sakhalin congregation size and overestimated its mortality rates. An updated assessment of the congregation size and survival rates of the animals will be performed in the near future.

Yearly individual identifications of gray whales 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 138 individuals (including 6 calves and 2 possible calves) from the Sakhalin gray whale catalogue were identified in both Sakhalin and Kamchatka in 2009 (Yakovlev *et al.* 2010), a total of 128 individuals (including 8 calves) in 2010 (Yakovlev *et al.* 2011), and a total of 137 individuals (including 15 calves) in 2011 (Yakovlev *et al.* 2012). Because photo ID effort is not expected to observe all whales in the population within any given year, the number of individuals identified during one season is likely an underestimate of the gray whale population size.

Surveys in 2011-2012 yielded similar results: The highest total number of whales recorded at one time in the eastern Sakhalin feeding congregation (totals of synchronized onshore counts in the Piltun area and vessel-based counts in the Offshore area) were 118 and 124 individuals, respectively (Vladimirov *et al.*, 2012a, 2012b).

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/). Gray whales in the Okhotsk-Korean population (i.e., whales in the Sakhalin feeding congregation) have also been placed in Category I (“threatened with extinction”) of the Russian Federation Red Book (2000). Lone gray whales occasionally found entangled in fishing nets off the Japanese coast in recent years and one even found in the South China Sea (Weller et Brownell, 2012) suggest that there might still be some extremely small number of whales belonging to the erstwhile western population, although the probability that the whales are migrants from the eastern (Chukotka-California) population is also rather high.

### *1.2.2 Gray Whale 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 subarctic and boreal waters (mainly in the Bering Sea, Sea of Okhotsk and Chukchi Sea). Gray whales feed at high latitudes where biomass of prey organisms is high during the summer-autumn season with limited or no ice cover. The whales 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 these portions of the feeding season largely on accumulated energy reserves stored in a layer of subcutaneous blubber.

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 have left Sakhalin waters completely by the time the sea starts to freeze. The gray whale wintering grounds were long thought to be the shallow bays on the southern coast of the Korean Peninsula (hence the name "Okhotsk-Korean population") (Rice and Wolman 1971). It was also thought that western gray whales likely winter, breed, and calve somewhere in the coastal waters of the South China Sea (Rice, 1998; Kato and Kasuya 2002; Jones and Swartz 2002, 2009; Weller *et al.* 2008). Whale migration pathways were assumed to lie along the east and west coasts of Japan, as confirmed by known past cases of entanglement of gray whales in fishing nets (Omura 1984); Cooke *et al.*, 2008). However, as described earlier, recent satellite tagging data for gray whales in the Sakhalin feeding congregation revealed that a significant number (or even a vast majority) of the animals from this congregation travel northeast across the Sea of Okhotsk and Bering Sea during their winter migration and return to the shores of Sakhalin by the same path in early summer (OSU 2011; Ilyashenko, 2012; Rozhnov *et al.*, 2012; Urban et al., 2012; Weller et al., 2012). Future tagging efforts will provide more insight on the exact gray whale migration routes, including the possible continued existence of a migration corridor southward along the Asian coast.

Recent regular sightings have placed known gray whales in the Sakhalin congregation off the eastern coast of Kamchatka (Yakovlev and Tyurneva 2008; Yakovlev *et al.* 2007, 2009, 2010, 2011, 2012). In addition, gray whales presumably from the same congregation have occasionally been observed in other coastal areas of the Sea of Okhotsk, especially near Magadan, the Shantar Islands, around the northern tip of Sakhalin Island, off Terpeniye Point, in Aniva Bay, along the Kurile Islands and along the western 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 catalogue. Two of these gray whales have been matched with the IBM catalogue.

## 1.3 MONITORING OF GRAY WHALES FROM THE SAKHALIN FEEDING CONGREGATION

### *1.3.1 Background*

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 Sakhalin gray whale feeding congregation 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 gray whales 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 for these animals were conducted.

To maximize the efficiency of the required Sakhalin gray whale feeding congregation research and monitoring studies, ENL and Sakhalin Energy initiated a joint industry-sponsored monitoring and assessment program in 2002. This program has primarily focused on the northeast Sakhalin shelf and has been conducted by scientists from leading Russian research institutes of the Far Eastern Branch of the Russian Academy of Sciences (Marine Biology Institute and POI, Vladivostok) and the All-Russian Fishery and Oceanography Research Institute (VNIRO, Moscow). In 2006, photo-ID work in Kamchatka was added to the program. The Kamchatka program included some benthic sampling (beginning in 2009). The joint ENL/Sakhalin Energy gray whale research and monitoring program is in the process of obtaining the prescribed endorsements from 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.

The primary study area of the joint ENL/ Sakhalin Energy Sakhalin gray whale feeding congregation 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 Bay and the northern part of Chayvo Bay (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 vessel-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 Sakhalin gray whale feeding, since it was the only known location where cow-calf pairs were observed until the summer-autumn season of 2008. A cow-calf pair was recorded for the first time offshore eastern Kamchatka (the cow had been observed offshore Sakhalin in previous years) (Yakovlev *et al*., 2009).

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, 2011, 2012a and b; 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, 2011).

In contrast to all other cetaceans, gray whales feed primarily on benthic (bottom dwelling) and epibenthic (near-bottom) invertebrates. A very high biomass of preferred prey items along northeastern coast of 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 Feeding Area since 2002, with average values ranging from 183.9 to 650.1 g/m$^2$ (Fadeev, 2012). Coastal feeding areas (areas offshore Piltun and Chayvo Bays) typically have lower biomass values of amphipods, ranging from 35.7±9.8 to 57.8±9.4 g/m$^2$ off Chayvo Bay and from 32.1±5.2 to 101.34±11.11 g/m$^2$ off Piltun Bay (Fadeev, 2012). 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 make foraging there more energy intensive 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, including amphipods, isopods, bivalve mollusks and worms, at depths of 5 to 15 m (Fadeev 2009-2012). In this region, the epibenthic amphipod, *Monoporeia affinis,* is the dominant species and forms the major part of the gray whale diet (Fadeev 2009). Although their preferred prey items 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 gray whales (Fadeev 2004-2012). Distribution surveys in 2004-2005 recorded higher 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, 2012).

The Offshore feeding area is characterized by patches of tube-dwelling ampeliscid amphipods with biomass up to 1351.2 $g/m^2$ (Fadeev 2003-2012) and up to 975 $g/m^2$ in 2011, with the average amphipod biomass in 2011 being 176.7±78.5 $g/m^2$ (Fadeev 2012). The density and biomass of these ampeliscid colonies are comparable to, and in some cases exceed, the corresponding 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.

### *1.3.2 Potential Impacts to Gray Whales in the Sakhalin feeding congregation*

Gray whales have a high affinity for coastal habitats. Much of the whales' life cycle is believed to take place in the coastal waters of densely populated countries with intensive fishing and shipping activities. Gray whales in the Sakhalin feeding congregation are likely exposed to anthropogenic activity during all three stages of their life cycle: (1) during whale reproduction in the wintering part of their range, the location of which needs to be determined; (2) during their long migrations between feeding grounds and wintering grounds, the exact route of which needs to be determined; and (3) in their known feeding areas off the northeast coast of Sakhalin Island and the eastern Kamchatka peninsula, Russia.

Gray whales in the Sakhalin feeding congregation 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. Five females were found entangled in fishing gear off Japan and in the South China Sea, resulting in their deaths (Weller and Brownell, 2012); this type of anthropogenic death is a serious danger to the Sakhalin congregation and possible remnants of the western population. If this anthropogenic mortality rate continues, even at a level of one individual per year, projections for the congregation suggest a 25% probability of population decline and a 10% probability of extirpation by 2050 rather than the estimated high probability (> 99%) of an increase in the size of the congregation in the absence of such mortality (Cooke *et al.* 2008).

Other potential threats to the whales 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 gray whales 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 pulsed sounds, Malme *et al.* (1986) found that ~10% of the eastern gray 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.

Gray whales in the Sakhalin feeding congregation have also been documented to respond to sounds produced during seismic surveys (Würsig *et al.* 1999; Weller *et al.* 2002a,b; Gailey *et al.* 2007; Johnson *et al*. 2007; ; 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 Sakhalin congregation's 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 aimed at assessing 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 summer/autumn feeding season in the Sakhalin feeding congregation.

### *1.3.3 Research and Monitoring Objectives*

To date, the joint ENL/ Sakhalin Energy Sakhalin gray whale feeding congregation research and monitoring program (the "joint program") has provided important information about the congregation that can be used to assess the status of this gray whale congregation and to minimize potential impacts associated with the exploration and production activities in the Sakhalin-1 and Sakhalin II projects. The joint ENL/ Sakhalin Energy Sakhalin feeding congregation gray whale research and monitoring program is designed to provide information on the following key questions:

- **How do gray whales utilize their feeding grounds offshore northeast Sakhalin on a daily, seasonal, and annual basis?**
- **What are the intra and inter seasonal variations in gray whale habitat use and gray whale movement between feeding habitats?**
- **How do individually identified gray whales inform us about the status of the population, including reproduction, survival rate and body condition?**
- **What is the benthic community composition in the gray whale feeding areas?**
- **What key prey species are targeted by gray whales, and what are the natural temporal and spatial variations in the availability of these species?**
- **How does natural variability in food benthos impact gray whale habitat use?**
- **What are the sources of the organic matter that support the production of the food benthos for gray whales?**
- **What is the level of anthropogenic pollutants (e.g., petroleum hydrocarbons, heavy metals and organochlorine pesticides) in the benthos of the gray whale feeding areas and how does it affect the biomass or composition of the benthic communities that gray whales feed on?**

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

- **Are there any observed changes in gray whale 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 gray whale distribution, movements, prey base, and behavior translate into population level processes and trends? Which changes are biologically and statistically significant, and which are not?**

The joint program presently consists of four 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 (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 Fishery and Oceanography Research Institute in Moscow (VNIRO) in collaboration with the Institute for Marine Biology (IBM) of the Far Eastern Branch of the Russian Academy of Science in Vladivostok.

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.

Note: As of 2011, a fifth component, shore-based behavioral studies measuring individual whale behavior parameters, was discontinued; the studies had been led by Texas A&M University with Russian scientists from the Far East State University in Vladivostok. Please refer to past annual reports for data and findings from this program.

This report presents the background and methods for three of these programs: distribution, photo-identification, and prey studies. Underwater sound propagation work is submitted in an additional report.


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

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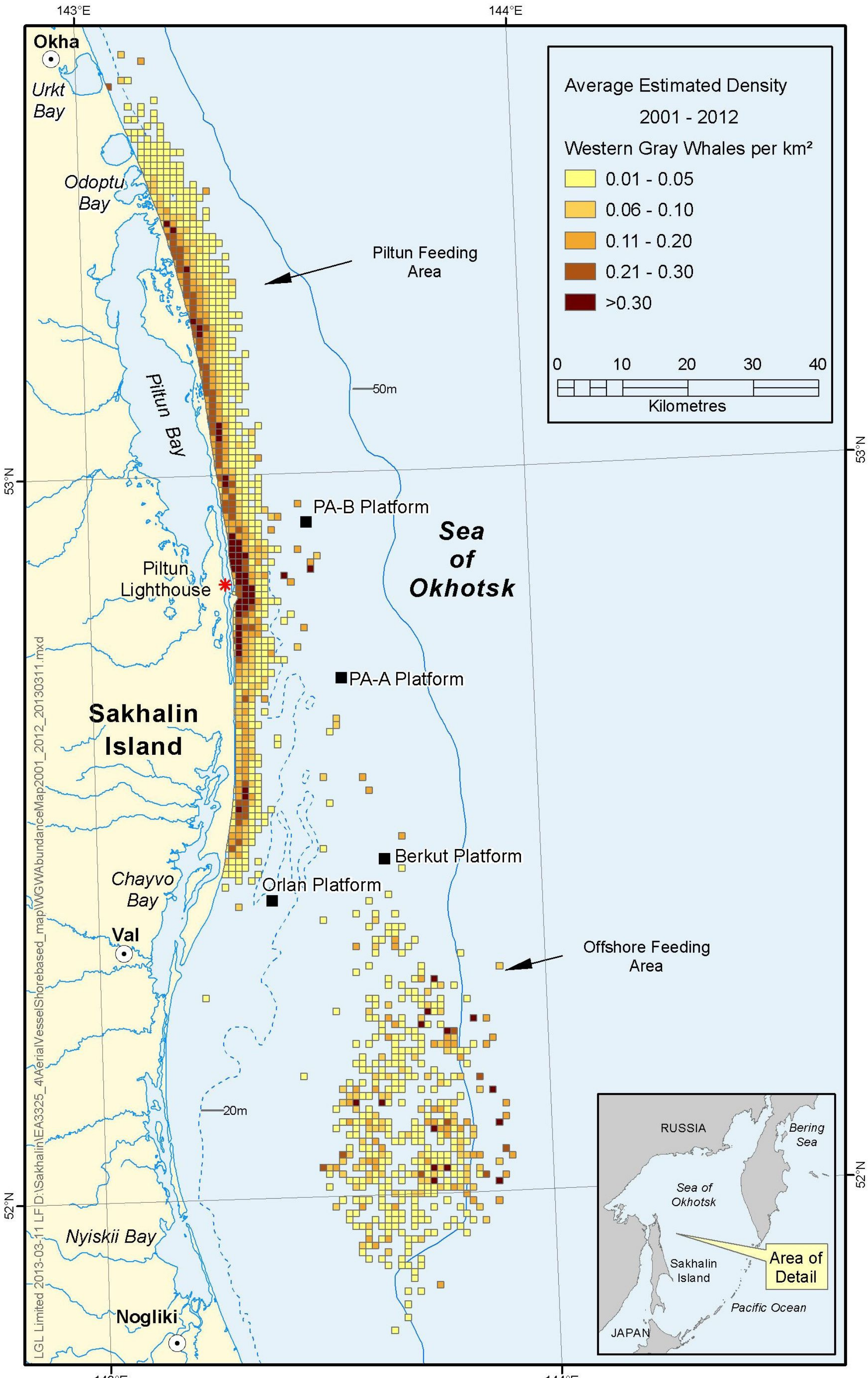


**Figure 2** Western gray whale average estimated density map based on 2001-2012 aerial, vessel and shore-based systematic survey data.

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_____________________ 2013

# CHAPTER 2

# SAKHALIN CONGREGATION GRAY WHALE DISTRIBUTION SURVEYS (VESSEL-BASED AND ONSHORE): INTRODUCTION AND METHODS

by
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Prepared for
Exxon Neftegas Limited and Sakhalin Energy Investment Company Limited

Moscow
2013

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**_______________ 2013**

# GRAY WHALE DISTRIBUTION AND ABUNDANCE OFF NORTHEAST COAST OF SAKHALIN ISLAND IN AUGUST-SEPTEMBER 2012
## (based on data from shore-based and vessel-based surveys)

**REPORT ON STUDIES**
**UNDER THE PROGRAM FOR MONITORING**
**OF THE OKHOTSK-KOREAN POPULATION OF GRAY WHALES**
**OFF THE NORTHEAST COAST OF SAKHALIN ISLAND**
**IN 2012**

## RESULTS AND DISCUSSION

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**Moscow**
**2013**

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# CHAPTER 2: DISTRIBUTION SURVEYS (VESSEL-BASED AND ONSHORE) OF SAKHALIN GRAY WHALE CONGREGATION: INTRODUCTION AND METHODS

## 2.1 INTRODUCTION

The main objective of the distribution surveys is to study and monitor spatial and temporal variation in the gray whale feeding congregation distribution and relative abundance[1] 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 congregation's 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 (Odoptu and Arkutun-Dagi fields) and Sakhalin-2 projects (Piltun-Astokh field). Shore-based surveys are performed from the Sakhalin Island eastern 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 gray whales that are using the Offshore feeding area;

[1] 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)

- gathering data on intra- and interseasonal variability in usage of the Offshore feeding area by the whales;
- monitoring the presence of and estimating relative abundance of whales 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 gray whales in the waters in the SakhalinSakhalin-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 gray whales in deeper water portions and areas outside the visibility range of the shore-based observers, i.e., south from the most southern onshore station, and from Odoptu Bay to Okha, i.e., north from the most northern onshore station.

Fixed-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 gray whales 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 gray whales 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 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 Area*

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 scanned by the onshore-based teams.

### *Offshore Area*

In 2011 the Offshore area survey design was slightly changed vs. earlier years, to allow coverage of a larger area in one day. Surveys were conducted on six transects oriented east to west that were 9 km apart. The survey area was bounded to the south and north by latitudes 51°52′ - 52°16′ N, and to the west and east by longitudes 143°30′ and 143°57′ 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 with which the Piltun gray whale feeding area is associated is partitioned into two parts by the natural channel connecting Piltun Bay to the sea. This channel is impassable by vehicles and the survey area was therefore divided into two parts – a Odoptu-Piltun (Northern) Section, covering the waters north of the mouth of Piltun Bay, and the Astokh-Chayvo (Southern) 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.

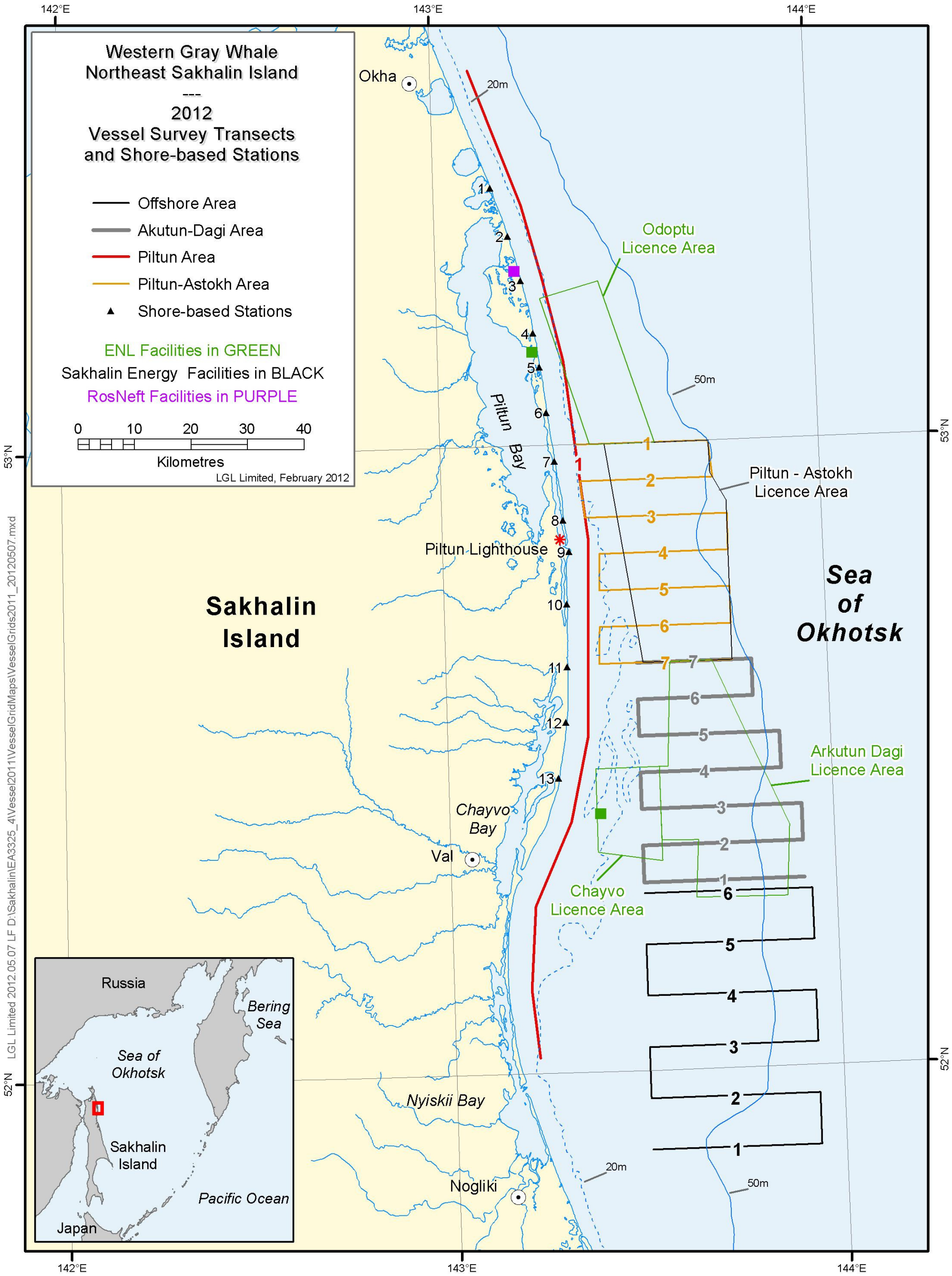


**Figure 1** Systematic vessel-based gray whale survey transects in the Piltun and Offshore feeding areas, and in the Arkutun-Dagi and Piltun-Astokh license areas in 2012. The locations of the 13 shore-based survey stations are also shown on the map.

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 zones 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, the exact station locations and station heights can change from year to year. Consequently, the station heights were regularly measured 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 shore erosion from winter storms, in 2008 at the northern eight stations, and in 2009, 2010 and 2012 at all thirteen stations. Table 1 provides geographic coordinates and other characteristics for all 13 stations measured in 2012.

**Table 1** Location of Onshore Monitoring Stations in 2012 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 | 12,4 | 14,2 | 1-2 | 9.08 |
| | 2 | 53.33517 | 143.19597 | 17,9 | 19,7 | 2-3 | 8.25 |
| | 3 | 53.26345 | 143.22717 | 33,2 | 35,0 | 3-4 | 9.53 |
| | 4 | 53.17961 | 143.25584 | 14,4 | 16,2 | 4-5 | 6.15 |
| | 5 | 53.12498 | 143.27012 | 8,7 | 10,5 | 5-6 | 8.12 |
| | 6 | 53.05245 | 143.28461 | 9,0 | 10,8 | 6-7 | 8.77 |
| | 7 | 52.97434 | 143.30208 | 8,2 | 10,0 | 7-8 | 10.03 |
| | 8 | 52.88049 | 143.31970 | 4,7 | 6,5 | 8-9 | 5.7 |
| Astokh-Chayvo section | 9 | 52,83012 | 143.33297 | 3,8 | 5,6 | 9-10 | 9,3 |
| | 10 | 52.74660 | 143.32285 | 4,6 | 6,4 | 10-11 | 11,2 |
| | 11 | 52.64637 | 143.31812 | 6,5 | 8,3 | 11-12 | 9.8 |
| | 12 | 52.55821 | 143.31059 | 8,7 | 10,5 | 12-13 | 9.6 |
| | 13 | 52.47003 | 143.28668 | 6,7 | 8,5 | | |

*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)*

*Station elevations were remeasured in 2012.*

## 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 of the "*Igor Maksimov*" scientific research vessel, 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 9.9 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 behavior, 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 Terpeniya.

***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 whale 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 gray whales (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 100-series Toyota Land Cruisers. 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, and 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 unfavorable 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) seemed the most efficient to the survey team, provided the data were analyzed consecutively.

The shore-based whale surveys were conducted using a continuous scan of the nearshore waters surrounding an observation station. 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/s 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 whales 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. Dot maps of whale sightings were also compiled after each survey. Tabular survey data and maps were transmitted to an authorized representative of SEIC as they were prepared.

Since there is no direct or indirect impact on the gray whale population during shore-based visual surveys, no special steps were taken to minimize the effect of the studies on the animals.

## 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" $\alpha$ and $\beta$, respectively) and the horizontal angle between the points (Figure 2 "Top-Down View" $\gamma$). The height of the theodolite's eyepiece relative to 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.

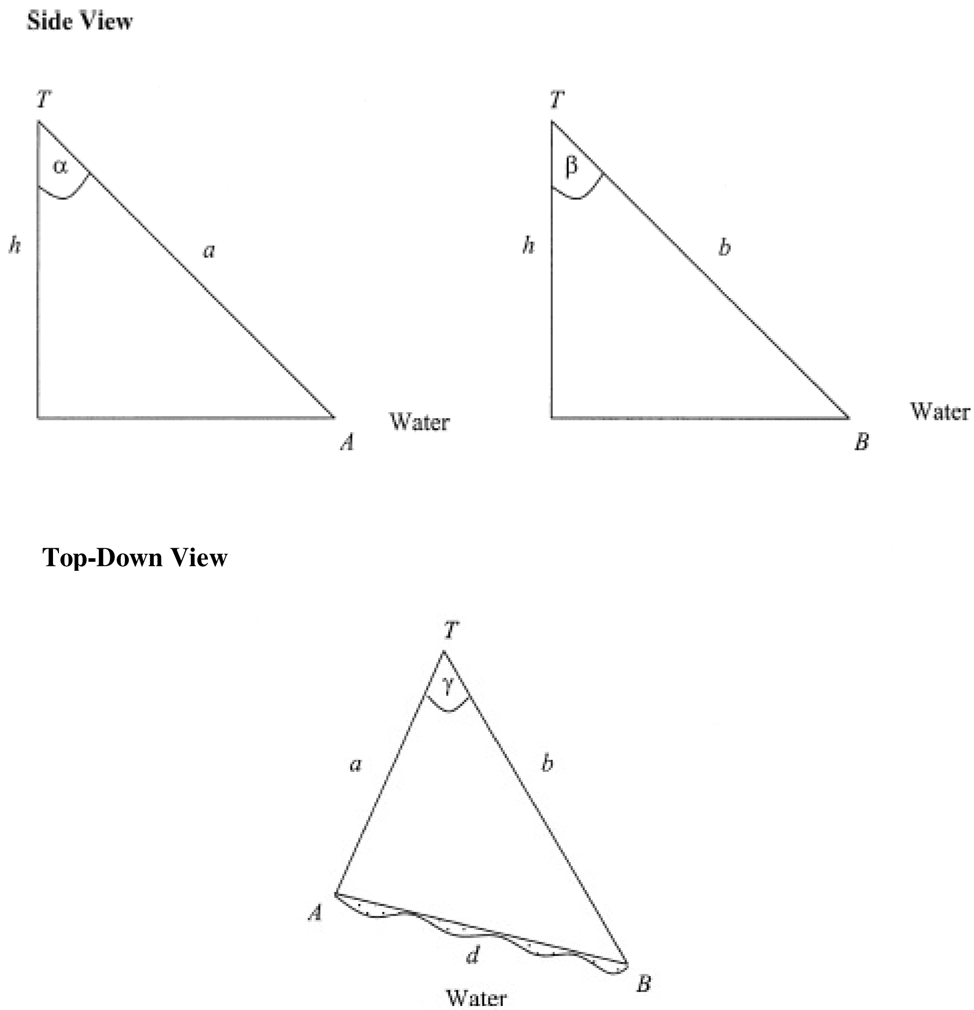


**Figure 2** Schematic for determining theodolite altitude (T is the position of the theodolite).

## 2.5 DATA ANALYSIS AND MAPPING

Calculation of whale 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-based, and shore-based distribution surveys and is expanded each year with the new data collected. Information on relative whale abundance and distribution is obtained by estimating the whale densities using the method outlined in the Density Analysis section below. Calculation of gray whale densities made it possible to combine data collected from different observer platforms. All 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 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:

$\alpha$ - the angle between a horizontal line (90°) and the horizon;

$\beta$ - the angle between the Observer and the target;

$\delta$ - the arc between the Observer and the target;

$\theta$ - 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:

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

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

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

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

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

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

where:

$\gamma$- 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;

$\beta$ - the angle between the observer and the target;

$\delta$ - the arc between the observer and the target;

$\theta$ - 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 $(6.371\times10^6\ \text{m})$;

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 ($\beta$) and between the target and the horizon ($\theta$) 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 ($\alpha_c, \theta_c$) 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 $\theta_c$, then substituting $\theta_c$ for $\theta$ 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 $\Phi_2$ and $\lambda_2$ - latitude and longitude coordinates of the animal's location, respectively (in decimal degrees)

$\phi_1$ and $\lambda_1$ - 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);

$\phi_{cp}$ - average latitude, computed by the formula below:

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

The water depth at the sighting location and the distance to shore for each whale sighting were 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 gray whale density (whales/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 whales 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 whale 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 whales 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 whale surface-respiration-dive cycle behavior (Würsig *et al.* 2002, 2003; Gailey *et al.*, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011).

2. Perception bias: This is the probability that an observer perceives an available whale. 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 whale 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 whale sightings made from a transect. The detection probability was then used in the calculation of whale 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 observing whales in shallow waters sharply decreased in this area due to difficulties in detecting whale blows against the light colored shore background, and the fact that whale blows are typically smaller in shallower waters. Accordingly, no whale density 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 Arkutun-Dagi, Offshore, or Piltun survey areas, and no survey monitoring was performed.

- 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 whale 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 2012 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) | Gray Whale Truncation Distance (m) at Tide Height of -1.5 m | Gray Whale Truncation Distance (m) at Tide Height of 0 m | Gray Whale Truncation Distance (m) at Tide Height 1.5 m |
|---|---|---|---|---|
| 1 | 12,4 | 7781 | 7277 | 6752 |
| 2 | 17,9 | 8000 (9485) | 8000 (9040) | 8000 (8581) |
| 3 | 33,2 | 8000 (13467) | 8000 (13112) | 8000 (12750) |
| 4 | 14,4 | 8000 (8424) | 7945 | 7447 |
| 5 | 8,7 | 6499 | 5936 | 5343 |
| 6 | 9,0 | 6608 | 6051 | 5464 |
| 7 | 8,2 | 6314 | 5742 | 5137 |
| 8 | 4,7 | 4926 | 4264 | 3544 |
| 9 | 3,8 | 4535 | 3840 | 3075 |
| 10 | 4,6 | 4884 | 4218 | 3493 |
| 11 | 6,5 | 5664 | 5053 | 4401 |
| 12 | 8,7 | 6499 | 5936 | 5343 |
| 13 | 6,7 | 5742 | 5137 | 4490 |

A whale 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) whale 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).

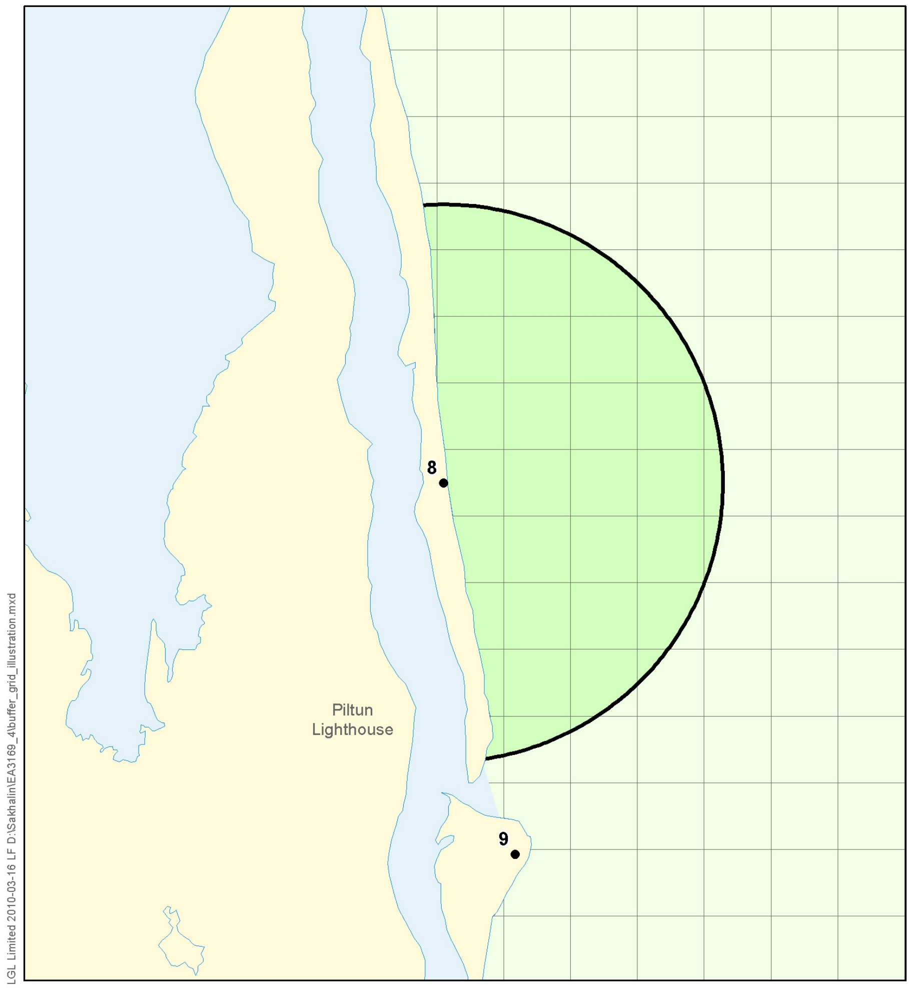


**Figure 3** An example of the surveyed area for station 8 is shown as the black semicircle outline. The green grid cells show the overlap of the area surveyed by the station with the 1 km by 1 km grid cells used in the density analysis. The area of each green grid cell represents the survey effort by 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.

As mentioned above, gray whale sightings beyond the truncation distances 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 whale density surface maps by month and for the entire field season that depict the spatial distribution and abundance of the animals 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 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 methodology 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 analysis of the data collected in 2012 and comparison with those data collected in previous years is described and discussed in Volume II, Chapter 1 of this 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 have been excluded from the density analysis described above and 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 whales were also observed in the Piltun feeding area beyond the shoreward end of the Piltun-Astokh transects.

## 2.7 ACKNOWLEDGEMENTS

We thank the sponsors of this program (ENL and Sakhalin Energy) for their assistance and support in the development of the methodology used to monitor the distribution and abundance of whales in the Sakhalin feeding congregation.

We also wish to thank many individuals who have contributed to the WGW distribution and abundance studies: S.A. Blokhin, , M.K. Maminov and A.S. Perlov (TINRO-Center), N.V. Doroshenko (Far Eastern State Technical University), A.V. Vladimirov (SEIC), V.V. Melnikov (POI FEB RAS) and S.P. Starodymov (VNIRO) for their work on the initial concept of the shore-based and vessel surveys, design of survey transects and locations of shore observation stations, and development of survey protocols, S.R. Johnson, P. Wainwright and S. Yazvenko (LGL Limited) for initial survey design and development of methodology to calculate sighting locations and WGW densities, J. Hall (ExxonMobil) for assistance and encouragement in further development of the WGW density analysis methodology, W. Koski (LGL Limited) for providing formulas to calculate the availability correction used in the WGW density analysis, L. Thomas (University of St. Andrews) for a valuable review of the WGW density analysis methodology, D. Gillespie (University of St. Andrews) for providing the algorithms to calculate the refraction correction.

We are grateful to Alexei Vladimivov (SEIC), Yuri Bychkov and Sergei Yazvenko (LGL Limited) for providing valuable edits and comments that improved upon earlier versions of this report. We also wish to thank Robin Tamasi and Lucia Ferreira (LGL Limited) for mapping assistance.

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# CHAPTER 3

# PHOTOGRAPHIC IDENTIFICATION OF THE WESTERN GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*) OFFSHORE NORTHEASTERN SAKHALIN ISLAND AND SOUTHEASTERN SHORE OF KAMCHATKA PENINSULA, 2012

## METHODS AND ANALYSES[1]

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March 2013

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[1] Chapter 3 *In* 2013. Western gray whale research and monitoring program in 2012, Sakhalin Island, Russia. Volume I Background and methods

Russian Academy of Sciences
Far East Branch

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RESEARCH REPORT

# Photo-ID of the Gray Whales (*Eschrichtius robustus*) Offshore Northeastern Sakhalin Island and Southeastern Kamchatka Peninsula, 2013

METHODS AND ANALYSIS

Yu.M. Yakovlev, O.M. Tyurneva i V.V. Vertyankin

VLADIVOSTOK
2013

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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 2005a,c,d; 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 Other Areas*

Photo ID studies were also conducted along the east coast of the Kamchatka Peninsula in 2004 on Khalaktyr Beach south of Cape Nalycheva along the central coast, i.e., at 53°11’ N – 159°42’ E, and, starting in 2006, in two areas that included Olga Bay (54°34’ N – 160°57’ E) and Vestnik Bay (51°28’ N – 157°34’ E) (see Chapter, Figure 1). These two areas are located approximately 600 km apart and are separated by a rocky coast that is probably unsuitable for gray whale foraging. The shorelines of the two bays are reminiscent of the shore of Piltun Bay because of their low-lying coast with sandy beaches. The beach in Vestnik Bay is approximately 23 km long (shoreline direction 80°-260°), while Khalaktyr Beach is approximately 25 km long (shoreline direction 65°-245°), and the beach in Olga Bay is approximately 35 km long (shoreline direction 90°-270°). Small rivers empty into the three bays. In all of the aforementioned gray whale concentration areas there are promontories that jut out into the sea (Capes Olga, Nalycheva, and Zhelty). Whales photographed off the east coast of Kamchatka were included in the Kamchatka catalogue (KAMGW).

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. No areas in the Sea of Okhotsk outside the main feeding areas off Sakhalin coast were sampled in 2012.

## 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, 2005a, 2006, 2008; Yakovlev *et al.* 2007, 2009b, 2010, 2011, 2012).

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, 2005a,b, 2006, 2008; Blokhin *et al.* 2003, 2004; Maminov 2003; Yakovlev *et al.* 2007, 2010, 2011, 2012; Tyurneva *et al.* 2008, 2011, 2012). 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, 2006, 2008, 2009, 2010, 2011, 2012; Yakovlev *et al.* 2007, 2009a,b, 2011a, b, 2012).

2012 photo-identification studies on the shelf of the Sakhalin Island were conducted in the Piltun feeding area south down to Chayvo Bay, and in the Offshore feeding area. Limited data on the identified animals were obtained from the deck of the vessel during stops or other studies. Vessel-based distribution surveys had reported a significant number of the gray whales towards the end of the field period (see Vessel Surveys section).

### *3.3.2 East Kamchatka Shelf and Other Areas*

In recent decades researchers have acquired more and more data on the range of gray whales in the summer, fall, and early winter months in the coastal waters of Southeast Kamchatka (Blokhin et al, 1985; Vladimirov, 1994; Vertyankin et al, 2004; Tyurneva et al, 2007b; Tyurneva et al 2010). According to Blokhin's data (1996), not a single gray whale was spotted during many years of planned and pilot observations in the area of Kamchatka's west coast. But in August 2000 a small gray whale was sighted at the entrance to Bolshaya River (52°08' N, 156°27' E) (Nikulin et al, 2004). Since 1979 gray whales, according to ship surveys conducted annually by the Kamchatka Basin Fisheries Conservation and Renewal and Fishing Regulation Administration, were sighted in coastal waters southeast of the tip of the peninsula (Cape Lopatka). It has also ben noted that since the mid 1980s solitary gray whales were sighted in the summer along the southeast coast of Kamchatka Peninsula (Blokhin et al, 1985; Vladimirov, 1994; Maminov and Blokhin 2004; Tyurneva et al, 2007b; Tyurneva et al, 2008).

In 2004 three gray whales were sighted and photographed during scheduled surveys on Khalaktyr Beach in the eastern part of Kamchatka Peninsula (Yakovlev et al, 2007). No matches were discovered in a comparison of these data with the catalogue of Western gray whales identified off the NE coast of

Sakhalin in 2002-2005. But in subsequent years two individuals seen in Kamchatka in 2004 were encountered off the shores of Sakhalin Island (Tyurneva et al, 2006, 2010, 2011).

In 2006 the photo-identification laboratory of the Institute of Marine Biology received photographs collected in the northern part of the Sea of Okhotsk in Kekurny Bay (July 13, 2006) and Babushkin Bay (July 28, 2006). Analysis led to the identification of 3 whales, which were assigned NOGW# catalogue numbers (Vladimirov et al, 2007). In 2007 one of these whales was sighted in Piltun Bay and in Olga Bay and was assigned corresponding catalogue numbers. A second whale was identified in Olga Bay and has also been encountered on a regular basis there in the feeding seasons since 2007.

Starting in 2006, researchers have been collecting photo-ID data in Vestnik and Olga Bays on Kamchatka Peninsula in hopes of determining whether whales belong to the Eastern or Western population. Based on the results of gray whale photo-identification in 2004 and 2006-2009, 116 gray whales and 2 temporary gray whales were identified on the SE shelf of Kamchatka Peninsula and 61 gray whales and 1 temporary whale are also found in the Sakhalin Catalogue of the Zhirmunsky Institute of Marine Biology of the Far East Branch of the Russian Academy of Sciences, i.e. they were also sighted earlier off Sakhalin Island.

The available data suggest that the geographical movements of gray whales between feeding areas within a year and from year to year may be attributed to the availability of food (Tyurneva et al, 2006, 2010a; Yakovlev et al, 2009a). Researchers also discovered that whales may forage both off the shores of Sakhalin and Kamchatka in the same season, i.e. the whales make long migrations during their feeding season.

Cases when whales visit and use different feeding areas in consecutive years are classified as movements from year to year. Twenty one whales of the whales that were photographed in 2009 only on the Kamchatka shelf had been recorded in the Sakhalin Catalogue in preceding years.

Half of the whales recorded in 2008 in Olga Bay off the shores of Kamchatka had been encountered earlier off Sakhalin Island (Figure A3). Ten whales sighted in 2008 off Sakhalin were recorded off Kamchatka in 2007. Of the 37 whales that were recorded in 2007 on the southeast shelf of Kamchatka, 20 whales were encountered off Sakhalin in preceding years. Five of the thirteen whales sighted off Kamchatka in 2006 were encountered off Sakhalin in preceding or subsequent years.

Photo-identification surveys were not conducted on Kamchatka in 2012.

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.

The results of satellite tagging conducted in 2010 and 2011 off the coast of Sakhalin by Bruce Mate's group (Oregon State University, USA) that indicated the movement of several whales between the West and East Coasts of the Northern Pacific were confirmed by a comparative analysis of many thousands of photographs of the whales from different catalogues, which revealed matches of pictures of Sakhalin and US and Mexican Pacific Coast whales (Urbán *et al.* 2012).

### *3.3.3 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, 2011, 2012; Yakovlev *et al.*, 2009, 2010, 2011, 2012).

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, 2010, 2011, 2012, 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, 2010a, 2011, 2012).

### *3.3.4 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, 2010, 2011, 2012). Improvement in the whales' physical condition was also recorded throughout the field seasons of 2008-2011when the number of sightings of underweight whales decreased over the course of the season (Yakovelev *et al.* 2009b, 2010, 2011, 2012; Tyurneva *et al.* 2010b).

### *3.3.5 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, 2010, 2011, 2012).

## 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.

The presence of mud plumes, both at whale feeding points 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 points 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 and Nikon D800 digital cameras with a fixed 300 mm f/4 telephoto lens, a Nikkor 80-400 mm zoom lens with image stabilizer (IS) , or Sigma 120-400mm F4.5-5.6 (both with image stabilizer (IS) ) were 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 JPEG or RAW format (NEF).

[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.

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; Yakovlev et al, 2011). 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 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.

***Satellite Tagging Team***

During the 2012 field season, the satellite tagging team was not involved.

## 3.4 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 (S. Swartz & M.L. Jones pers. comm. 2007). A "match" was considered to be made made when two separate sightings were judjed to belong to the same individual based on 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, 2005d). 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*

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, 2010, 2011, 2012; Tyurneva *et al.* 2010d).

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## 3.6 ACKNOWLEDGEMENTS

The whale photographic identification surveys were made possible by the participation of scientific personnel and crew members of vessel *Igor Maksimov*. Special thanks go to Yu. I. Tonkonog, the captain of the vessel *Igor Maximov*, for leading the cruise and managing safe operations; to the marine mammal observers (led by M.S.Kornienko, Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok) for providing information on whale distribution and whale movements and transmitting this information to the Zodiac during the 2011 photo-ID surveys; to E.P.Shvetsov, A. Yu. Yakovlev and O. N. Miroshnikova for help in processing the data in the laboratory.

We wish to thank Igor Zhmaev and Christina Tombach-Wright for consistent help and support; Yury Bychkov for technical assistance in the creation and maintenance of the database, Jennifer Dupont (ExxonMobil), Koen Broker (Shell), and Sergei Yazvenko for providing valuable comments and edits; Yury Bychkov, Sergei Yazvenko, and Christina Tombach-Wright (LGL) for the assistance in compiling the edits and comments; and LGL for the formatting of this report.

Support and funding for this study were provided by the Sakhalin-1 (operator Exxon Neftegas Limited, ENL) and Sakhalin II (operator Sakhalin Energy Investment Company) projects.

We wish to give special thanks to Jennifer Dupont (ExxonMobil) and Ervin Kalinin (ENL), for their support in the organization and conduct of the cruise.

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# CHAPTER 4

## BENTHOS STUDIES IN FEEDING GROUNDS OF THE SAKHALIN GRAY WHALES, 2012

## METHODS AND ANALYSES

Photo taken by Y.M. Yakovlev

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Vladivostok
March 2013

RUSSIAN ACADEMY OF SCIENCE
FAR EASTERN BRANCH

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# REPORT
ON THE RESEARCH PROJECT

# BENTHOS STUDIES OF GRAY WHALES FEEDING OFF SAKHALIN ISLAND, 2012

## METHODS

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2013

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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 2002-2011), in the Intermediate area in 2002, 2007-2010 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 (but no sampling was conducted in 2011 due to limited time).

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 2002-2012). 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, and (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.

The following chapter describes the methodology and analytical approach of the benthic studies conducted in the Sakhalin area during August–September 2012 by scientists of the Institute of Marine Biology of the Far East Branch of the Russian Academy of Sciences (IBM FEB RAS). The research vessel *Igor Maximov* was used in 2012.

## 4.2 MATERIALS AND METHODS

### *4.2.1 Survey Areas*

In 2012, regular grid benthic samples were taken in the Piltun feeding area, 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 2012 Survey Design and Site Selection*

The sampling locations in 2012 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. No sampling was conducted there in 2011 because no feeding whales were observed. In 2012 feeding whales were observed there, and 5 benthos stations were collected.

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 and 2012 (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 points 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 2010-2012 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) in 2012 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 2012: (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 sampled again in 2012. The entire grid of the Intermediate area, sampled in 2002, 2007, 2008 and 2009, was also sampled in 2010 and 2012. A consistent approach was used in planning the locations of benthos stations in these areas in 2002-2008 , as described in more detail below.

In 2004-2010 the stations were samples from the *Academic Oparin* research vessel, equipped with powerfull high-speed winches. In 2011, the stations were sampled from the *Igor Maximov* research vessel with slower and less powerful winches. In 2012, a powerful high-speed winch was installed on Igor Maximov, which allowed for a successful fulfilment of the full scope of field work.

#### *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 2008-2012.

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 a flat-bottomed 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. A Petersen grab (0.025 $m^2$) and a small (1/3 size) variant of Sigsby trawl were used. 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.

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 sampled 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. Only two stations were sampled in 2011-2012, both within the Piltun area.

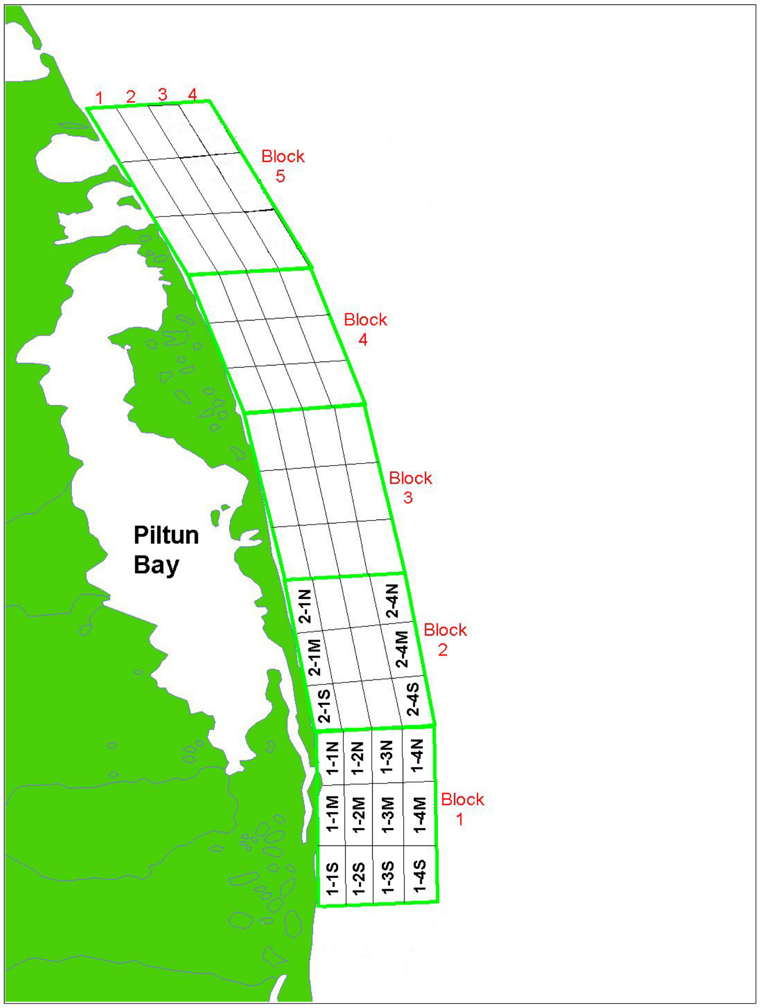


**Figure 1** Benthic sampling grid of the Piltun Feeding Area (> 1000 km$^2$). Each year benthic and sediment samples were taken from one location in each sector, totaling 60 locations.

**Table 1** Benthic samples collected from *Maximov* in August–September 2011.

| Area | van Veen Grab | Epibenthic net | Bongo plankton net |
|---|---|---|---|
| | Stations/samples | samples | samples |
| Piltun area | 81/243 | 0 | 0 |
| Offshore area | 48/144 | 0 | 0 |
| Intermediate area | 12/36 | 0 | 0 |
| Feeding points | 13/39 | 60 | 120 |
| Total | 11/33 | 60 | 120 |

**Table 2** Stations, including feeding points, diving surveys and grid location, by depth in Piltun area for 2002–2011.

*Note: * denotes diving collections.*

| Depth Range, m | Number of Stations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2012** | **2011** | **2010** | **2009** | **2008** | **2007** | **2006** | **2005** | **2004** | **2003** | **2002** |
| 1 - 5 м | 8 | 0 | 0 | 0 | 12* | 14* | 5* | 6* | 6* | 0 | 0 |
| 6 -10 м | 19 | 10 | 9 | 10 | 19* | 18* | 6* | 7* | 7* | 10 | 6 |
| 11-15 м | 35 | 16 | 21 | 27 | 33 | 20 | 16 | 15 | 6 | 19 | 25 |
| 16-20 м | 12 | 8 | 13 | 11 | 8 | 18 | 14 | 12 | 13 | 7 | 16 |
| 21-25 м | 15 | 13 | 16 | 26 | 15 | 17 | 14 | 27 | 14 | 12 | 20 |
| 26-30 м | 14 | 9 | 14 | 19 | 10 | 14 | 13 | 15 | 13 | 10 | 11 |
| 31-35 м | 3 | 7 | 9 | 3 | 6 | 3 | 3 | 5 | 5 | 5 | 2 |
| Total | **106** | **63** | **82** | **96** | **103** | **104** | **74** | **87** | **64** | **63** | **80** |

### *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 2008–2011. Stations collected in the Offshore area are shown on Figure 4.

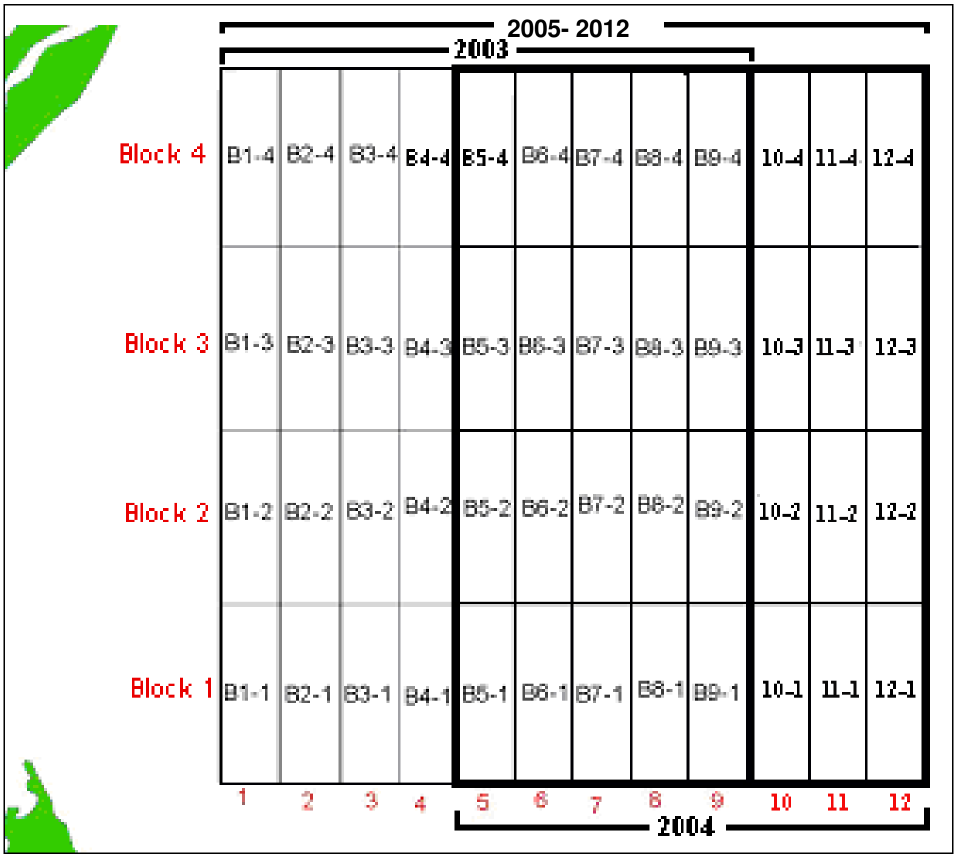


**Figure 2** Benthic sampling grid in the Offshore Feeding Area (~2000 km$^2$). The area includes a total of 48 sectors in twelve lines oriented parallel to the coast. Lines 10, 11, and 12 have been sampled since 2005.

### *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 13 stations in 2002 and at 15 stations in 2007-2008 , at depths from 8 to 24 m, with an average collection depth of 18.1±1.1 m. In 2009-2012, 36 samples were collected from 12 stations.

### *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. No sampling was conducted in 2011 because no feeding whales were recorded there. In 2012, feeding whales were observed, and 5 stations were collected in the area.

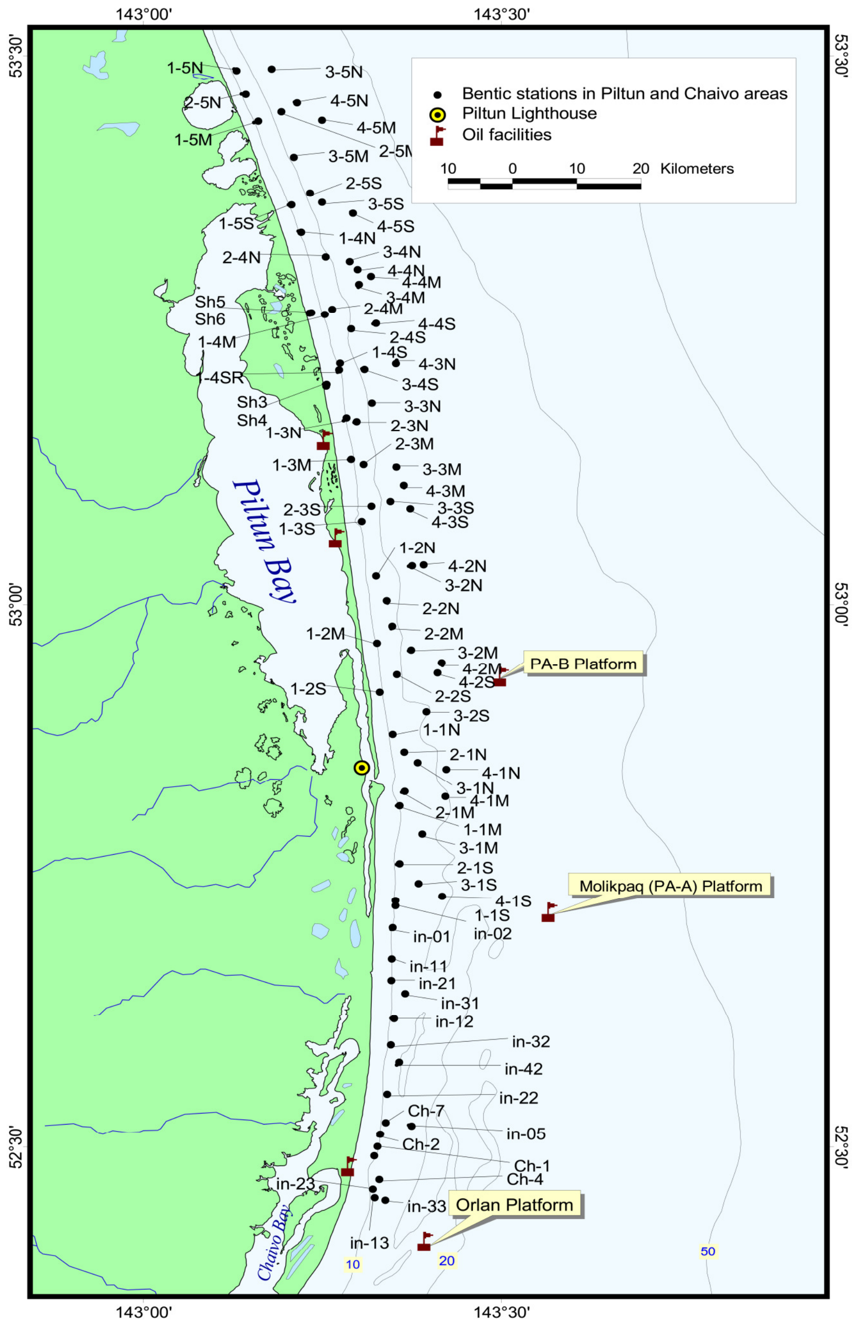


**Figure 3** Locations of bottom grab sample stations in the Piltun and Intermediate areas in 2012.

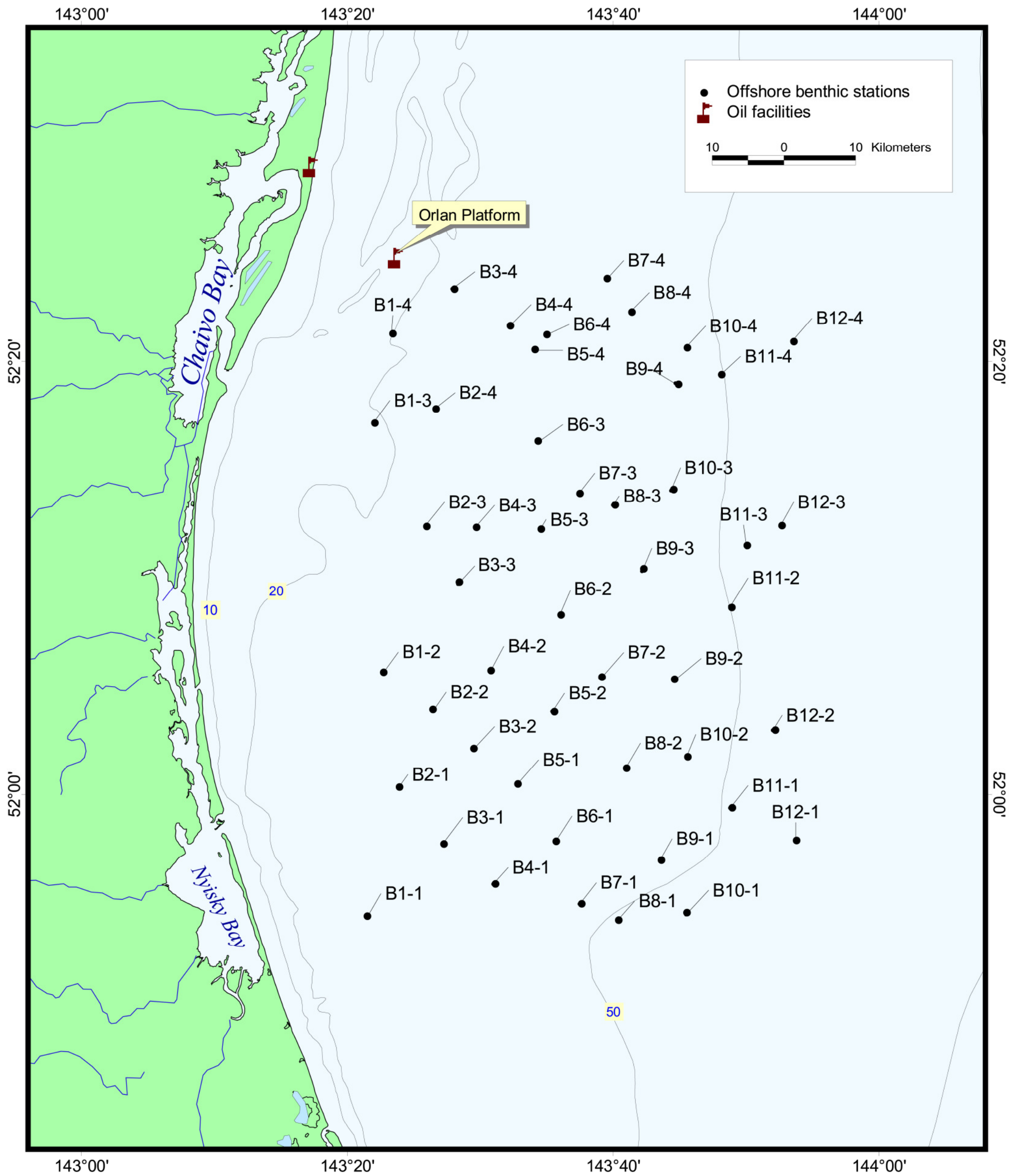


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**Figure 4** Locations of bottom grab sample stations in the offshore area in 2012

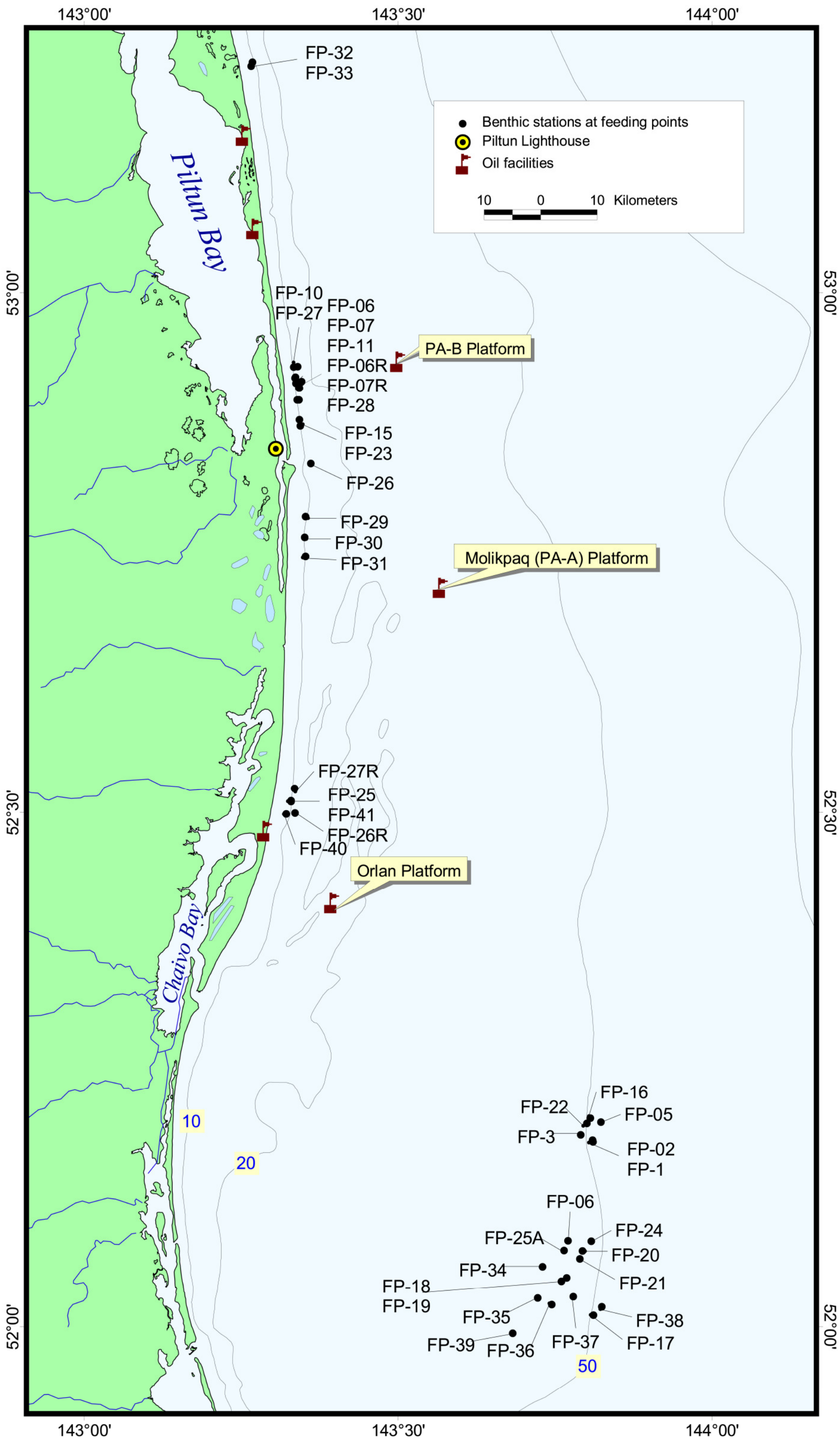


**Figure 5** Locations of bottom grab sample stations in the GW feeding points in 2012

### *Gray Whale Feeding Points*

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. Due to time limitations, sampling at only three feeding points was conducted in 2012. The locations where these samples were taken are shown on Figure 3.

## 4.3 FIELD SAMPLING PROTOCOLS

All benthos samples taken from the research vessel Maximov 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 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. In 2011, a new research vessel (the *Igor Maximov*) used which required reconfiguration of sampling equipment. A winch was used which is typically made for use with tow trucks/cars. Hence, instead of being dropped quickly, the Van Veen grab was slowly lowered to the sediment surface thereby providing much less penetration of the sediment. Smaller volumes of sediment were sampled which were largely representative of the surface communities. Therefore, there are sampling/statistical challenges in comparing the 2011 data with previous years. These are addressed in Volume II of the report.

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 | Grc | 10-5 | |
| | medium | Grm | 5-2 | |
| | fine | Grf | 2-1 | |
| Sandy (psammites) | Sand: | | | |
| | coarse | Sc | 1-0.5 | 1-0.5 |
| | medium | Sm | 0.5-0.25 | 0.5-0.25 |
| | fine | Sf | 0.25-0.1 | 0.25-0.1 |
| Silt (silts) | Coarse silts | Ac | 0.1-0.05 | 0.1-0.05 |
| | Fine silt silt | Af | 0.05-0.01 | 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$^{o}$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 $\alpha$- and $\gamma$-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 $\times$ 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; $\alpha$-HCCH and $\gamma$-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

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[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*

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): $I = \frac{\sigma^2}{\bar{x}}$,

where $\sigma^2$ – dispersion of the density of the colony, and $\bar{x}$ – 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 $\chi^2$ – 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:

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

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).

## 4.5 ACKNOWLEDGEMENTS

Thanks go to Sergei Yazvenko, LGL Limited, for critical review, translation, and formatting of this chapter. Helpful comments were also provided by Tatyana Konovalova (Sakhalin Energy), Koen Broker (Shell), Jennifer Dupont (ExxonMobil Upstream Research Company), and Lisanne Aerts (LAMA Ecological). LGL helped with the formatting of this report.

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