Sakhalin Energy Investment Company Ltd.

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Date: 03.12.2021

Report on gray whale monitoring program off northeast Sakhalin island in 2020

Отчет по программе мониторинга серых китов у северо-восточного побережья острова Сахалин в 2020 г.

Change document metadata

Document Number	**SEIC-HS-03373**
Confidentiality Level	Unclassified
Information Custodian	A.D. Samatov, Head of Corporate Environmental Division
Revision Number	01
Issue Purpose	AFU – Approved for Use
Effective Date (corresponds to the approval date unless specified otherwise)	
ACAL ID	**N/A**

APPROVED	APPROVED
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June /____ / 2021	June /____ / 2021

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REPORT
ON GRAY WHALE MONITORING PROGRAM
OFF NORTHEAST SAKHALIN ISLAND
IN 2020

2021

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Photo: Yu. M. Yakovlev

Exxon Neftegas Limited

Sakhalin Energy Investment Company Ltd

May 2021

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EXPLANATORY NOTE

A group of North Pacific gray whales (commonly referred to as the Okhotsk-Korean gray whale or the Western gray whale [WGW]) feed during the ice-free season on the Okhotsk Sea shelf off the north-east coast of Sakhalin Island in the immediate vicinity of the offshore oil and gas fields developed by Exxon Neftegas Limited (ENL) and Sakhalin Energy Investment Company Ltd. (Sakhalin Energy). These gray whales, due to their high conservation status both in the Red Book of the Russian Federation and the Red List of the International Union for Conservation of Nature (IUCN), have been the subject of scientific research sponsored by ENL and Sakhalin Energy since 1997. The Companies combined their efforts in 2002 with the establishment of a Joint Program for monitoring gray whales and their feeding areas.

In connection with the development plans for the Ayashsky license block located in the immediate vicinity of one of the gray whale feeding areas, Gazpromneft-Sakhalin LLC (Gazpromneft-Sakhalin) carried out an environmental monitoring program which included gray whale observations in 2018 and 2019.

Given the fact that Sakhalin-1, Sakhalin-2 and Sakhalin-3 license blocks are located in vicinity of gray whales' seasonal feeding areas, all three project operators, ENL, Sakhalin Energy, and Gazpromneft-Sakhalin, believe that sharing the data is necessary to enhance the efficiency, practical application and scientific significance of monitoring programs results. The work under the programs have resulted in acquiring information that aids in development and implementation of measures providing conservation of gray whales and their habitats, and enables the Companies to mitigate the potential effect of conducted activities on the gray whales.

This report includes the results of gray whale monitoring off the northeastern coast of Sakhalin Island, obtained as a result of the implementation of the Joint Program in 2020.

The gray whale monitoring program implemented by the scientists from leading Russian research institutes is comprised of four key research areas: photoidentification of gray whales; study of their distribution within the feeding areas; study of benthos communities constituting the food resources for these animals; as well as the acoustic monitoring of underwater natural and anthropogenic noise.

From May to November gray whales are sighted off the northeastern coast of Sakhalin Island where two primary feeding areas of these animals are located. The feeding areas are characterized by high biomass of benthic food organisms, which include amphipods, isopods, the sand lance, and polychaetes. The gray whales show great affinity for the feeding areas, with the majority of the whales observed arriving there every year. Since the discovery of approximately 20 gray whales off northeast Sakhalin in the early 1980s, their numbers off northeast Sakhalin have steadily increased each year. In 2002, the first year of the Joint Program, 47 animals were identified. A total of 175 gray whales were identified near Sakhalin in 2020 including 9 calves and 2 new first recorded adults. The total number of gray whales recorded in the Sakhalin catalog reached 332 individuals.

The winter habitats and migration routes of gray whales coming to the shores of Sakhalin to feed were unknown until satellite tagging sponsored by the companies established the migration of three animals to coastal North America in 2010-2012. The overlap of the habitats of the western and eastern gray whale aggregations established by satellite tracking was further verified by other scientists through comparisons of photo-ID catalogs and genetic matches. As of today, more than 50 individuals have been documented in the joint habitat of the Western and Eastern gray whales. Based on these data, the assumption can be made that all gray whales inhabiting the Pacific Ocean most likely belong to a single large North Pacific population. These data could be very important for the development and implementation of measures to conserve gray whales.

The factors threatening gray whales include both natural threats (e.g., predation, disease and food insufficiency due to the limited feeding areas and competition) and anthropogenic threats (aboriginal subsistence whaling, entanglement in fishing gear, vessel strikes, sea pollution, and anthropogenic noise). As part of their commitment to mitigate the impact on gray whales during production activities, the companies developed their own Marine Mammal Protection Plans (MMPPs) that specify methods for conducting operations in a manner protective of gray whales and other marine mammals. The measures implemented have significantly reduced the potential risks and made it possible to avoid incidents involving gray whales over the entire period of companies' operations. Additionally, the implemented measures were instrumental in reducing the noise impact to a level believed not to affect the gray whales.

INTRODUCTION

Exxon Neftegas Limited (ENL), Operator of the Sakhalin-1 project, and Sakhalin Energy Investment Company, Ltd. (Sakhalin Energy), Operator of the Sakhalin-2 project (companies) have been developing oil and gas reserves on the continental shelf area of the Sea of Okhotsk off northeast Sakhalin Island.

The projects are located in direct proximity to habitats used by the gray whale (*Eschrichtius robustus*) during ice-free months. Gray whales were believed to be extinct in the western Pacific Ocean until approximately 20 individuals were sighted off the northeastern coast of Sakhalin in the early 1980s. The occurrence of gray whales within their previous habitat range led to the conclusion that these whales were remnants of the Okhotsk-Korean western gray whale population inhabiting this region in the past. Following the discovery of these individuals, the Okhotsk-Korean gray whale population was listed under Category 1 as “endangered” in the Russian Federation Red Book. Pursuant to the RF Ministry of Natural Resources and Ecology Order No. 162 of March 24, 2020 "On Approval of the List of Fauna Species Included in the Red Book of the Russian Federation" (registered on April 2, 2020 under No. 57940), western gray whales are assigned Category 1 rarity status (endangered), Category 1 with respect to the extent and priority of implemented and planned environmental protection measures, as well as the CE category (critically endangered) with respect to the status of being in danger of extinction.

The western gray whale population was listed as “on the verge of total extinction” by the International Union for the Conservation of Nature (IUCN). However in 2018, their conservation status was changed to “endangered” sub-population (Cooke et al., 2018; https://www.iucnredlist.org/species/8099/50345475).

The Environmental Impact Assessments (EIAs) and the State Ecological Expert Reviews (SEERs) conducted for the Sakhalin-1 and Sakhalin-2 Projects identified the gray whale as the most vulnerable subject to offshore production operations of both companies. Following the SEER recommendations, each company have been conducting monitoring studies of the Sakhalin gray whale population and their feeding conditions since 1997. In 2002, ENL and Sakhalin Energy combined their efforts and financing with the establishment of the Joint Program for gray whales studies and their habitats off northeast Sakhalin Island (Joint Program).

In 2018, in connection with its development plans for the Ayashsky license block, Gazpromneft-Sakhalin commenced an environmental monitoring program, including collection of data on gray whales in the water area in the immediate vicinity of the Offshore feeding area.

Given the fact that Sakhalin-1, Sakhalin-2 and Gazpromneft-Sakhalin’s license blocks are located in the same common gray whale seasonal feeding area, all three project operators, ENL, Sakhalin Energy, and Gazpromneft-Sakhalin, believe that sharing monitoring programs’ data is necessary to enhance the efficiency, practical application and scientific significance of both programs. The Operators believe that mutual exchange of the data will enable them to produce more comprehensive reports and assist them in development and implementation of gray whale habitat conservation and impact mitigation activities. This report combines the results of the gray whale monitoring programs under the Joint Program (2002-2020) and the environmental monitoring program of Gazpromneft-Sakhalin (2018-2019), hereinafter referred to jointly as the Gray Whale Monitoring Programs (Figure 1).

The Gray Whale Monitoring Programs include four primary areas: photo-identification surveys, studies of distribution within the feeding areas, studies of the structure and indicators of the abundance of benthic communities and the state of the food supply, the acoustic monitoring of underwater natural and anthropogenic noise. Satellite tagging and observations of gray whales in the waters off the Kamchatka Peninsula were conducted in certain years to study migration routes and features. Tissue samples (biopsy) were also taken from gray whales for genetic and biochemical studies.

The gray whale monitoring is one of the long-term multi-disciplinary research programs that focuses on a specific area and a specific marine mammal species. Prior to initiating the Joint Program, there were insufficient reliable scientific data about gray whales feeding off northeast Sakhalin Island. The understanding of these animals at that time was based on unproven secondary information, questionable historical data, and often unsubstantiated conclusions and assumptions. The Joint Program has established a scientific framework for obtaining the information necessary to expand the knowledge about the gray whales, their range, and potential threats to them.

The 2020 gray whale monitoring program included: photo-identification surveys and studies of gray whale distribution within Piltun and Offshore feeding areas.

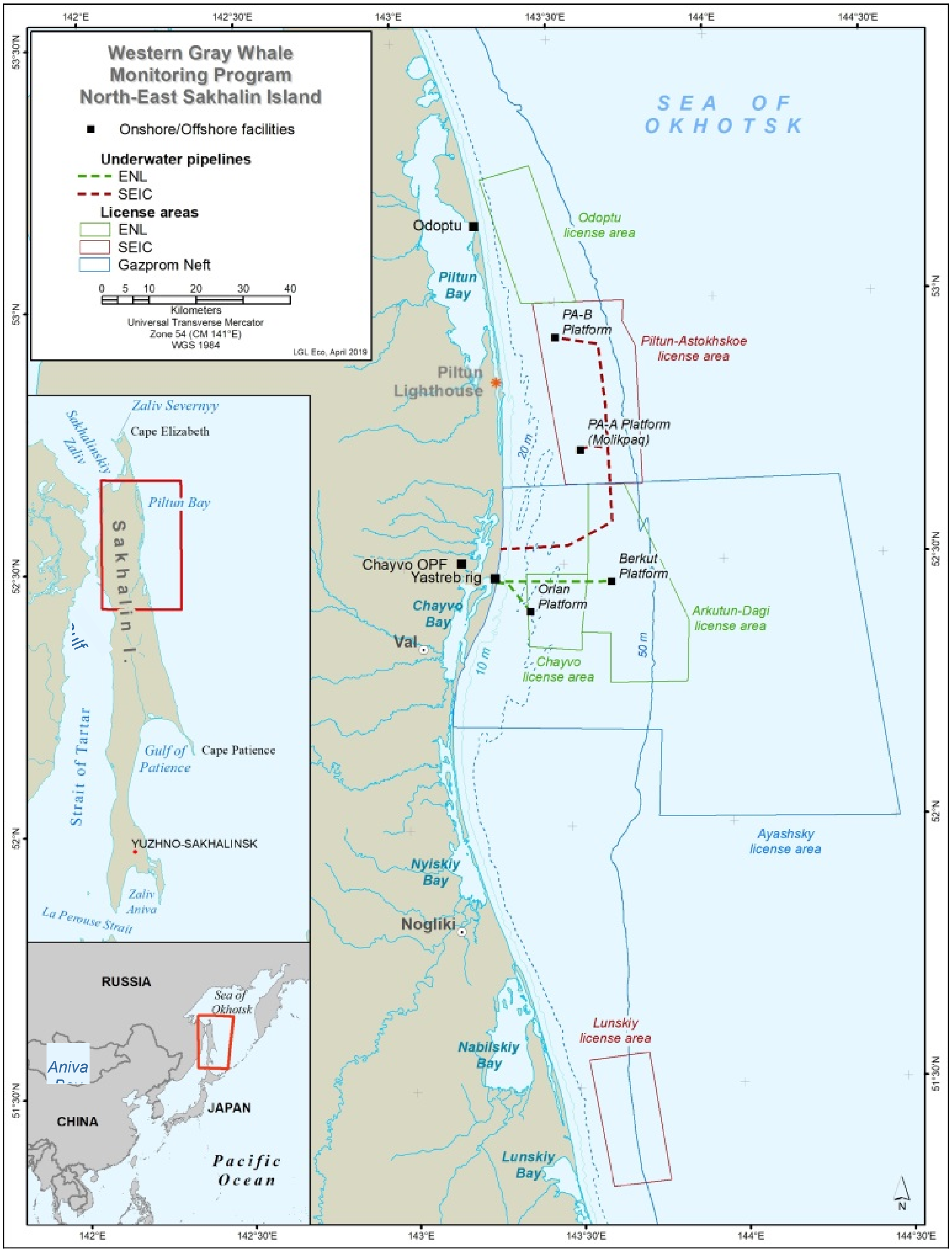


Figure 1. Area of Gray Whale Monitoring Programs Implementation – Sea of Okhotsk Shelf off Northeast Sakhalin Island.

1 GRAY WHALE MONITORING PROGRAMS

1.1 GOALS AND OBJECTIVES OF MONITORING PROGRAMS

The main goal of the programs is the implementation of comprehensive observations of the gray whale population and its habitat off the northeastern coast of Sakhalin Island to develop and implement measures for the conservation of this feeding aggregation by the Companies.

The monitoring programs' objectives are: to assess the abundance and distribution, demographic and individual features, as well as the gray whale feeding conditions. The implementation of the monitoring programs allows to expand the scientific knowledge about gray whales and their habitat, as well as about the factors impacting the status of the feeding aggregation.

The information gathered under the programs is used by the Companies to develop measures for the preservation of the habitat of protected animal species during their commercial operations pursuant to the requirements of Russian laws, and to conduct and revise a monitoring program and environmental protection measures aimed at mitigating the risks for the gray whales and their feeding areas during the process operations.

1.2 COMPONENTS OF MONITORING PROGRAMS

The Sakhalin gray whale monitoring programs are conducted by specialists from the leading Russian research institutes and universities in the Far East and Moscow. The components, the institutions and lead researchers involved in the programs implementation are presented below:

- ***Photo-ID Studies of Gray Whales***

Photo-ID studies have been conducted annually since 2002 to identify and assess the condition of individual gray whales. The identification provides information on population dynamics and demography, social structure, and individual life cycles. In addition, the photo-ID data is used for long-term assessments of the population abundance and health status. The studies are carried out under the guidance of Yu. M. Yakovlev, Ph. D. (Biology), and O. Yu. Tyurneva – the research associates of the National Scientific Center for Marine Biology under the Far Eastern Branch of the Russian Academy of Sciences in Vladivostok (NSCMB).

- ***Gray Whale Distribution Study***

Gray whale distribution and abundance have been studied under the programs annually since 2002 in the Piltun and Offshore feeding areas, located within the water areas of Odoptu, Piltun-Astokh, Chayvo, Arkutun-Dagi and Ayashsky license blocks (Figure 1). The gray whale distribution studies were conducted both by shore-based and vessel-based teams of researchers. The gray whale distribution studies were conducted by the experts under the guidance V. A. Vladimirov, Ph. D. (Biology), and with the coordination of work by the Sakhalin State University (SakhSU).

- ***Study of Food Supply***

Benthic studies were conducted from 2002 to 2016 to evaluate the status of the gray whale food supply in the feeding areas. Samples of benthos and bottom sediments were collected for study in the two main feeding areas – Piltun and Offshore, or in the immediate vicinity of them. Benthic studies were carried out by the staff of the National Scientific Center for Marine Biology under the guidance of V. I. Fadeev, Ph.D. (Biology) and V. V. Ivin, Ph.D. (Biology).

- ***Acoustic Monitoring***

Acoustic monitoring, intended to record and study the levels of natural (intrinsic) and anthropogenic underwater noises in the gray whale feeding areas, was a component of the Monitoring Program from 2003 to 2016. In addition to measuring sound levels, hydrology data were collected that allow understanding and modeling and of sound propagation in the gray whale feeding areas. The acoustic monitoring was conducted by the Pacific Oceanological Institute with the Far Eastern Branch of the Russian Academy of Sciences in Vladivostok (POI) under the leadership of Doctor of Physical and Mathematical Sciences Alexander N. Rutenko.

1.3 METHODS OF PROGRAMS IMPLEMENTATION

The methods used in each specific study have been developed and refined over the course of the programs implementation. Today, these methods are state-of-the-art and, as needed, they are refined each year to meet the current tasks of the programs, technical and logistical requirements, and to minimize the impact on gray whales. The applied methods are described in details in the “2012 Methods Report” (Joint Program, 2013). Any revisions made during the implementation of the components of the programs are described in the individual reports provided in the Appendices hereto.

1.4 MONITORING RESULTS

This report presents the primary results of the monitoring programs. Appendix I to this report contains the list of all program publications in the referred scientific journals and the proceeding of scientific conferences.

The detailed results, methods for conducting field surveys, a description of the data gathered, processing of the samples and instrumental data of the 2020 Sakhalin gray whale monitoring programs, as well as the comparative results for the entire period of the Sakhalin monitoring programs implementation (2002-2020), are provided in the scientific reports prepared separately for each component - see Appendices II and III to this Report.

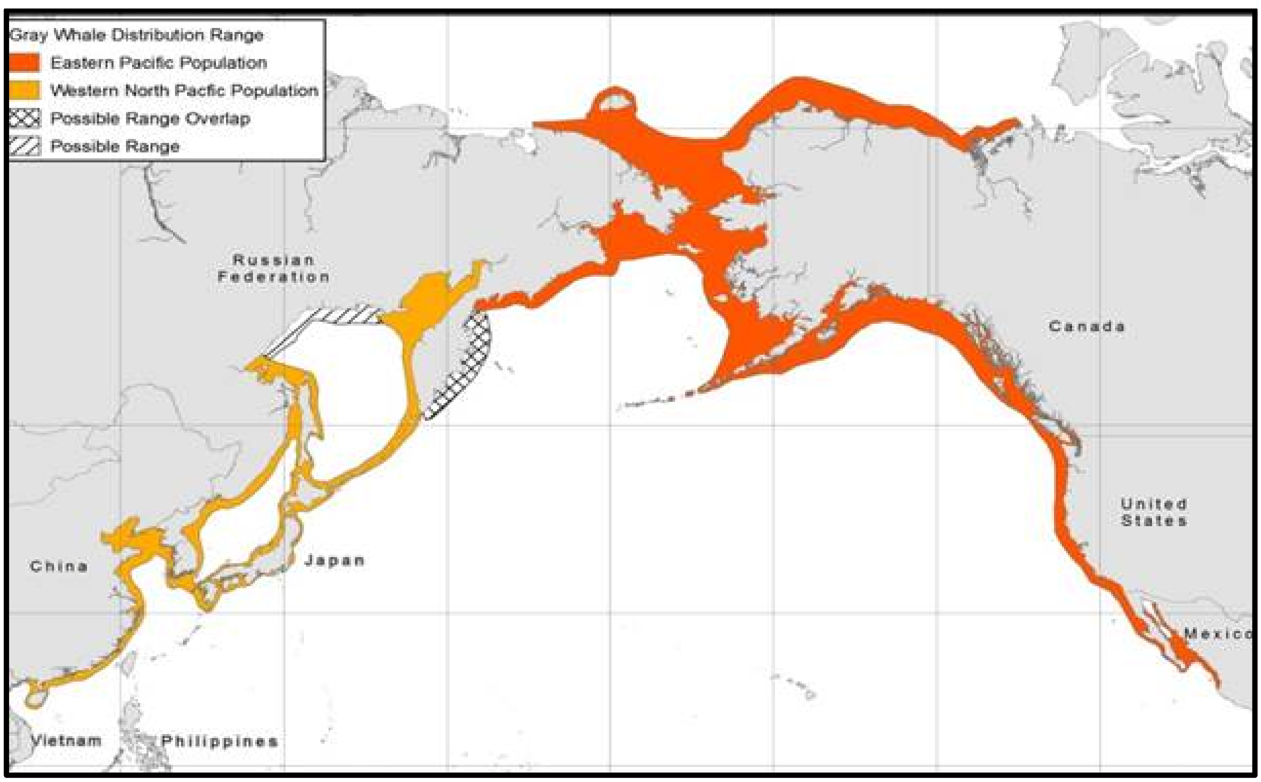
2 SUMMARY OF CURRENT UNDERSTANDING ABOUT GRAY WHALES OF SAKHALIN

Since the commencement of the gray whale studies in 1997 and initiation by the Companies of their collaboration under the Joint Program (since 2002), a great deal of new information has been acquired about the gray whales and their habitat, including their distribution, movements, behaviors, and food supplies. This section of the Report provides an overview of the current understanding of the Sakhalin feeding aggregation of gray whales and its habitat, and includes a discussion of the potential threats to the population, and the mitigations implemented by the Companies that reduce potential risks posed by their operations around the offshore oil and gas fields.

2.1 GRAY WHALE POPULATION

Gray whales (GW) of the northern part of the Pacific Ocean traditionally have been divided into two populations or groups: (1) "Okhotsk-Korean" or "Western" gray whales (WGW) inhabiting the northern part of the Pacific coast of Asia (Russia, Japan, China, Korea), and (2) "Chukchi-Californian" or "Eastern" gray whales (EGW), living in the Pacific coastal waters of North America (Canada, USA, Mexico) and Chukotka (Russia) (Figure 2). During the 19th and 20th centuries, the numbers of North Pacific gray whales were significantly reduced by commercial whaling. In 1938, the US government established a moratorium on commercial whaling for EGW, and in 1948 the International Whaling Commission (IWC) extended the moratorium to all gray whales. These actions resulted in a gradual recovery of the gray whale numbers. The latest EGW population estimate is 27,000 whales (Durban et al., 2017) and presently the Eastern gray whales are not considered endangered.

The population of the Okhotsk-Korean gray whales was estimated to have numbered about 1000-1500 individuals prior to 1910 (Berzin & Vladimirov, 1981), and then believed to have been essentially hunted to extinction by the mid-20th century. However, in 1983, approximately 20 gray whales were observed off northeast Sakhalin (Blokhin et al., 1985) and as it was assumed at the time, those whales were the remnant survivors of the Okhotsk-Korean gray whale population.



Since the sighting of the gray whales in Sea of Okhotsk waters off northeast Sakhalin in the 1980s, the cumulative total number of whales has invariably increased. In 2002, the first year of the Joint Program photo-ID studies, 47 individual gray whales were identified. Based on the annually augmented data, during the 2020 field surveys, 11 new whales including 9 calves were discovered bringing the total number of known GW included in the Sakhalin catalog of NSCMB (FEB RAS) to 332 individuals.

- ***Population Growth***

The growth and sustainability of any population is dependent upon a multitude of factors, including successful reproduction and survival of offspring. Two key issues related to growth of the Sakhalin gray whales population are: 1) to obtain an accurate estimate of the annual rate of growth, and 2) to estimate the degree to which any observed increase is due to internal reserves (calves born to mothers of the population) or external reserves (immigrants from other populations).

Modeling utilized the WGW photo-ID data of the Russian-American team collected from the Piltun feeding area. The latest population assessment for the Sakhalin non-calf gray whale aggregate is 219-245 individuals, and the rate of growth of that feeding aggregate is 4.3-5.3% a year (Cooke, 2019). Precise estimation of the growth rate is dependent on several key assumptions of the model (e.g., number of females of reproductive age; calf mortality rate; and the closedness of the system) that are not known, uncertain, and may be inaccurate (e.g., the population may not to be a closed system, since new non-calf whales are identified nearly every year).

It could be stated with confidence that the number of whales discovered northeast of Sakhalin has been increasing every year since the sighting of about 20 individuals here in 1983. To a certain extent, the increase in the early years of the study was due to the increased effort and/or expanded area of coverage. Nonetheless, the consistent growth in the number of whales sighted each year, the documented calf births and occurrence of new reproductive mothers over the past two decades confirm a consistent growth of population. For the period of 2006 to 2020, the number of identified WGW (both calves and adults) added to the NSCMB catalog increased annually by an average of 6.3% (ranging from 3.1 to 9.6%).

- ***Mothers with Calves***

Under the gray whale monitoring programs, mother/calf pairs in Sakhalin and Kamchatka waters are constantly recorded through photo-ID studies. Although the number of these pairs varies from year to year (between 3 and 22 in 2003–2020), it is evidence of the healthy state of the population and reproductive success. Obtaining an accurate count of the number of new calves each year is challenging, since a calf is often difficult to identify when separated from its mother. Mother/calf separation happens throughout the summer, but accelerates by late August, with most calves in the Piltun feeding area believed to be independent from their mothers by mid-September. The number of mother/calf pairs, obtained from the results of the photo identification, is usually considered to be the most accurate, since only a photographic analysis allows us to determine a mother/calf pair, as well as individual calves.

In the Piltun feeding area, mother/calf pairs were most often observed around the mouth of Piltun Bay. Although such pairs have also been observed feeding in other parts of the Piltun feeding area and in Olga Bay off southeast Kamchatka (the first pairs were observed there in 2008), the area near the mouth of Piltun Bay seems to be the best suitable area for the calves, since this is where they are most often observed. Over the entire monitoring period under the Sakhalin programs, calves have never been recorded in the Offshore feeding area. It is hypothesized that calves may require shallow waters (11 m or less) to learn to feed independently, and that at the greater depths (40-60 m in the Offshore feeding area) it would be physically difficult for calves and yearlings to feed.

Olga Bay off southeast Kamchatka may be much more important for mother/calf pairs than data from earlier years suggested. Between the first observations in 2008 and until 2012, 20 mother/calf pairs were observed in Olga Bay. From 2013 to 2017, no studies were conducted in Kamchatka. Based on shared photographs from outside researchers, 4 mother/calf pairs were identified in Olga Bay in June- early July of 2019. These same pairs were identified in the Piltun area in July/August 2019. Most of the mothers (55%) sighted with the calves in Kamchatka were also photographed in the Sakhalin feeding area- either in the same year or in previous years, and were included in the Sakhalin gray whale catalog. Three mothers observed in 2009 in Olga Bay were never seen off Sakhalin, but were observed in Kamchatka before and after 2009.

It is believed that one of the important reasons for mother/calf pairs to concentrate in coastal shallow waters such as the mouth of Piltun Bay is that they are more protected here from attacks of transient killer whales typical for east Sakhalin waters. In cases of such attacks, gray whales can escape to coastal shallow waters where the mother can successfully protect the calf. The potential predation of gray whale calves by killer whales can explain the absence of mother/calf pairs in deep waters of the Offshore feeding area, where they would be more vulnerable to killer whale attacks. Cases of predatory behavior of killer whales towards gray whales have been observed within the Piltun feeding area, although rarely. It is difficult to assess if such attacks is an important factor affecting calf survival during the feeding season in Sakhalin waters.

- ***Gray Whale Physical Condition***

Based on photographs, it was observed that some individual gray whales appear to be thin or in poor physical condition, at least early in the feeding season. The photo-ID data for each year of observation showed 10-20% of whales were in poor physical condition, at least early in the feeding season. According to the physical condition of the whales during the feeding season two main trends emerged: (1) the physical condition of most whales, estimated as poor at the beginning of the feeding season, improved by the end of the feeding season, and (2) most of the whales in poor physical condition were nursing mothers (i.e. females with calves). Both trends make sense considering the biological cycle of gray whales. In early spring, gray whales migrate from their winter habitat to feed in areas rich in food resources. It is believed that during the migration period whales barely eat anything (Nerini, 1984), using their fat resources during migration, thus the nursing mothers are the most emaciated.

2.2 ANNUAL GRAY WHALE MIGRATION

Prior to 2010, little was known of the winter migrations of the gray whales observed annually off the northeastern coast of Sakhalin mainly from June to November. Each year as the sea ice clears in late May to early June, gray whales begin to appear here. During June and July the number of whales observed increases, and by August most of the sighted whales are concentrated in the two primary feeding areas, the Piltun and Offshore areas (Figure 3). Gray whales are observed until ice begins to form (November-December), when they begin their winter migration, and by mid-December depart from the waters off northeast Sakhalin.

Based on historical records of gray whale sightings in the waters of Japan, Korea and China by whalers and seamen, it has been assumed by some scientists that the Sakhalin gray whales migrate to winter breeding grounds at undetermined locations in the South China Sea. This assumption was bolstered by infrequent gray whale sightings and reports of gray whales tangled in fishing nets or stranded on beaches in Japan and China. However, due to the lack of regular gray whale sightings in intensive shipping areas and the small amount of data from special gray whale monitoring efforts in the South China Sea and other areas along their assumed Asian migration route (e.g., Japan, Korea, and China), scientists remained uncertain as to where the Sakhalin gray whales go each winter when they leave the ice-bound waters of Sakhalin.

The winter migration routes and wintering locations of the Sakhalin gray whales were unknown until the Sakhalin offshore satellite tagging program in 2010 and 2011 helped identify winter migration timeframes and routes, at least for some of them. The tags allowed to track the travel paths of three tagged individuals during their winter migration from Sakhalin to Kamchatka and further eastwards, to the North America coastal waters. The satellite tag on one whale, set in 2011 (female Varvara), assisted in tracking her full-year migration cycle from Sakhalin to the Gulf of California (Mexico) – a known winter ground of gray whales , then back to Sakhalin shelf, returning to the Piltun feeding area on May 18, 2012 (Mate et al., 2015). She was not identified by the photo-ID teams in 2012 even though her transmitter showed that the whale was in the Piltun area until it quit transmitting on October 12th.

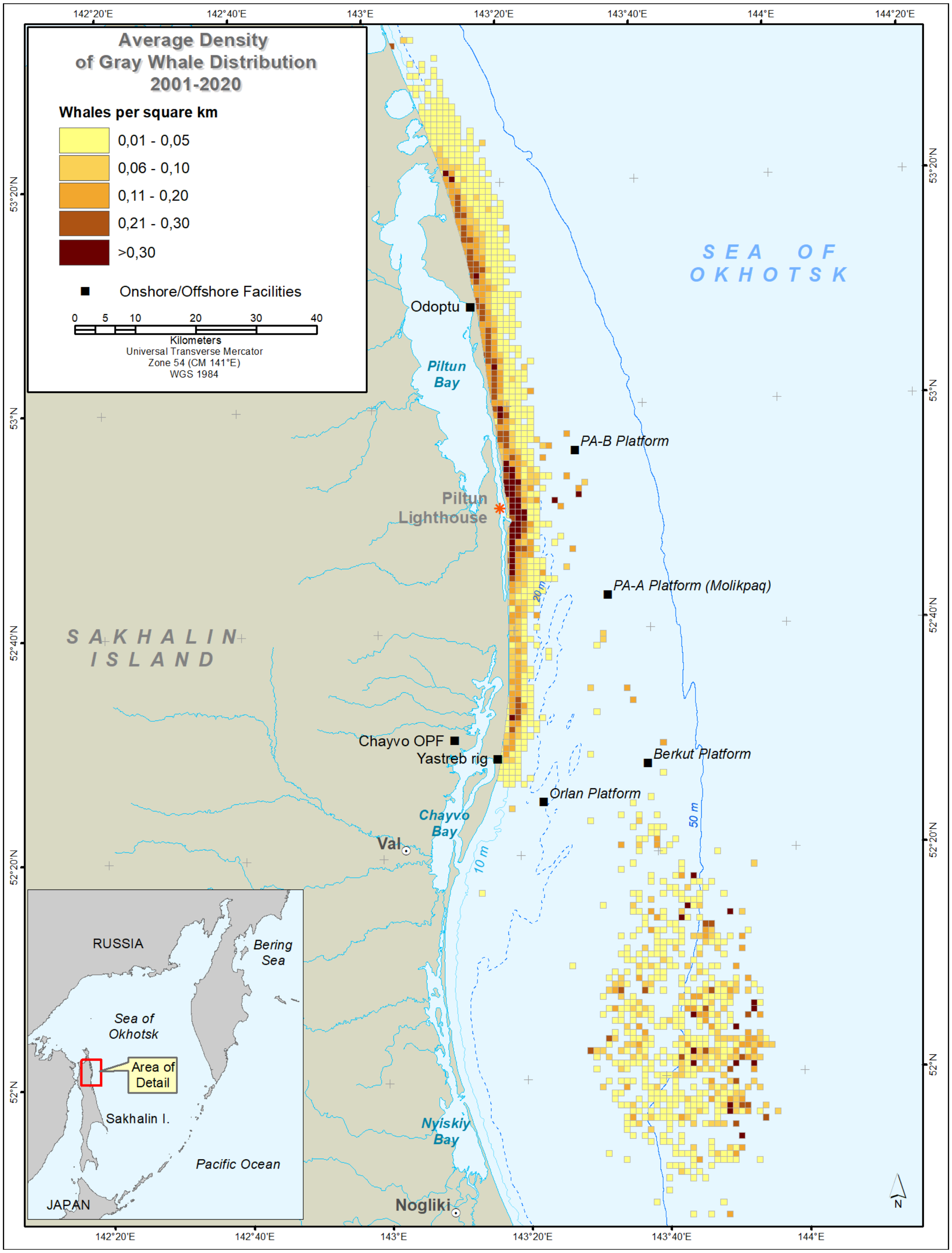


Figure 3. Distribution of Gray Whales in Piltun and Offshore Feeding Areas in 2001-2020.

The sightings of a single gray whale in 2010 in the Mediterranean Sea near Spain and Israel (Scheinin et al., 2011) and the sighting of another gray whale in 2013 in the Atlantic Ocean off the coast of Namibia provide evidence that gray whales are capable of covering significant distances. Thus, the occasional sightings of gray whales off Japan's coast and in other areas south of Sakhalin are not surprising much as the encounters in Arctic waters. The Atlantic Ocean sightings hold promise that gray whales have the potential of repopulating areas such as the North Atlantic Ocean from which they have been extirpated by whaling. Such a repopulation may be an explanation for the occurrence of gray whales in the Sea of Okhotsk and off of Sakhalin after the western population was assumed to be extinct.

2.3 GRAY WHALE DISTRIBUTION OFF NORTHEAST SAKHALIN

Gray whales are known to migrate to the Sea of Okhotsk each spring and summer, and spend much of the ice-free months in the two identified feeding areas off northeast Sakhalin where they have access to abundant benthic food resources. The data collected by the distribution and photo-ID teams since 2002 has facilitated the understanding of gray whale abundance, distribution, and movements in these waters. However, the distribution and abundance of whales in other areas of the Sea of Okhotsk remains uncertain, since observations conducted under the Sakhalin gray whale monitoring programs are limited to the area off northeast Sakhalin that includes the license blocks of oil and gas projects (Figure 1).

During the implementation of the Joint Program, two areas were identified north-east of Sakhalin as the main feeding water areas for gray whales: Piltun, or "nearshore," and Offshore feeding areas (Figure 3). Each year, most whales observed by monitoring teams were encountered within these two primary feeding areas. However, in addition to these two areas, gray whales have also been observed in other locations in the Sea of Okhotsk, including near west Kamchatka.

The photo-ID and distribution studies under the Sakhalin programs indicate that individual gray whales move back and forth between the two primary feeding areas during each feeding season, and that their relative abundance within each feeding area varies in both space and time.

- ***Piltun Feeding Area***

The Piltun feeding area (PFA) adjacent to Piltun Bay extends along the coast from 52°20' to 53°30' N, with an area of slightly less than 1000 km^2 (Figure 3). Gray whales within the Piltun feeding area are sighted along a 120 km stretch of shoreline and prefer depths of less than 15-20 m, at a distance of no more than 4-5 km from the shore. Based on the observation data, it can be concluded that the boundaries of the area defined as the Piltun feeding area have remained stable for more than 30 years (i.e., 1984-2020).

Each year, gray whales begin arriving in the PFA in May as ice begins to break up along the coast of northeast Sakhalin. Due to ice and fog conditions typical of May and early June, whales are not easily sighted from shore; therefore, their abundance and distribution within PFA during the early season are not well documented. In 2012, satellite-tagged whale Varvara was recorded in the Piltun Bay area on May 18 following her migration from Mexico through Kamchatka prior to the complete breakup of the ice cover.

It can be concluded from the 2002-2020 data that the greatest abundance and concentration of gray whales are typically observed near the mouth of Piltun Bay (Figure 4). At the same time, the concentration of the gray whale in the northern and southern parts of PFA vary considerably. At the end of summer, an aggregation of gray whales was also observed in the northern part of the Piltun feeding area, and in some years (for example, in 2004 and 2005) whales gathered there in large groups and stayed in them almost until the end of the season. In some years, small groups of gray whales were also sighted south of the mouth of Piltun Bay.

The number of whales sighted within PFA by the shore-based survey teams varies from year to year. Based on shore-based survey data, the number of gray whales observed during single-day synchronized counts were highest in 2004-2006 (128-138 individuals) and lowest in 2018-2020 (8-17 individuals). The variations in the numbers of whales observed in PFA within a single year and between certain years are due to the redistribution of whales among the feeding areas (i.e., Piltun, Offshore, and Kamchatka)

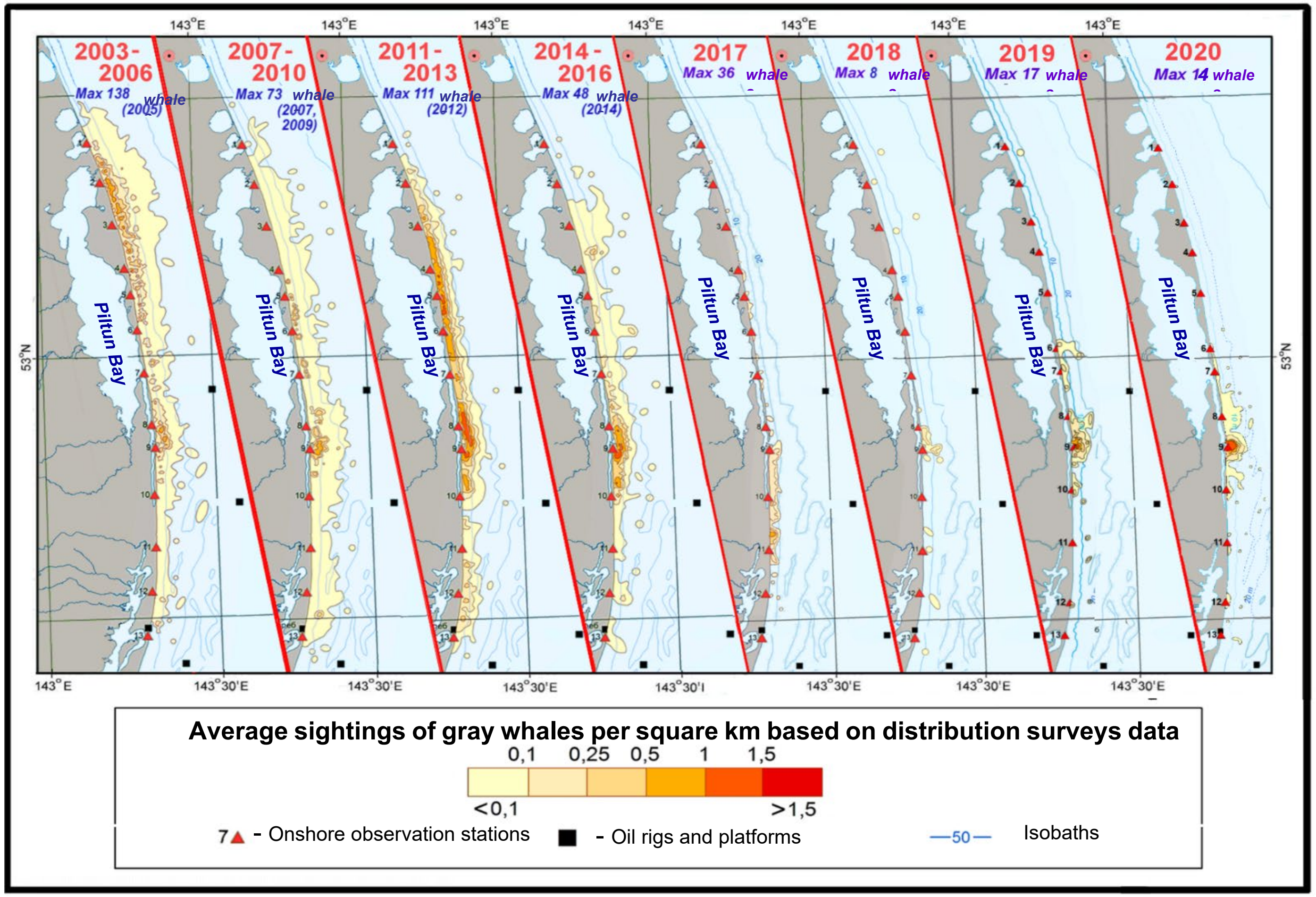


Figure 4. Rate of gray whale occurrence in the Piltun feeding area.

Based on the monitoring data, gray whales tend to stay closer to shore during the early months of the feeding season (i.e., June-August) as compared to the rest of the season (September). Up to the end of August, approximately 80% (in 2007-2010) of the whales sighted in the PFA were observed within two kilometers from the shore at water depths of less than 10 meters. Mother/calf pairs and single calves were observed even closer to shore (< 1 kilometer) than adult individuals.

The greater abundance of both adults and calves in the PFA during June and July may be explained by a combination of high biomass of benthic food resources and the shallow water depths. Mother/calf pairs have only been observed off Sakhalin in the shallow, near-shore areas and have not been sighted in deeper areas of the PFA or the Offshore feeding area. Yearling calves may have limited abilities to dive to depth, thus it would be natural for them to remain in shallow areas to feed. As benthic biomass is probably easier to harvest at shallower depths, some of adult whales start feeding here upon arrival in the coastal waters of Sakhalin. Another factor explaining why the whales appear to prefer shallow areas during the early feeding season is that protection of the calves (and adults) from their primary predator, the killer whales, would be much easier in the shallow waters.

Later (in September), some whales move to the deeper waters of the Piltun area; they can be observed two to five kilometers from the shore, where the water depth is approximately 10 to 20 meters. Gray whales are believed to make the movement to deeper areas of the Piltun and Offshore feeding areas in search for the higher biomass of their preferred prey which may be somewhat reduced in near-shore areas by intense consumption (eating up). However, the majority of whales observed in the PFA through the entirety of the feeding season were sighted in the near-shore zone of less than two kilometers from shore.

- ***Offshore Feeding Area***

The Offshore feeding area (OFA), located about 40-50 kilometers south-southeast of the Piltun feeding area and eastward of Chayvo and Nyiskiy Bays, extends from ~25 to 50 kilometers from shore at approximate latitude of 51°40’ to 52°20’ and covers an area of ~1400 km^2 (Figure 3). Prior to the discovery of the Offshore feeding area by the scientists of Sakhalin programs in 2001, it was assumed that the PFA was the sole Sakhalin feeding area for gray whales. The importance of the OFA to the whales is now well established. The OFA is characterized by water depths ranging from 35 to 60 meters and high benthic biomass of food organisms subject to minor changes over the years of monitoring. Importantly, the Offshore feeding area provides a source of preferred benthic food resources (i.e., amphipods) that can supplement the Piltun feeding area (Demchenko et al., 2016). Due to the greater depths of the Offshore feeding area, feeding is more energy intensive than feeding in the shallow Piltun feeding area.

Through the years of the monitoring programs, there has been considerably less survey effort in the OFA than that in the Piltun feeding area. Typically, four to six vessel-based surveys within the established transects of the feeding area were done each year during the August-September timeframe (Figure 5). The feeding area surveys require the use of vessels, which were not available every day since the vessels were used for other activities. These surveys were dependent on hydrometeorological conditions; due to poor conditions (fog, wind, waves) surveys are not typically conducted during June, July, or October. Nevertheless, the vessel-based surveys conducted in the Offshore feeding area make it possible to assess both the inter-seasonal and intra-seasonal variability in the use of the feeding areas (Figure 6). At the end of the feeding season, the number of gray whales in the OFA goes up. Such increase typically corresponds with an observed decrease in numbers of animals in the PFA toward the end of the feeding season (i.e., September), suggesting a preference for feeding in the OFA at this time.

As in the PFA, substantial inter-seasonal variation in the distribution and abundance of sighted gray whales is observed in the Offshore feeding area. Since 2004, there has been a gradual expansion of the OFA southward, with more frequent sightings of gray whales along the eastern portion of the survey grid. In 2009, a considerable number of whales (11 individuals) were sighted in the northeastern part of the OFA, where whales had not been previously sighted. This eastward shift toward deeper waters was also observed in 2010. In 2012 the gray whales shifted to the central, shallower part of the OFA; while in 2013 - to the southeastern part of the OFA with depths of about 50 meters.

However, in 2018-2019, the whales were noticed to move back to the northern part of the feeding area (Figure 6) and this suggests that the OFA also experiences periodic changes in the spatial distribution of forage resources, although their total biomass can completely satisfy the feeding demand of the sighted number (and possibly even far more) of whales feeding in this area (Labay et al., 2018).

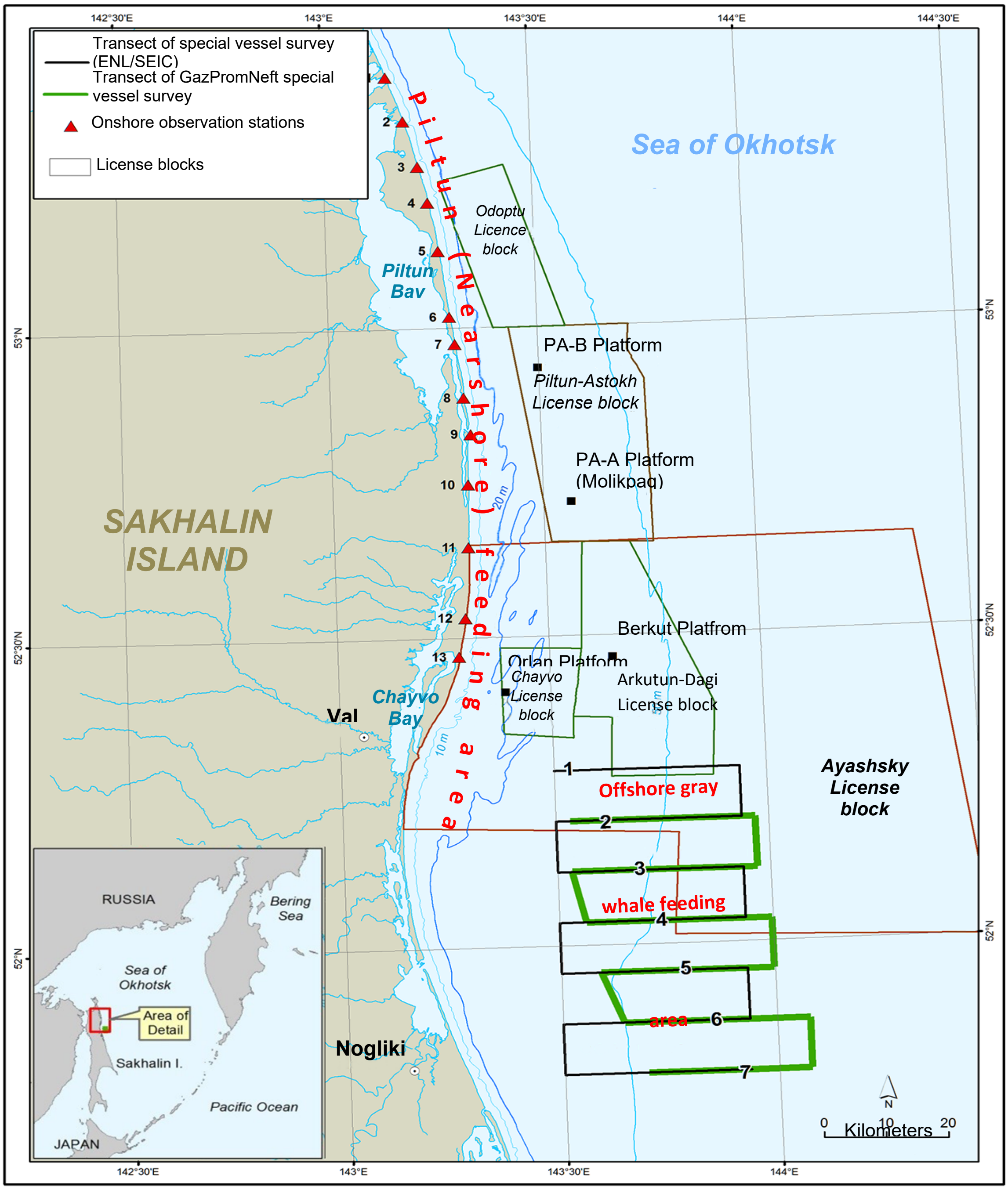


Figure 5. Transects of Gray Whale Vessel-Based Survey.

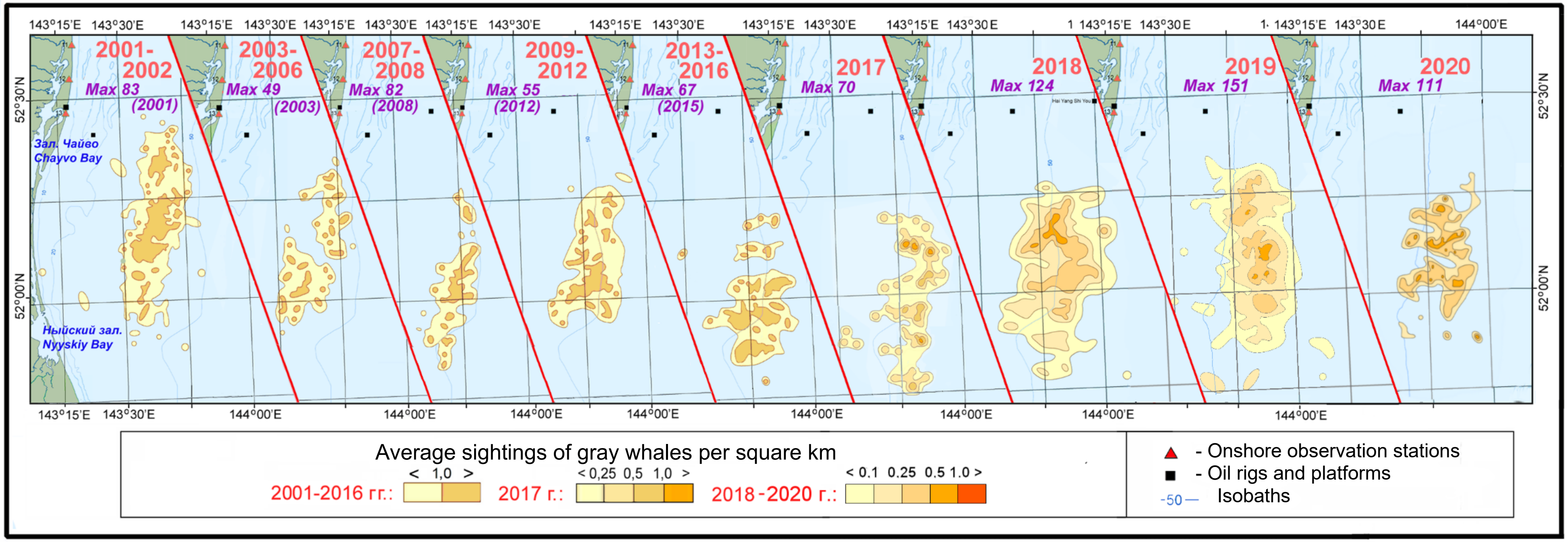


Figure 6. Frequency of gray whale occurrence in the Offshore feeding area.

Summary data on the changes in gray whale abundance registered off the northeast coast of Sakhalin Island in 2001-2020 are provided in Figure 7.

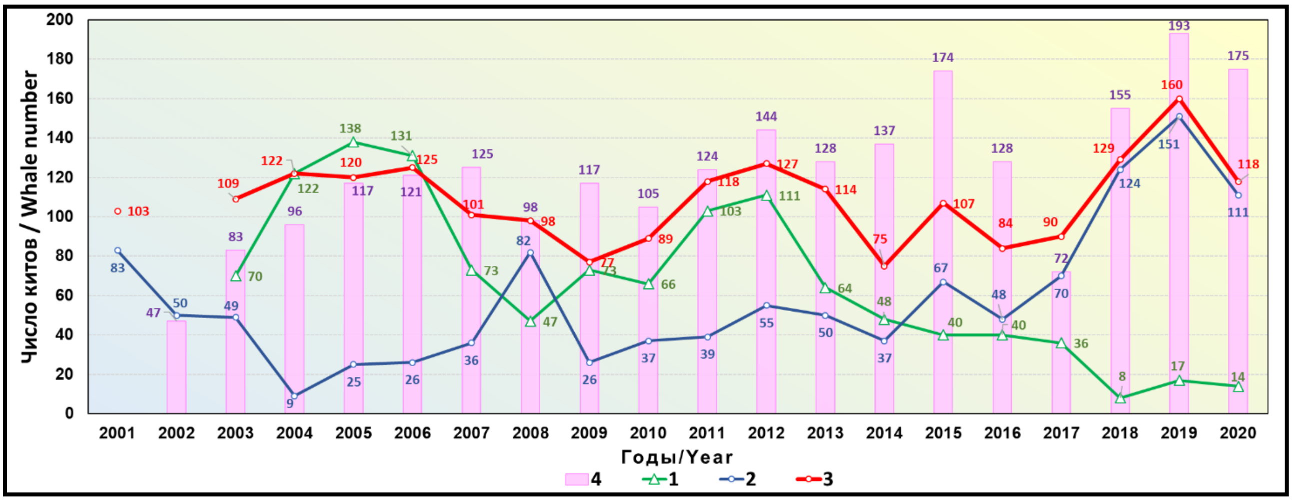


Figure 7. Summary Data on Changes in Gray Whale Abundance Offshore Northeast Sakhalin Island in 2001-2020.

2.4 GRAY WHALE FOOD SOURCES

The gray whales feed primarily on benthic (bottom) and epibenthic (near-bottom) invertebrates. From 2002 to 2016, the Joint Program monitored the benthic communities off northeastern Sakhalin believed to serve as a food supply for gray whales, in order to study the spatial and temporal structure variations (Figure 8). Since gray whales migrate each year to coastal waters of Sakhalin to feed, study of the benthos that could serve as a food resource for gray whales provides important information for understanding gray whale ecology, abundance, distribution, movement, and behavior within the Sakhalin feeding areas. High benthic biomass that can serve as a food supply for gray whales in the Piltun and Offshore feeding areas provides a compelling explanation as to why gray whales return to Sakhalin year after year (i.e., exhibiting high site affinity). Monitoring of benthic communities has significantly added to the knowledge of gray whale food supplies, including species composition, numbers and biomass of individual species, and of the influence of environmental parameters (e.g., hydrology and type of sediment) on these benthic communities (Fadeev, 2011).

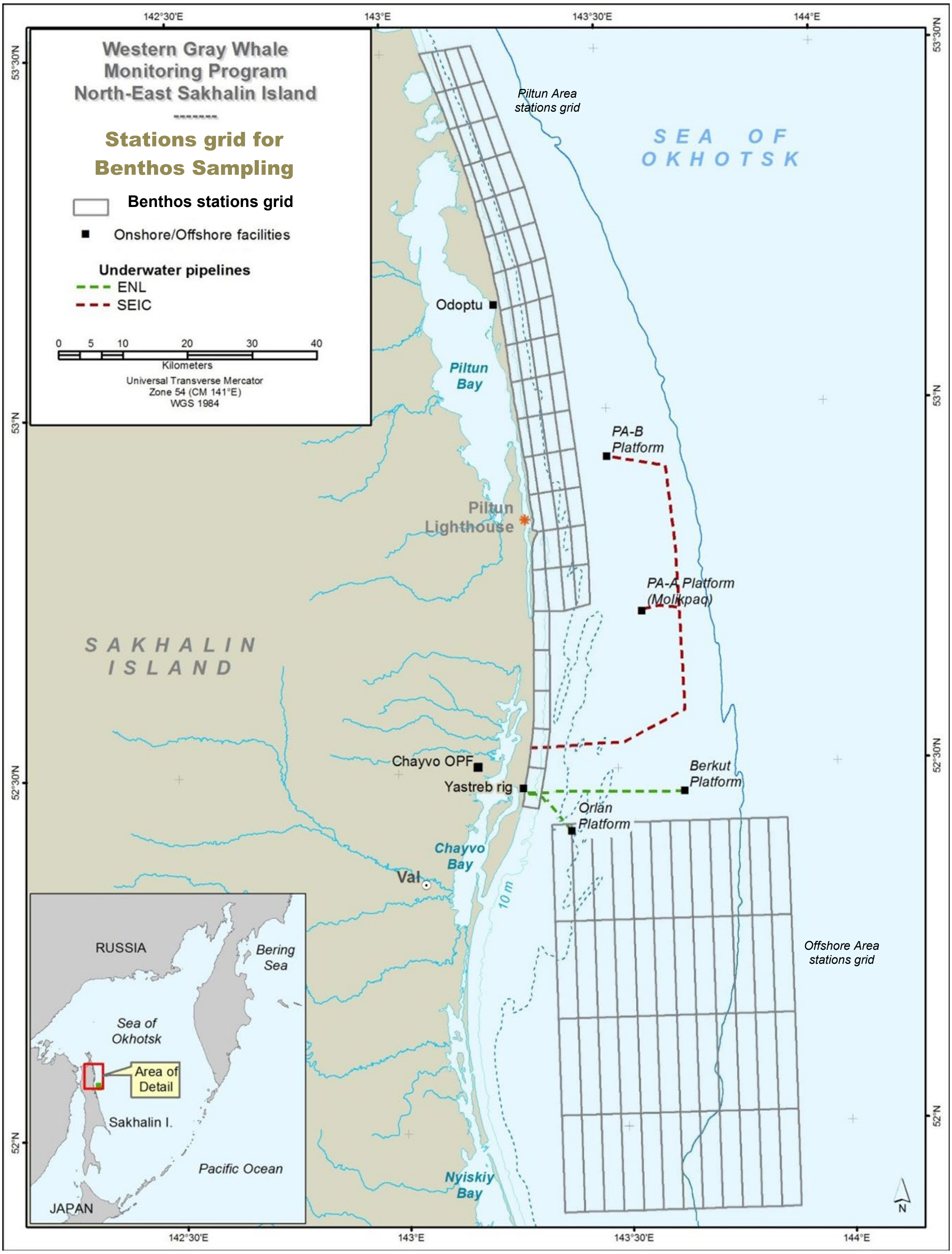


Figure 8. Stations Grid for Benthos Sampling in the Piltun and Offshore Feeding Areas.

- ***Benthos in the Piltun Feeding Area***

Three communities of macrobenthos can be distinguished in the Piltun area (Fadeev, 2007): 1) Amphipoda, 2) Bivalvia and 3) *Echinarachnius parma*. Such communities are clearly delineated by depth range: 1) 3–23 m (12 m), 2) 12–28 m (21 m), 3) deeper than 20 m. the latter practically is not used by the gray whales for feeding. Amphipoda community is distributed in bands along the Piltun area coast. The average biomass of macrobenthos is determined by amphipods – 34–71%, isopods – 3–16% and Bivalvia – 8–28%. Four species of amphipods are of the highest abundance: *Monoporea affinis, Eogammarus schmidti, Eohaustorius eous* and *Anisogammarus pugettensis*. Bivalvia community is clearly distributed in spots. The dominating species in shallow areas is *Megangulus luteus*, and *Astarte arctica* – in deeper places (over 20–25 m). Sporadically, the biomass of amphipods and isopods *Saduria entomon* within the community can reach 50% of mollusks biomass.

The average total biomass of benthos in the Piltun feeding area in 2002-2016 has remained relatively stable from year to year. In 2016, the value of this indicator was 621.1 ± 133.7 g/m^2 (n=43); for comparison, average total biomass of benthos in 2015 was 571.4 ± 119.2 g/m^2 (n=55), in 2014 - 599.8 ± 151.5 g/m^2 (n=56), and in 2013 - 614.1 ± 132.2 g/m^2 (n=58). Year-to-year variations of average total biomass are not statistically significant (t-test, $p > 0.05$).

The average benthos biomass in the Chayvo subarea in 2016 ranged from 21.6 (st. In12, depth 11.4 m) to 108.5 g/m^2 (st. Ch02, depth 11.5 m) and averaged 43.3 ± 10.1 g/m^2 (n=8). For comparison, in 2015 this indicator was 66.8 ± 10.0 g/m^2 (n=12); in 2014 – 52.4 ± 5.9 g/m^2 (n=12) and in 2013 - 62.9 ± 6.8 g/m^2 (n=12). Year-to-year variations of biomass is not a statistically significant indicator (t-test, $p > 0.05$).

Amphipods and isopods are believed to be the most important food supply for gray whales. Other benthic organisms, such as sand lance (a fish), also contribute to the total benthic biomass and are prey. Although sea urchins dominated the overall biomass, they are believed to have little food value for gray whales (Fadeev, 2011).

The biomass of the sand lance *Ammodytes hexapterus* in the Piltun area in 2016 ranged from 0 to 323.2 g/m^2 (st. 4-1S, depth 18.4 m) and averaged 32.8 ± 10.5 g/m^2 at a frequency of occurrence throughout the study area >63% (n=43) which is higher than in previous years. For comparison, in 2015, the average biomass of this species was 27.1 ± 5.2 g/m^2 (n=55); in 2014 – 5.35 ± 1.51 g/m^2 (n=56), and in 2013 – 7.04 ± 1.49 g/m^2 (n=58). Accumulations of this species with the greatest density were found on sections of sandy bottoms mixed with gravel. The results of previous studies show both significant year-to-year variations of the sand lance (*A. hexapterus*) abundance and its frequency of occurrence (the percentage of samples where sand lance was found) in the Piltun area (Ivin and Demchenko, 2016).

In general, according to studies, the biomass of the key benthic forage organisms (amphipods and isopods) in the Piltun area was decreasing throughout the entire monitoring period. Three periods can be distinguished: 1) high biomass (2002–2004), 2) average biomass (2005–2012) and 3) low biomass (2013–2016). These data explain the redistribution of gray whales predominantly from the Piltun (2002-2007) to the Offshore area (after 2016) (Fig. 7), where the biomass changes were less distinct (Labay et al., 2018).

- ***Benthos in the Offshore Feeding Area***

Four macrobenthos communities are distinguished within the limits of the Offshore area (Fadeev, 2007): 1) Echinarachnius parma, 2) Diastylis bidentata + Amphipoda (= Diastylis bidentata + Bivalvia; = Bivalvia), 3) Ampelisca eschrichtii + Bivalvia + Actinia and 4) Ampelisca eschrichtii. The first community is observed in the northern part of the Offshore area along isobath lines of 18–43 m (33 m) and is barely used by gray whales for feeding. The community with the dominance of cumaceans D. bidentata and amphipods A. eschrichtii significantly changed over the monitoring period. Amphipods and cumaceans gradually disappeared as the key species; in recent years, the community has been identified as the Bivalvia complex. The average depth is 26 m (20–38 m). A community dominated by ampelisks, bivalves, and sea anemones. The average depth is 46 m (in the depth range of 25–52 m). On the periphery, the ampelisca community was registered in patches. A community dominated by the amphipod A. eschrichtii is concentrated in the depth range of 36–72 m and occupies the southern and eastern parts of the area. The biomass of the dominant group – amphipods – was 48–74% of the total.

The average benthos biomass in the Offshore area in 2016 ranged from 99.7 (st. B1-2, depth 30.1 m) to levels above 4,400 g/m^2 (st. B5-4, depth 32.5 m), and averaged 878.9 ± 140.1 g/m^2 (n=34). For comparison, in 2015 this indicator was 879.3 ± 92.5 g/m^2 (n=48), in 2014 – 963.8 ± 125.7 g/m^2 (n=48), in 2013 – 896.2 ± 112.9 g/m^2 (n=48), in 2012 – 469.7 ± 112 g/m^2 (n=48), in 2011 – 435 ± 178 g/m^2 (n=38), and in 2010 – 578.6 ± 123.3 g/m^2 (n=48). Considerable increase of the average benthos biomass since 2013 is related to the increase of sea urchin biomass. Year-to-year variations of biomass is not a statistically significant indicator (t-test, $p>0.05$).

2.5 FACTORS AFFECTING BENTHOS ABUNDANCE AND DISTRIBUTION

The abundance and distribution of benthos are affected by a variety of abiotic and biotic factors. As part of the Joint Program, hydrological parameters – temperature, salinity, and bottom sediment characterization were measured to help determine factors that influence benthos abundance and distribution in the Sakhalin gray whale feeding areas.

- ***Bottom Sediments***

Sediments at most sampling locations are characterized by predominance of sand fractions. Of the 223 samples analyzed in 2012, 86% were predominantly sands, while 14% consisted of gravel-pebble soils containing some sands of various grain sizes. The fine sand fraction exceeded 70% almost at all locations. For the monitoring period (2002–2016), fine sands predominated at depths up to 10–15 m throughout the Piltun feeding area. With increasing depth, fine sands are replaced by medium- and coarse-grained sands and areas with gravel–pebble soils containing some sands of varying size.

In the Offshore feeding area the content of silt-clay in the sediment increased with water depth. Overall, fine sands predominate at more than 85% of the stations in the Offshore area. Gravel soils and coarse-grained sands occur in patches mainly in shallower parts along the western area.

- ***Hydrology***

The Piltun feeding area can be characterized as a shallow-water coastal area with a 20-meter isobath at 5-10 km from the shore and the 50-meter isobath at 20-30 km from shore. The Piltun feeding area transformed freshened water from the Amur Estuary and water from Piltun and Chayvo Bays.

During upwelling (this phenomenon occurs in these waters when there are seaward winds), the near-shore zone is filled with deep waters that have lower temperature and higher salinity than the relatively warm freshened surface waters, which are mixed further out to sea.

The upwelling is considered to be a significant factor in phytoplankton primary production in some parts of the Sea of Okhotsk (Shuntov, 2001). In summer, upwelling is observed on the NE shelf when winds blow from the south (Borisov et al., 2008) and/or from the southeast. Hydrological observations indicate that prolonged upwelling may occur over large areas of the NE Sakhalin shelf, and for long periods in some parts (Krasavtsev et al., 2000).

Benthos is also influenced by the influx of freshened water and detritus from the Amur River and, in a lesser degree, by water from Piltun and Chayvo Bays. This shallow water influx appears to be constant and steady with no significant variations from year to year. Therefore, ice (during cover breakup), biogenic and organic substances from the Amur River waters, summer influx from Piltun and Chayvo Bays during flooding, and the phenomenon of predominant sinking of the surface warm layer in water column during frequent north-eastern and eastern winds in summer season are variable factors potentially affecting biological productivity of the area.

The increased productivity in the Offshore area could be explained by the formation of the vertical convection zone during the warm season, which contributes to the exchange of biogenic substances between the bottom and near-surface layers of water and warming of water near the bottom (Labay et al., 2019).

The combined effect of these processes ensures high biological productivity in this part of the Okhotsk Sea, making this area a primary feeding zone for gray whales in the summer-autumn season.

- ***Ice Cover***

Early or late breakup of the ice cover offshore northeastern Sakhalin significantly impacts the onset of the phytoplankton growth process, which may subsequently impact the benthic organisms.

- ***Climatic Factors***

Changes in climate patterns significantly influence marine ecosystems across the Pacific Arctic region, creating significant ecosystem transformations and changes. Macrobenthic species are essential prey for numerous marine mammals and seabirds, but the influence of climatic drivers on macrobenthic community population dynamics in critical prey habitats is not studied sufficiently. Using the benthic data collected in 2001-2015, Blanchard et al. (2019) studied the correlation between environmental, temporal, and climatic covariates and the biomass concentrations of six prey groups (Actinopterygii, Amphipoda, Bivalvia, Cumacea, Isopoda, and Polychaeta) in major gray whale habitats off northeast Sakhalin Island in the Sea of Okhotsk. Prey community biomass concentrations were correlated with water depth, year, and climate indices reflecting oceanographic and climatic patterns associated with large-scale climate impacts. The correlation of prey biomass with water depth and year account for ~90% of total variation in canonical correlation analyses, and climate indices account for ~10% of total variation. Water circulation in winter may be particularly important for maintaining populations through the advection of particulate organic carbon entrained in winter currents. Overall, the temporal trends in the biomass concentrations of gray whale prey resources appear to reflect climatic and oceanographic factors that are driving ecosystem changes across the Sea of Okhotsk and the Pacific Arctic region.

2.6 GENETICS OF GRAY WHALES

During the studies period, biopsies were taken from individual gray whales for genetic analysis. The biopsy samples were taken from 71 whales totally. Gender identification determined 42 females and 29 males in this group. Seventeen females of the group were observed during the 2002 – 2018 period with at least one calf, which accounts approximately for 50% of the known females of reproductive age in the Sakhalin aggregation. According to the photos review, the group subjected to sampling include 21 mother-calf pairs, 1 mother - daughter – grandson group and 7 pairs of siblings. According to the photo identification and satellite telemetry, 7 whales, including 5 mothers, from this group were observed near the shores of North America.

Thus far, the results of the genetic analysis of gray whale biopsies have resulted in five peer reviewed publications and two papers in preparation whose data have been collected and are presently in the data analysis stage. There are also a series of unpublished reports and proceedings presented at scientific conferences, and non-reviewed articles published in the International Whaling Commission materials (Appendix 1).

The first whole-genome sequence of 3 gray whale individuals from remote regions (2 Sakhalin whales and 1 Alaska whale) was presented in 2017 (DeWoody et al., 2017). A panel of 96 genetic markers, referred to as single-nucleotide polymorphisms (SNP), was selected based on genome sequences. 92 of these markers are located in functional genes and comprise a panel of markers that may be used in the future for more accurate study of gray whales' genetics compared to microsatellite markers that were used before. Successful use of the SNP panel was demonstrated on 35 biopsy samples taken from Sakhalin Island whales.

The three genome sequences (DeWoody et al., 2017) were used to study gray whale evolution history and historical demography (Brüniche-Olsen et al., 2018a). Methods of assessment of random mating, relatedness, and effective population size (N_e) were used when comparing 3 genome sequences for two Sakhalin gray whales and one whale from Alaska (EGW). N_e is a measure of the degree of genome genetic variations induced by genetic drift, and, consequently, the degree of the correlation between the variations and the size of the population, rather than selection. It was found that a zero hypothesis of random mating cannot be disapproved, which demonstrates the potential for three whales to belong to the same population. A test showed the two Sakhalin whales to be more closely related to each other than either was to the Alaskan whale. However, the Alaskan whale was more closely related to both of the Sakhalin whales than expected by chance, which again is consistent with a single population, but not necessarily conclusive. Calculations of the effective population size based on 3 genome sequences showed that both Sakhalin whales belonged to the population of lesser calculated effective size than the whale from Alaska. Nevertheless, despite more than a 100-fold difference in abundance between the Sakhalin whale group and EGW, N_e indicated only 1.2-fold difference between the Alaska whale and the whales from Sakhalin. Another test called runs of homozygosity, which estimates the amount of in-breeding in the history of the individual, showed that the two Sakhalin whales had higher in-breeding than did the Alaskan whale.

Historical demography was also studied using a MSMC software for N_e calculation in different periods of time. It shows evolution history of the population an individual belongs to, namely the trend of effective population size variation over time. If individuals belong to different populations, the trends of population variation are expected to be different. The results presented in Figure 9 show that there are some differences between the whale from Alaska (solid black line) and two Sakhalin whales (solid red and blue lines), however, they are not significant, and additional sequences are required to prove the existence of considerable differences.

The SNP panel developed by DeWoody (DeWoody et al., 2017) was used for the analysis of samples taken from gray whales near Sakhalin Island and in Mexico. Eighty-four (84) SNP autosomal loci (markers) were analyzed from 111 whales from Mexico and 55 Sakhalin whales (Brüniche-Olsen et al., 2018b). The analysis identified a statistically significant measure of population differentiation (F_{st}) between two populations. This result is similar to the data acquired during the previous studies with another type of genetic marker used (microsatellites) (Lang et al., 2010; Lang et al., 2011). Thus, it appears to be clear that the Sakhalin population is, indeed, genetically different from EGW, at least based on allele frequencies, for two types of genetic markers: SNP and microsatellites. Multivariate statistical analysis known as “discriminate analysis of principle components” (DAPC) was applied to further study this aspect. The analysis also showed that the two populations are different, but with considerable overlap.

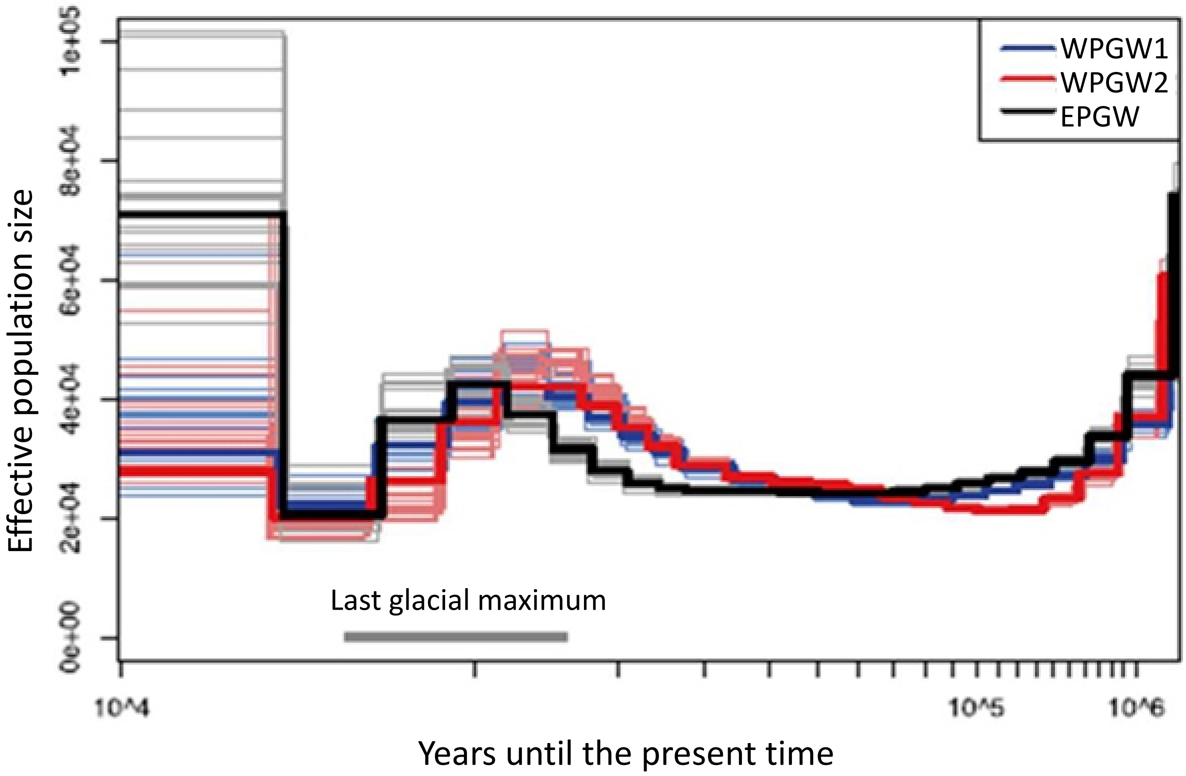


Figure 9. Interpretation of long-term demographic history based on whole-genome sequences of three whales from the North Pacific gray whale population (Brüniche-Olsen et al., 2018a).

Two analyses were conducted in which the individual whales are not assigned *a priori* to populations (Brüniche-Olsen et al., 2018a). STRUCTURE is a genetic clustering program in widespread use (Pritchard et al., 2000), while LEA (Frichot et al., 2015) is a more recently developed program that essentially solves the same problem using a different mathematical approach. Both software packages attempt to assign each individual to a population, and hence, estimate the number of populations presented by samples. Random mating and linkage equilibrium are assumed in hypothetical base populations. The software programs attempt to identify the combination of individuals with the minimum deviation from the Hardy-Weinberg equilibrium and from linkage equilibrium. Hence, individuals are assigned to a hypothetical population or estimated to be admixed from two or more such populations. The results of the LEA and STRUCTURE analyses both identified two populations, or genomes. One population or genome predominates in the samples from Sakhalin, while the other predominates in the samples from Mexico. Some individuals are identified as admixed, meaning they have mixed ancestry presumably resulting from past hybridization. The analysis results showed that Sakhalin gray whales are a mixed stock aggregation, consisting of: 1) minority of whales, with ostensible EGW genotypes; 2) majority of whales with genotypes distinct from that of EGW; and 3) a few whales with mixed ancestry. The assumption suggests itself that they are historical eastern and western populations of gray whales and their hybrids, however, the situation is complicated by the fact that Sakhalin whales of both eastern and western genotypes are known to migrate to North America (Brüniche-Olsen et al., 2018a).

To further explore the significance and test the reality of the two ostensible populations identified by the LEA analysis, a series of mitochondrial DNA (mtDNA) genes were sequenced in the laboratory of National Scientific Center of Marine Biology, Far East Branch of the Russian Academy of Science (NSCMB) (Brykov et al., 2019). The mtDNA control region (CR) and three protein-coding genes were sequenced from 64 (CR) and 65 (proteins) Sakhalin whales samples. Samples included those taken from 45 and 46 whales with LEA estimates based on CR and protein-encoding genes. Samples from other whales were not provided for the SNP tests, therefore, there were no LEA estimates for them. The previous studies of the mtDNA CR consistently showed a statistically significant value F_{st}, when comparing Sakhalin whales with various sets of EGW samples (Leduc et al., 2002; Lang et al., 2011). Nevertheless, their analyses had no evidence of geographical structure with regard to CR sequences, as it could be expected when the populations are separated by the ocean. It means that all haplotypes found in Sakhalin whales were also found in EGW, but with different frequency. Comparisons between populations of other marine mammal species with distribution similar to the distribution of the population of the North Pacific gray whales usually demonstrate a set of allied haplotypes that are unique for one or another population. With regard to gray whales, it was not observed during the previous mtDNA studies, and mtDNA haplotype frequencies are the only evidence indicating the difference between populations. Nevertheless, considering the results of the SNP LEA and STRUCTURE analyses, it could be possible that presence of the EGW individuals in the Sakhalin population masked the presence of unique groups of related haplotypes among the whales with western SNP genotypes.

The analysis performed showed that Sakhalin whales with seemingly “eastern” SNP genotypes identified during the LEA analysis, exhibited significant G_{st} и F_{st} values (as measures of population differentiation similar to F_{st}) for both the mtDNA CR and the 3 mtDNA protein-coding genes despite small sample sizes (Brykov et al., 2019). This suggests that the populations identified during the LEA and STRUCTURE analyses are real. However, when the haplotype networks, which show the relationships of the haplotypes, were constructed for both the mtDNA CR and the mtDNA proteins, again there was no evidence of sets of related haplotypes unique either of the eastern or western LEA populations.

In order to search further for unique haplotype lineages within Sakhalin whales, the full mitogenome sequences from 74 whales (including 38 Sakhalin whales and 36 Mexican whales) are being studied (Brüniche-Olsen et al., 2021). Once again, there is no evidence of unique haplotype lineages within the Sakhalin population.

Taken together, the results presented in DeWoody et al. (2017), Brykov et al. (2019) and Brüniche-Olsen et al. (2018a, 2018b, 2021) do not provide a definitive answer as to the nature of the Sakhalin gray whales (Okhotsk-Korean or Western_ population). Conclusive results will require analyzing pre-whaling samples with which to make direct comparisons between the WGW and EGW populations and to show if the present population at Sakhalin differs from the pre-whaling population.

But while these studies are not in and of themselves conclusive, the weight-of-evidence they provide indicates that the Sakhalin feeding aggregation of gray whales is comprised of two groups (eastern and western genotypes) and both groups are likely to have been recently derived from the EGW population. If the western genotype animals were in fact derived from EGW ancestors, and not WGW ancestors, it would explain why: 1) they do not show distinct mtDNA lineages and only show low levels of differentiation at mtDNA haplotype frequencies, SNP frequencies and microsatellite frequencies (these are all expected results of a recent founder event); 2) these animals travel from Sakhalin to Mexico, a trip of considerably greater distance, and energetic cost, than from Sakhalin to the presumed Asian wintering grounds in the South China Sea; and 3) no evidence is seen in the genetics and genomics results that suggest there is a distinct western breeding stock. Cooke et al. (2019) estimates that this comprises approximately 45% of the Sakhalin population. We would expect this group to be distinct from the eastern genotype and western genotype animals, since members of both these groups are known to travel to Mexico. No evidence of a third genotype group was found in the LEA or STRUCTURE analyses reported by Brüniche-Olsen et al. (2018a).

Thus, it seems most parsimonious to conclude the whales of the Sakhalin feeding aggregation are not the descendants of the pre-whaling WGW population. Rather they are descended directly from eastern gray whales. This hypothesis is testable if paleo or archaeological samples can be obtained from the whaling era or before.

2.7 THREATS TO GRAY WHALES

Gray whales face potential threats throughout their range of habitat from both natural and anthropogenic sources. Threats to gray whales include aboriginal subsistence whaling entanglement in fishing nets and gear, collisions with vessels, pollution, habitat damage, oil spills, and disturbance or displacement from key habitats.

- ***Natural Threats***

Natural threats to gray whales include predation (by killer whales), disease, epizootic mass mortality, climate change followed by the ecosystem degradation, insufficient food resources and competition. The killer whale (*Orcinus orca*) is the only non-human predator of gray whales. Predation of gray whale calves by killer whales is perhaps the most significant threat to the gray whales, and is a threat not unique to the Sea of Okhotsk. Although the degree of losses from predation is not known, the calves during the first two years of life are the most vulnerable. Attacks on gray whales by pods of killer whales are well known and have been witnessed offshore Sakhalin by the programs' scientists (fortunately, no cases of loss of a gray whale calf were witnessed).

Threats to gray whales from disease are still not completely understood. However, the decrease in EGW that occurred during the 1980s-1990s (estimated decrease from 30,000 to 20,000 individuals), is believed to be the result of the numbers of gray whales exceeding the feeding productivity of the environment, which could have led to disease and/or insufficient food resources to support the large number of whales.

Calculations of the ecological capacity of the environment showed the importance of a food competition factor, since the level of benthos consumption by fish is comparable to that by WGW (Labay et al., 2018).

- ***Anthropogenic Threats***

The main threats of anthropogenic nature that could have a negative impact on gray whales include: catch of individual species during traditional Alaska and Chukotka aboriginal fishing activities, entanglement, leading to injury and possible death in fishing, primarily, drift nets, potential collisions with ships, pollution, potential oil spills and noise. In recent years, cruise ships offering tourists the chance to see gray whales up close have regularly visited the Piltun feeding area. For example, cruise ships stopped in the Piltun feeding area at least 4 times in 2014-2017. During the visit on September 2, 2014, nine inflatable boats carrying 10 tourists each approached whales and followed them so take photographs could be taken. On September 1, 2017, ten inflatable boats with a total of 70 tourists spent several hours approaching whales near the mouth of Piltun Bay.

Environmental Impact Assessments (EIAs) conducted by each company for their respective offshore developments identified three main threats to gray whales as a result of the companies' operations: collisions with ships, noise that could affect hearing and cause disturbance/behavioral changes, including abandonment by the gray whales of their traditional feeding areas, and potential oil spills. A risk assessment has been performed for each of these threats, and measures have been developed to reduce the threats to an acceptable level. Each company implements mitigation measures through their Marine Mammal Protection Plans (MMPPs) to reduce the collision risk to whales.

MMPPs establish special vessel operation criteria that minimize the likelihood of vessel collisions with gray whales. Key MMPP mitigations include use of Marine Mammal Observers (MMOs) and Watch Standers, vessel speed restrictions, use of defined navigation corridors, limiting vessels to operate at a minimum distance to gray whales, and the prohibiting of companies' vessels in feeding areas, except when conducting the components of the monitoring programs and in case of emergencies.

Neither Company participating in monitoring programs has had any vessel collision or a near-miss with gray whales or other cetaceans in dangerous proximity to each other over the entire period of the project implementation in Sakhalin waters, which confirms the effectiveness of the MMPP.

Bottom sediment contaminant monitoring to identify potential changes in pollutant concentrations and grain-size-distribution is conducted as part of the individual companies' environmental monitoring programs around their facilities. Analytical results show that pollutant levels (e.g., total oil hydrocarbons) in the sediments in the monitored areas are not above background level.

The impact of a potential oil spill on gray whales may depend upon a variety of factors, including the distance of a spill source to gray whales and their habitat, the size and timing of the spill, and current environmental conditions (e.g., wind, rough seas, ice, etc.). Spilled oil may directly impact a whale through contact to skin and other surfaces, causing irritation and other reactions; and potentially indirectly as a result in damage to gray whale habitat and food resources.

It has long been recognized that anthropogenic noise from main and associated oil and gas production activities such as seismic exploration, construction and operation of offshore facilities has the potential to disturb whales. Noise disturbance of whales could possibly result in behavioral changes, displacement from main feeding grounds, and in extreme cases, physiological injury to hearing organs. In 2003, under the Joint Program, annual acoustic monitoring was implemented to further study noise levels, both of natural origin (storm) and generated during the companies' operations (e.g. seismic surveys, construction and production of hydrocarbons) (Figure 10). As necessary, measures were taken to reduce the noise impact, including changes in work schedules (timelines) and/or equipment upgrades.

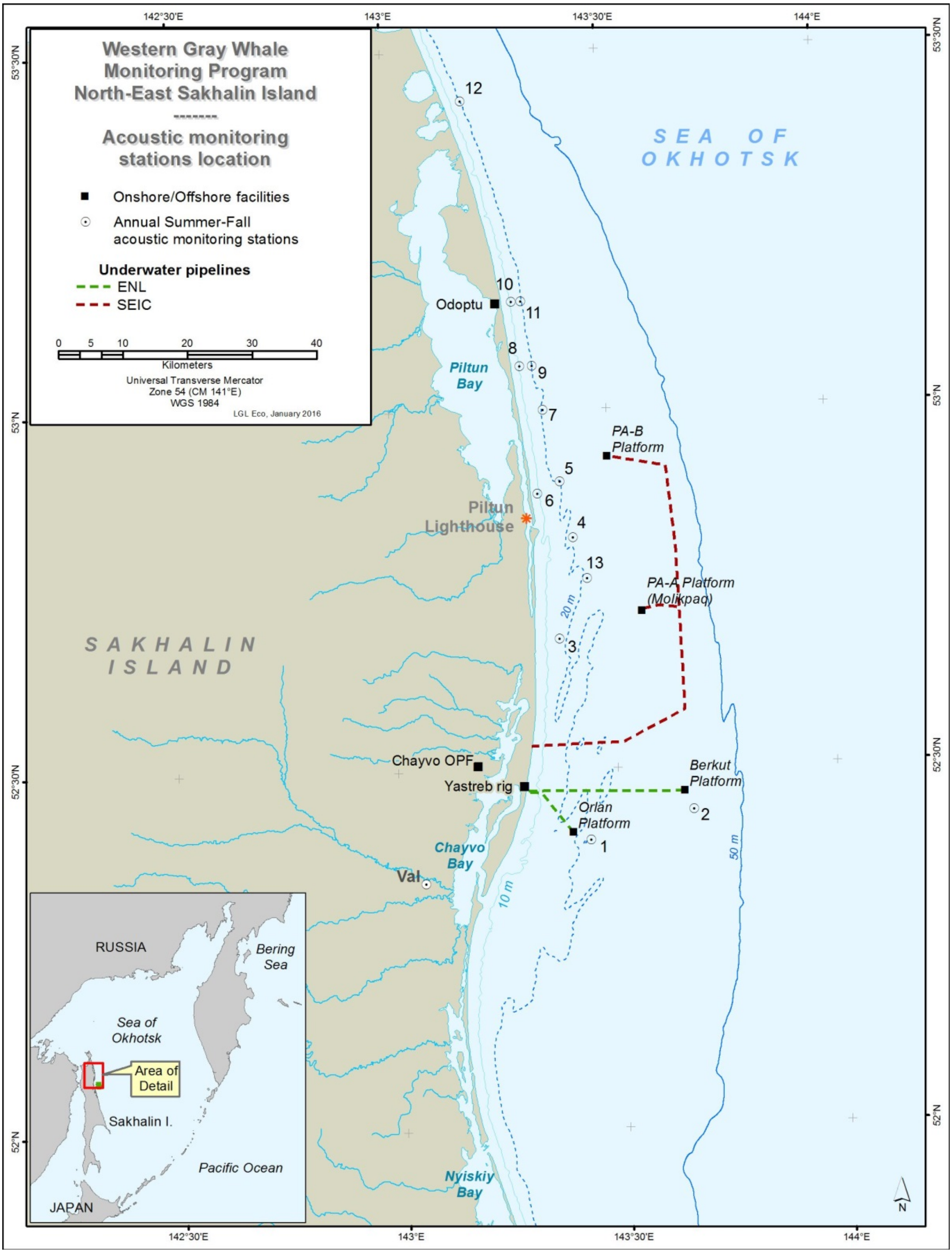


Figure 10. Locations of Acoustic Monitoring Stations.

CONCLUSION

The implementation of the Sakhalin gray whale monitoring programs and special studies involving research institutions significantly improved the understanding of the gray whales feeding offshore Sakhalin and their habitat. Annual reports on the results of the programs (2002-2020), based on a large amount of representative data, give the companies and other stakeholders a basis for an objective assessment of the status of the Sakhalin gray whales and their habitats. Below are key conclusions from the results of the monitoring programs and other studies sponsored by the companies.

- ***Gray Whale Feeding Aggregation***
  - Since 1983, when gray whales were sighted off NE Sakhalin, the number of known gray whales has steadily increased from about 20 to over 300 individuals. As of 2020, the total number of gray whales amounted to 332 individuals included in the Sakhalin catalog of the NSCMB with the Far Eastern Branch of the Russian Academy of Sciences. During the 2020 field season, 11 new individuals were added to the photo-identification catalog, 9 of them were calves.
  - Typically, each year there are two to five adult gray whales sighted for the first time off NE Sakhalin. It is unknown whether these individuals are new to the region, or visited the Sakhalin area in previous years and not photographed and identified, or its markings have changed to a degree that the whale no longer can be matched to earlier photographs. In 2020 two new adult whales were registered.
  - Typically, 50-60% of individual gray whales identified in the NSCMB Sakhalin catalog are sighted each year by the photo-ID teams under the programs. The number of whales sighted each year is positively correlated to the scope of the photo-ID effort and extent of good weather.
  - The status of gray whales encountered offshore Sakhalin during ice-free season (population, subpopulation, feeding aggregation) may be further refined after the completion of genetic analyses of biopsy samples, and a comprehensive discussion of scientific hypotheses and publication of the results.
- ***Gray Whale Migration***
  - Gray whales migrate each spring and summer to the Sea of Okhotsk to feed, where, according to monitoring data, they are recorded throughout the ice-free months off the coast of NE Sakhalin.
  - In 2010 and 2011 three individuals with satellite tags were tracked during their winter migration from Sakhalin to North America coastal water. The satellite transmitter on one female whale (Varvara) was tracked throughout the entire annual migratory cycle from Sakhalin to the known wintering habitat of gray whales in the Gulf of California (Mexico), and subsequently back to Sakhalin, Piltun feeding area. The North American migration for more than 50 Sakhalin whales has been confirmed by scientists with matches between photographic catalogs, genetic matching and satellite tagging (Urbán et al., 2012, 2013, 2019).
- ***Gray Whale Feeding Areas***
  - Two primary feeding areas for gray whales are known in the continental shelf of the Sea of Okhotsk off the coast of NE Sakhalin: the Piltun feeding area and the Offshore feeding area.
  - It is known that some gray whales regularly move between these two Sakhalin feeding areas during the feeding season. Mother-calf pairs have not been recorded in the Offshore feeding area.
  - Prior to the Offshore feeding area discovery in 2001, it was assumed that the Piltun feeding area was the primary feeding area off NE Sakhalin and that gray whales only feed at depths of no more than 20 m. Adult (including sub-adult) gray whales are now found in both areas and can feed at depths of ~50-60 m as minimum.
  - According to observations, in certain years some whales were at a depth of over 20 meters in the northern part of the Piltun feeding area, which coincided with the high density of sand lance in this location.

- Gray whales were observed in other areas outside of the two primary feeding areas, including Vostochny nature reserve, Severny Bay located north of Sakhalin, as well as Olga and Vestnik Bays off southeast Kamchatka. It is highly likely that whales use other undetermined feeding areas, since many whales listed in the Sakhalin NSCMB catalog have not been sighted for several years.

- ***Gray Whale Distribution and Abundance***
  - Gray whales are observed off the northeast coast of Sakhalin Island, from late May to early December. The peak gray whale abundance in the Piltun feeding area is observed annually in August. Abundance in the Offshore feeding area peaks at the end of the summer season (September-October).
  - In the Piltun feeding area, whales are routinely seen throughout the Piltun feeding area, but the highest concentration of whales is usually found in a 30 km stretch of coastline centered on the mouth of Piltun Bay. Juvenile whales, age 5 and under, are exclusively found in this area, as are mother-calf pairs.
  - The annual maximum number of gray whales sighted during surveys of the Piltun feeding area (i.e., scans at 13 locations conducted at the same time) ranged from 8 to 138 whales with an average of 67. In the Offshore feeding area from 2002 to 2020, the annual maximum number ranged from 9 to 151 whales with an average of 57. In recent years, the number of whales in the Piltun area tends to decrease due to natural causes, however, in contrast to decrease of the whales number in the Piltun area, their number in the Offshore area has noticeably increased after 2017. Similar cases of whale redistribution between feeding areas off northeast Sakhalin were also observed before, in 2004-2006 and 2008. Also, low counts of whale sightings typically occurred due the lack of available vessel time, resulting in only 2-3 observations in the Offshore area.
  - Coordinated distribution surveys over both feeding areas are rare due to difficulties of covering the vast area and routinely uncooperative weather. The annual maximum number of gray whales observed during simultaneous surveys of both feeding areas has ranged from 75 to 160 with an average of 109.

- ***Gray Whale Physical Condition***
  - Each year, some whales arriving at the Sakhalin area appear emaciated, i.e. in poor body physical condition (BC). The occurrence of such condition is believed to be a natural result of individuals having depleted a large portion of their body fat over the course of their winter migrations. Each year, about 10 to 20% of the gray whales off Sakhalin each year have been observed in poor BC.
  - Many whales arriving offshore Sakhalin in poor BC (at the beginning of the feeding season) have turned out to be nursing mothers, but their calves were well-nourished.
  - It is believed that that there is little to no feeding during the winter migration from the Sakhalin feeding areas. Whales spend the ice-free months off the NE Sakhalin coast consuming large quantities of prey and building up fatty tissue. During the feeding period, the physical condition of most gray whales improves, and, according to observations, by the end of September the physical condition of approximately 80-91% of the initially emaciated whales becomes normal. It should be noted that the feeding season lasts until late November-early December.

- ***Gray Whale Food Sources***
  - Gray whales are known to feed on benthic organisms. Amphipods and isopods are the primary food source for gray whales off northeast Sakhalin. Gray whales accumulate in Sakhalin feeding areas each year due to the large biomass of their preferred prey.
  - The overall percentage of amphipods in the benthos biomass within the Piltun feeding area is highest in the near-shore zone in water depths of 5 to 15 meters and decreases sharply at depths greater than 20 meters. The community with the amphipod *Monoporea affinis* as a dominant

species is predominant. Among the fish species, sand lance (*Ammodytes hexapterus*) is also a possible food source for gray whales and a component of the benthic biota that occasionally reaches high abundance. The highest densities of sand lance accumulations were recorded in northern part of the Piltun feeding area at depths greater than 20 m.

- The amphipod Ampelisca eschrichtii is the main food item in the Offshore feeding area. Average amphipod biomass in the Offshore feeding area is rather stable from year to year. Whales in the Offshore feeding area have been observed to feed predominantly at depths of 40 to 60 meters.
- Based on the monitoring results, gray whales are attracted to areas with relatively high forage biomass. The amphipods and isopods biomass in the feeding areas is over 100 g/m^2 which accounts for over 50% of the overall level.
- Olga Bay in Kamchatka has amphipod biomass slightly lower and similar to the values found in the Chayvo Bay area.

- ***Content of Pollutants in Gray Whale Feeding Areas***
  - Pollutant concentrations in bottom sediments of the monitoring areas off NE Sakhalin do not exceed background levels.
  - The content of petroleum hydrocarbons in the bottom sediments of the gray whale feeding areas do not exceed the average values for the NE Sakhalin coast. Sediments closer to shore had even lower petroleum hydrocarbon concentrations.
  - The concentration of heavy metals in the sediments in the study area did not exceed the background levels for the NE Sakhalin coast prior to the beginning of active industrial activities and they were substantially below the values of the Probable Active Concentration at which an adverse impact on benthic organisms can be expected. Heavy metal concentrations in polychaetes in the Piltun feeding area confirmed that heavy metals were not above the background content.
- ***Noise in Gray Whale Feeding Areas***
  - Since 2003, the Companies have conducted environmental acoustic monitoring, including of anthropogenic noise, through the Joint Program and with activity-specific monitoring in the feeding areas and offshore work areas to ensure that levels do not exceed specified thresholds.
  - The monitoring results demonstrate that natural noise levels vary significantly depending on atmospheric phenomena (wind and rain) and wave activity, which can elevate the background by more than 20 dB; noise levels can be near 100 dB during storms.
  - Offshore construction activities by the Companies generally induced broadband noise at the boundary of the Piltun feeding area within 120 dB/1 μPa (that is below the level of behavioral disturbance reactions of cetaceans to anthropogenic sound) except for brief surges lasting a few hours. This was largely achieved through the planning of activities with the aid of modeling tools to avoid scenarios that could lead to aggregation of noise sources.
  - Ships are the most significant sources of predominant noise of anthropogenic nature as a result of the activities of the Companies, with the exception of seismic surveys or piling works. Noise levels from moving vessels are generally regular, though insignificant, and are unlikely to cause persistent disturbance to whales in the area.
  - Systematic monitoring of anthropogenic noise from company activities conducted through 2016, allowed to obtain a significant quantity of data collected during routine operations and made it possible to identify noises of different origin, which in turn provided an opportunity to revise practices or make engineering alterations to minimize acoustic output.
  - In future, when the Companies conduct special activities associated with elevated levels of noise generation, such as seismic surveys, acoustic component may be included in the environmental monitoring program for the projects.
  - Multivariate analyses of behavioral data collected during seismic survey operations have

indicated that even at higher sound exposure levels, no more or less significant changes in gray whales behavior were observed.

- ***Gray Whale Conservation***
  - The companies' facilities have been designed and built to the highest standards in order to minimize the risk of adverse impact on the environment. Rigorous operating, services, monitoring, and auditing procedures are strictly adhered to by each company to mitigate potential risks to the environment and the gray whales in the coastal zone of Sakhalin Island.
  - The companies interact with leading scientists, international organizations, and other stakeholders through participation in their meetings and scientific publications in order to promote and facilitate efforts to conserve gray whales and their habitats.
  - The monitoring program provides a scientific basis for assessing the status of gray whales that feed off the northeast Sakhalin coast every year. The monitoring results demonstrate that the number and distribution of gray whales in the feeding areas have not been adversely affected by the companies' activities.
  - The Marine Mammal Protection Plans implemented by the companies proved to be highly effective at eliminating and/or mitigating the potential impacts of offshore operations on gray whales, having resulted in no incidents with gray whales and other marine mammal species related to the companies' activities.

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APPENDICES

APPENDIX I. Joint Program Publications.

APPENDIX II. Photo-Identification of Gray Whales (*Eschrichtius robustus*) off the Northeast Coast of Sakhalin Island in 2020.

APPENDIX III. Distribution and abundance of gray whales in shelf waters of Sakhalin during August-September 2020.

APPENDIX I.

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