Chapter 4: Baseline Environmental Conditions

4.1 Regional Setting

4.1.1 Location

Sakhalin Island is situated on the east coast of the Russian Federation, north of Japan, between 46 - 54ºN (Figure 4-1). The island is elongate in shape, ~950 km long and up to 160 km wide. It is separated from the Russian mainland to the west by the shallow Tartar Strait, which is ~100 km in width but narrows to 10 km at Pogibi at the north-east coast of the island. To the south, the island is separated from the Japanese Island of Hokkaido. To the east and north, Sakhalin Island is bordered by the Sea of Okhotsk.

4.1.2 Coastal Regions and Sea Floor

Barrier spits separating coastal bays from the Sea of Okhotsk are narrow and long constructional landforms composed almost completely of fine sands. Bays in the region are at least 3,200 years old. The barrier spits are generally 35-45 km long (Nabil Spit, Chayvo Spit), sometimes up to 60 km long (Piltun Spit), and 0.6-1.0 km wide, but with extreme widths ranging from 3.0-3.5 km (the Chayvo Spit).

There are several generations of old beach ridges superimposed on the spit surface and marking subsequent stages of the barrier accretion (up to 30 on the Chayvo Spit). Locally, the older ridges are reworked by wind into dunes 7-20 m high, with shallow overgrown lakes within inter-ridge depressions.

Erosional troughs of inlets are the most dynamic elements of the bay coasts; they are classified as either permanent or seasonal. Large, shallow bays in the northeast, such as Piltun, Chayvo, Nyiskii, and Nabilskii, have permanent inlets. Some of them are more than 10 km long (Piltun and Nabilskii inlets, Aslanbekov Bay) and 1-2 km wide (Nyivo, Anuchin). Dagi and Lunskaya are much smaller (not more than a few hundred meters wide). Active erosion from tidal currents has resulted in the deepening of some inlet bottoms relative to the floor of the bay and the adjacent seabed.

The eastern coast of Nevelski Strait is within the limits of a coastal region extending for 62 km from Lakh Cape in the south to Vagis Cape in the north. Erodible sandy coasts make up more than 62 % of its length.

The Chikhachev Bay coasts between Capes Ivana and Neprimetny consist of a marine erosion type and feature a high wave-cut cliff. Only at the central part of the bay (between Capes Ivana and Alekseev) does the Mount Davydov slope descend gradually to the shoreline. Cliff height varies from 15-20 m to 60 m. Wave-cut notches up to 2.5 m deep and caves occur frequently at the cliff base. The beach is undeveloped and many places are impassable along the shoreline.

4.1.3 Climate

Sakhalin Island can be divided into three distinct climatic zones: Northern, Mid, and Southern Sakhalin.

FIGURE 4-1. Map of Sakhalin Island with locations mentioned in text.

The North Sakhalin climate zone (settlements of Piltun, Val, Nogliki, and Nysh) is characterised by cold windy winters with little snow and cool, foggy summers. The average annual temperature is ~ –1ºC with an average minimum in January (-22.8º C). The average maximum temperature occurs in August (+14º C). The currently recorded absolute minimum (in Nogliki) is – 48º C. The average air temperature during the summer is 8.9º C on the coast and 9.5º C offshore.

The northeastern coast of Sakhalin is characterised by high relative humidity, especially in the summer time (84-93%). During the winter, relative humidity is about 70-78%. Annual average precipitation ranges from 539 to 709 mm, with an average of 600 mm. Annual precipitation is characterised by an increase in the monthly average between February and September-October, and a decrease in the monthly average from October to January. Southerly and southeasterly winds prevail over northeastern Sakhalin Island, with average wind speeds of 4 - 7 $m \cdot s^{-1}$ in December to January, up to 10 $m \cdot s^{-1}$ during July to August, and peak winds reaching 37-40 $m \cdot s^{-1}$.

Summers are usually cloudy, with the average number of cloudy days reaching 12-18 days a month. In the winter months, the average number of cloudy days reaches 7-13 days a month. The greatest cloud cover occurs in July, and the lowest cloud cover occurs in January. Fog generally occurs during the warm periods of the year, and is most frequently observed between June - July (15-19 days per month). In Nevelsky Strait, fog is most prevalent in May; the number of foggy days decreases starting in August. Between October and March, fog is infrequent (1-4 days per month). Thunderstorms are a summer-phenomenon, usually beginning in April or May, and ending in November; they are most frequent in July and August. The duration of a thunderstorm is usually short (1.2 - 1.8 hours). The tail ends of as many as many as six tropical cyclones have been known to affect the project area in a single year, although in some years no tropical cyclones may be recorded.

Snow cover usually appears during the second or third week of October and continues until mid March. In northeastern Sakhalin, snow cover may occur 170-196 days annually. Snowstorms are typically observed from October-May, with the most frequent and longest storms between November and March. Atmospheric icing is observed during the cold periods of the year (October-June) and is associated with mixed precipitation or crystallization of atmospheric water vapor.

The Mid-Sakhalin climate zone is characterised by annual average temperatures of 1.4º C. The average minimum temperature is in January (-15.5º C), and the average maximum temperature is in August (16.4º C). The absolute maximum was reported for August 1930 (+36º C), and the absolute minimum was recorded in January 1910 (-40º C).

Average annual precipitation based on many years of observations is ~800 $mm \cdot y^{-1}$. The prevailing wind velocity in the central part of the island is 3.6 $m \cdot s^{-1}$. In summer, southerly and southeasterly winds prevail, with a velocity of 3.2 $m \cdot s^{-1}$. In winter, the direction of the wind changes to northerly and northwesterly winds at a velocity of 3.9 $m \cdot s^{-1}$. The central part of the island is characterised by rather high humidity during summer (89%). During winter, the humidity is reduced to 71%.

The South Sakhalin climate zone (the region of the proposed LNG plant and oil export terminal) is characterised by more moderate climate. The average annual temperature is ~2-3ºC with an average minimum in January (-14º C) and average maximum in August (22º C). The currently absolute recorded range is – 40.4 to +35º C.

Precipitation is moderate at ~800 mm·y^{-1}. Winds are mainly from the west and are persistent and moderate, with average winds in December-January of 2-4 m·s^{-1}. In summer, light winds from the south are prevalent. Fog is common ~60 days per year, occurring mainly in summer.

4.1.4 Natural Hazards

Hazardous meteorological conditions that could significantly affect operations include snowstorms, icing over machines and mechanisms, and hail. During winter, vessels and offshore facilities in the area could ice over from November to May, and in some cases, even during June, September, and October.

4.1.5 Oceanography

The Sakhalin II project is located in an area characterised by fluctuating tides and sea currents, high waves, sea ice, formation of ice ridges and hummocks, and a potential for seismic events that may generate tsunamis.

4.1.5.1 Tides and Currents

Tides are principally diurnal off the northeastern coast of Sakhalin Island. Over the fortnightly lunar cycle, tides range between 1.7 and 2.2 m high. Currents associated with daily tidal events are most pronounced between 5-10 and 20-25 km offshore. Winds are another important factor that influence current speed and direction, either enhancing or reducing tidal currents. Averaged over time, surface currents in the Chayvo area are ~35 cm·s^{-1} (or ~0.7 knots) and are predominantly directed towards the north-south and northeast-southwest directions during open-water periods. Average near-bottom currents of 17.8 cm·s^{-1} (~0.4 knots) are primarily directed north and south. Maximum currents may reach 150 cm·s^{-1} (3 knots) and 130 cm·s^{-1} (2.6 knots) at surface and near bottom depths, respectively, particularly in a belt 7-15 km offshore. Those strong near-bottom currents are responsible for the large-scale transport of sediments on the shelf and the resultant formation of a variety of bed forms (e.g., large sand waves, sand banks, and sorted gravel deposits).

Over the summer monsoon period (June-August), seas with southeasterly and southerly currents are primarily observed off northeast Sakhalin, with average wave heights of 0.8-1.1 m. Storms result in waves up to 4.5 m. In September, as the winter monsoon sets in, the frequency of stormy seas with winds from the northeast and north increases. Average wave heights are 2.0-2.2 m, with maximum waves of up to 11.5 m during severe autumn-early winter storms. Between January and April, the sea ice cover effectively eliminates wave activity in the project area.

There is little information on historical tsunamis to assess risks in the project area. The primary source of tsunamis is from earthquakes in the Pacific Ocean. Fortunately, the Kuril Islands screen most of the wave energy from the northwestern Pacific Ocean that would otherwise propagate toward Sakhalin Island. Tsunamis generated in the Kuril-Kamchatka oceanic trough following an earthquake with a magnitude of 8 would have a wave height of 1.3-2.5 m.

4.1.5.2 Seawater Characteristics

Off northeastern Sakhalin Island, surface water temperatures typically have a relatively narrow range of about 12º C throughout the year, with minimum temperatures of 0 to –1° C in the winter and maximum temperatures of 10-12° C in the summer. The formation of a stable thermocline does not usually occur until sometime after ice melt and cessation of spring storms. That is also the time when the algae begin to bloom and consume most of the dissolved nutrients in the water column. By late June, the longer day lengths and higher air temperatures have warmed surface seawaters and created a strong thermocline at depths of 10-20 m. With the onset of cooler temperatures and stormy weather in the fall, the thermocline begins to break down and is usually absent by October. Water temperatures continue to decline to winter minima. Temperatures at depths exceeding 20 m vary little over the year, remaining around 0 to –1° C.

Salinity levels are affected by the seasons and reflect the input of freshwater from rivers and ice melt. Off the northeast coast of Sakhalin Island, minimum surface salinities are recorded in June (~28 ‰). Through the summer months and early fall, salinities in the surface layer (above the thermocline) gradually increase to 30.5-32 ‰. At deeper depths, salinities are consistently at 32-33.5 ‰.

A complex frontal zone exists in the Piltun-Astokhskoye and Lunskoye area, where two types of fronts actively interact: Estuarine fronts, with very sharp horizontal drops in salinity (up to 3–5 ‰), and upwelling, with considerable changes in temperature (up to 10° C). The active frontal dynamics cause rapid fluctuations in temperature, salinity, and water density. Within one day, the temperature and salinity can change by as much as 10° C and 5 ‰, respectively. Water temperatures as high as 20.7° C have been recorded in those areas.

4.1.5.3 Ice Conditions

Ice typically forms in mid to late November along the coastal areas of the northeastern shelf, extending 16-24 km offshore. By February, the entire coastal area is frozen and ice ridges begin to form. Ice ridges are frequently associated with bottom scour, modifying a significant portion of the seabed in waters less than 30-m deep. Storms with strong winds from the northwest, north, and northeast cause short-term increases in southerly drift. Strong winds from the west or northwest push pack ice offshore, opening a polynya (or lead) along portions of the coast. A polynya is a band of open water or thin ice running parallel to the coastline between the land-fast shore ice and heavier pack ice to the east. Polynyas are transient but can persist from days to weeks during the winter. Polynyas are quite common in the Piltun-Astokhskoye and Lunskoye areas from January to mid-March, when predominant winds are from the north. Conversely, strong winds from the northeast or east push the drifting pack ice up against the coast and in turn generate more ice ridges and hummocks. Many of those thickened pieces of ice become grounded and often persist until break-up. In a typical year, sea ice may be gone by mid-May, in a severe year by the end of June. The ice period may last up to 210-220 days of the year.

Ice concentrations on the northeast Sakhalin Shelf can be variable, but are normally high during the winter. Ice can have a thickness of up to 1.5 m in normal winter periods. The ice is almost always rough and deformed and very dynamic. Ice is nearly in continual motion, because of winds, currents, and tides. Mean drift speeds of 0.4 $m \cdot s^{-1}$ and maximum speeds of up to 1.5 $m \cdot s^{-1}$ have been observed. The movement is predominantly

to the south. The thickness of pack ice in the region is typically 3-4 m with a maximum draft (of ice keels) in the range of 10-15 m. Extreme ice keels may reach 20 m deep or more at times, but are considered to be rare.

In Aniva Bay, the freeze up typically begins in late December to early January. Once formed, the ice normally persists until late March to early April when ice break-up begins. Final ice clearance usually occurs by late April, a month or so earlier than clearance in the Piltun-Astokhskoye and Lunskoye fields.

A polynya usually occurs at the northern coastline of Aniva Bay. The polynya is caused by the predominantly northerly winds and leads to frequent thin ice conditions in the area, generally in the range 0.1-0.3 m thick. Although ice in the north of Aniva Bay is generally thin, thicker and larger ice floes can enter the bay, when ice is originating in the Sea of Okhotsk is pushed in a southerly direction driven by northerly winds and currents. The severest ice conditions generally occur at the end of winter. However, ice conditions are far less severe in Aniva Bay than those found on the northeast Sakhalin Shelf.

4.2 Acoustic Environment

There are many different sources of anthropogenic sounds from activities associated with the development of oil and gas on the northeastern Sakhalin Shelf. The activities include seismic surveys, drilling exploratory wells, development drilling, dredging, construction of platforms, laying offshore pipelines, vessel and helicopter traffic, and operation and maintenance of oil-producing complexes.

Marine mammals rely heavily on the use of underwater sound to communicate and to gain information about their surroundings. Experiments also show that baleen whales hear and react to many anthropogenic sounds, especially sounds at low frequencies (see review in Richardson *et al.* 1995). Gray whales are not considered very vocal, but they do produce sounds that are thought to be important for communication (Dahlheim 1987; Crane 1992). Dahlheim *et al.* (1984) suggested that gray whales can change the frequencies of their calls in response to human noise, in order to mitigate against anthropogenic masking of important communication sounds.

Thus, anthropogenic noise in the area may affect the behaviour and distribution of the western gray whales that feed in the Piltun Bay area.

The following discussion focuses on the levels and types of noises that have been detected on the northeastern Sakhalin Shelf that may affect gray whales on their feeding grounds.

Acoustic measurements were taken near Piltun Bay in the summer of 1997, during seismic exploration in the P-A license area (Würsig *et al.* 1999). In areas where gray whales were present, results indicated received noise levels of approximately 153 dB re 1 μPa when the seismic ship was approximately 30 km away.

Acoustic measurements taken near the Vityaz Complex in 1999 and 2000 showed that the main sources of noise with the greatest intensities were from the FSO, oil tankers, moving and stationary supply vessels, and the Molikpaq platform (Sobolevsky 2000, 2001). At 1 km from Molikpaq, recordings of noise generated by moving ships peaked at 38 Hz at a level of 159 dB. At a different time on the same date, recorded ship noise ranged from

128-145 dB up to a frequency of 600 Hz (Sobolevsky 2000). The spectrum of the acoustic noise generated by the Vityaz Complex, including maintenance vessels, had tonal and narrow-band components that exceeded wide-band noise levels by 10-15 dB (Sobolevsky 2001). When there was movement by a vessel, sound intensity increased by 15-20 dB (Sobolevsky 2001). Previous studies have shown that supply ships produce continuous broadband source levels of about 170-180 dB re 1 μPa at 1 m (Richardson *et al.* 1995).

Acoustic recordings were also made near the traditional feeding area of western gray whales near Piltun Bay. In that area, the main source of short-term, high-frequency sounds were from Zodiac engines (Sobolevsky 2001). Noise from motor boats generally exceeded the background noise by 15-20 dB. Noise from the Vityaz Complex was also detected at all times. The tonal and narrow-band noise signals that were measured in the aggregation area, just over 20 km away from the Molikpaq platform, were 80-100 dB re 1 μPa rms at frequencies less 90 Hz; within the band of 100-500 Hz, sound levels were 70-96 dB; and within the band of 600-1000 Hz, sound levels were up to 76 dB (Sobolevsky 2001). The power peaks were typically observed at frequencies of approximately 1.6, 2, 2.8, and 3 kHz, with levels of 78, 65, 56, and 55 dB re 1 μPa rms, respectively (Sobolevsky 2001). During the movement of a vessel, the level of the wide-band noise sharply increased by 10-20 dB.

Noise levels from the Vityaz Complex detected in the western gray whale feeding area were found to be highly variable, but generally <100 dB re 1 μPa rms (Sobolevsky 2000, 2001). That is well below 180 dB re 1 μPa rms, the level thought to cause physiological impacts on western gray whales and other baleen whales. However, levels of 100 dB are within the hearing range of gray whales and potentially within the range to elicit subtle behavioural responses (Würsig *et al.* 1999, 2000).

Sobolevsky (2000) also found that industrial noise with frequencies greater than 1 kHz was not readily detected at distances >30 km from the Vityaz Complex. In contrast, industrial sounds below 1 kHz were more easily detected in the gray whale feeding area and areas up to 30.5 km away from the complex. A 500 Hz sound wave generated at a depth of 5 m near the Molikpaq platform attenuated by ~60 dB during propagation toward the coast at the mouth of Piltun Bay, a distance of ~30 km (Sobolevsky 2000). Although sound significantly attenuated during propagation from Molikpaq to Piltun, the noise was still detected in the gray whale feeding area.

In spite of the high anthropogenic noise in the area, the acoustic signals generated by marine mammals were continuously recorded in the area. Acoustic signals, likely generated by killer whales, recorded 1 km from the Molikpaq platform, were strongest at 600-2000 Hz, 4-4.5 kHz, and 6-7 kHz (Sobolevsky 2000). The signals reached a level of 118 dB at a frequency of ~1.5 kHz (Sobolevsky 2000). Acoustic signals from killer whales were also recorded in the shallow-water part of the shelf, ~20 km from the Molikpaq platform; those exceeded the acoustic background noise of moving vessels by 10-15 dB (Sobolevsky 2001).

Additional acoustic studies were conducted in 2001 to further document anthropogenic noises generated by the Vityaz Complex, with specific objectives to define noise attenuation, i.e., transmission loss at different distances from varying sources (production, tanker load-out, vessel activity). Acoustic measurements were carried out in different areas, including the gray whale concentration area near Piltun Bay, and several other

locations between Piltun and Molikpaq. The study was conducted in conjunction with acoustic studies conducted in 2001 by Exxon Neftegas Limited as part of the monitoring programme associated with their seismic surveys.

Acoustic studies were conducted to determine both ambient and industry-related noise levels in the marine environment near industry activities (i.e., near the Molikpaq) and at locations where gray whales are known to occur (off Piltun Bay). That information is important in helping SEIC evaluate and potentially adjust existing mitigation and protection measures for gray whales. It will help define noisy activities that should be avoided when gray whales are present in adjacent feeding areas, define aircraft flight corridors, and determine avoidance distances for SEIC operations and vessels operating in the area. The information may also prove useful in helping to evaluate and mitigate potential noise impact during the design stage of future installations.

4.3 Distribution and Biomass of Prey

The gray whale is a unique cetacean because it feeds predominantly on benthic (bottom-dwelling) organisms (Zenkovich 1934, 1937; Mizue 1951; Pike 1962; Zimushko and Lenskaya 1970; Rice and Wolman 1971; Thomson and Martin 1983; Nerini 1984). Würsig *et al.* (2000) suggested that concentrations of western gray whales observed in the nearshore area off Piltun Bay indicate that the area may be primary western gray whale feeding habitat, and that surrounding areas and offshore waters may represent secondary gray whale feeding habitat. It has been suggested that the distribution and abundance of western gray whale prey may be a limiting factor in their distribution (Sobolevsky 1998; Sobolevsky *et al.* 2000).

In the northern Bering Sea, eastern gray whales feed on an extensive infaunal (submerged in the sediment) community dominated by amphipod crustaceans, most notably *Ampelisca macrocephala*. The benthic amphipods construct partially-buried tubes 10-15 cm deep in the sand bottom that form "mats" on the ocean floor. The mats can be extremely dense in some areas, with up to 24,000 individuals$\cdot$m^{-2} in the Eastern Bering Sea (Stoker 1981). Biomasses in the Bering Sea off Chukotka, Russia, where eastern gray whales feed, are 482±286 g$\cdot$m^{-2} (Thomson and Martin 1983; Stoker 1978 *in* Nerini 1984), of which *Ampelisca macrocephala* alone comprised about 30% of the total benthic biomass.

The benthic communities off the northeast coast of Sakhalin Island are of two general types, one located inshore and one located offshore (Koblikov 1982). Estimates of the biomass (wet weight) within the 20 m isobath range from 200-1000 g$\cdot$m^{-2} (Kuznetsov 1964). Koblikov (1986) conducted an 8-year benthic survey programme that involved the collection and analysis of 845 sediment samples along the entire east coast of Sakhalin Island, including a small number of samples collected near Piltun Bay. Generally, in the nearshore area in waters >20 m deep, the benthic community was dominated (93% total biomass) by *Echinarachnius parma*, the common sand dollar. The biomass of that community was estimated at 684 g$\cdot$m^{-2}. The community is widespread and dominates sediments in coastal waters of Sakhalin Island from the northern tip of the island south to the area around the mouth of Chayvo Bay (52°20'N). It is unknown if western gray whales are foraging on sand dollars along the northeast coast of Sakhalin Island. Eastern gray whales have not been documented to feed on sand dollars; those summering in Clayoquot Sound, Canada, avoid patches of sand dollars when feeding on benthic amphipods in sandy habitats (D. A. Duffus pers. comm. 2002). Kussakin *et al.* (2001)

suggested that food value of large amphipods, isopods, cumaceans, and polychaetes with their thin skeleton per weight unit was significantly higher than that of sand dollars. Most likely, whales are feeding on localised patches of benthic or epibenthic prey within a larger landscape of feeding habitat dominated by sand dollars.

At Nabilskii Bay (51°40'N), the benthic community is dominated by ampeliscid amphipods, mainly *Ampelisca eschrichti*. The mean biomass of ampeliscid amphipods near Nabilskii Bay was estimated at 393 $g{\cdot}m^{-2}$, of which 56% was *Ampelisca eschrichti* (Koblikov 1986). Benthic samples taken opportunistically near SEIC's Molikpaq (PA-A) drill platform (see Würsig *et al.* 1999) contained amphipods, bivalves, the echinoid *Dendraster excentricus* (eccentric sand dollar, a species related to the common sand dollar), and several species of polychaete worms. No estimates of biomass or proportions of different organisms were provided. Recent studies (1994-1999) in the Chayvo and Arkutun-Dagi areas also indicate highly productive benthic communities on the northeast shelf of Sakhalin Island (O'Reilly *et al.* 2000). Biomass estimates of 8-5030 $g{\cdot}m^{-2}$ (averages of 590-1,760 $g{\cdot}m^{-2}$) and 150-176,320 individuals$\cdot m^{-2}$ (averages of 3,350-24,150 individuals$\cdot m^{-2}$) were recorded from eight survey periods. Variations in benthic biomass and abundance are mostly determined by variability in the distribution of the three main groups of fauna: Echinoderms, bivalves, and polychaetes (VNIRO 1997). Video and still photography collected in 1996 documented the benthic habitat and provides visual evidence of the wide variety of benthic habitat and some of the key fauna (arthropod crustaceans, echinoderms, molluscs, polychaetes, and amphipods). Benthic samples taken at the Chayvo oil-gas field in 1999 were dominated by cumaceans (*Diastylis bidentata*) and sand dollars (*Echinarachnius parma*) in terms of abundance and biomass, respectively (Rukhlov and Samatov 2000). The average abundance of benthos was 24,149 individuals$\cdot m^{-2}$ and biomass estimates ranged from 8–3390 $g{\cdot}m^{-2}$ with an average estimate of 586.5 $g{\cdot}m^{-2}$. Amphipods were the second most abundant invertebrates, dominated by *Ischyrocerus sp.* and *Pleusymtes vasinae*. In 2000, cumaceans and sand dollars once again dominated in terms of abundance and biomass, respectively (Radchenko *et al.* 2001). The average abundance of benthos was 27,010 individuals$\cdot m^{-2}$ and biomass estimates ranged from 19–1406 $g{\cdot}m^{-2}$, with an average biomass estimate of 397.8 $g{\cdot}m^{-2}$. Amphipods were the second most abundant benthic invertebrates (3%), however the most dominant amphipod species were *Eonaustorius eous eous* and *Orchomenella lepidula*. The distribution of dominant groupings of benthic invertebrates changed significantly between years, indicating a patchy and/or dynamic system of benthic communities.

Maximum wet weight biomass recorded during quantitative sampling by divers in the area off Piltun Bay in 1995 was 427 $g{\cdot}m^{-2}$ at one location 7 m deep (Sobolevsky *et al.* 2000). Bivalve molluscs (212 $g{\cdot}m^{-2}$), amphipods (75 $g{\cdot}m^{-2}$), and polychaete worms (40.6 $g{\cdot}m^{-2}$) comprised most of the biomass at that location. In another location 12 m deep, the biomass of benthos was considerably less - ranging from 85-137 $g{\cdot}m^{-2}$, suggesting that food sources are patchy in the region. In 2001, divers conducting a benthic study along the northeast coast of Sakhalin Island repeatedly noted high concentrations of epibenthic chaetognaths (arrow worms) 5-10 cm above the substrate in the vicinity of Piltun Bay in waters 5-15 m in depth (Fadeev 2001). The significance of chaetognaths in the diet of the western gray whale is unknown.

Samples taken near feeding whales in the Piltun feeding site by SCUBA divers in 1995 (Sobolevsky *et al.* 2000) indicated that brackish-water amphipods, mainly *Pontoporeia*

affinis, *Anisogammarus pugettensis*, and *Eonaustorius eous eous* comprised the largest group (4,360-26,800 individuals·m^{-2} at biomass 72-85 g·m^{-2}). The isopod *Synidotea cineria* (biomass 0.4-11.2 g·m^{-2}) and the bivalve mollusc *Siliqua alta* (biomass 0.1-0.2 g·m^{-2}) were also abundant in the area. Gray whale foods and faecal samples collected near feeding whales in the Piltun feeding site in 1998 indicated that they had been feeding mainly on amphipods and isopods (Würsig *et al.* 1999), both known to be common in the benthos of the area (Sobolevsky *et al.* 2000). In 1998 and 1999, amphipods and isopods were collected from sediment plumes where whales were feeding in coastal areas 1-3 km from the coast (Weller *et al.* 1999). In addition to amphipods and isopods, whale fecal samples contained unidentified zoea larvae. Although swarms of porcelain crab larvae (Family Porcellanidae) are an important prey source for eastern gray whales summering along Vancouver Island, Canada (Dunham and Duffus 2001, 2002), the role of crab larvae in the diet of western gray whales is unknown.

In summary, in the Piltun area in water 7-20 m deep, amphipods are the most abundant and diverse in species composition (34 species) (Sobolevsky *et al.* 2000). The amphipod *Pontoporeia affinis* is the most abundant species at these depths comprising 63-95% of the total biomass of amphipods and approximately 89% of amphipod population density. The amphipod species *Anisogammarus pugettensis, Eonaustorius eous eous, Eogammarus schmidti,* and *Pontharpinia longirostris* are also present. At depths of 7-12 m, large isopods *Saduria entomon* and *Synidotea cineria* have been observed to be numerous and present with amphipods. Polychaetes (*Onuphis shirikishinaensis*) may also be a significant prey item for western gray whales. The sand dollar *Echinarachnius parma* is not regularly observed in waters 7-12 m, but over 16 m is a dominant species.

4.4 Western Gray Whales

There are two extant populations of gray whales (*Eschrichtius robustus*), both dwelling in the Pacific Ocean: (1) the Eastern North Pacific or California-Chukotka population, and (2) the Western North Pacific or Okhotsk-Korean population (Jones *et al.* 1984; LeDuc *et al.* 2000). An Atlantic population was extirpated prior to the 19th century (Jones *et al.* 1984).

Currently, there are approximately 17,000 California-Chukotka gray whales (hereafter referred to as the eastern gray whale) that over-winter in the lagoons of Baja California and summer in the Bering and Chukchi seas (Rugh *et al.* 1999). The eastern population is not endangered and has been extensively studied. Most of the general biological and behavioural information in this document has been drawn from the eastern population, as the western population has not been studied to the same extent.

The other population of gray whales is the Western North Pacific or Okhotsk-Korean population (hereafter referred to as the western gray whale). It is believed to breed in the South China Sea during the winter months. The only presently-known summering and feeding area of the western gray whale is located off the northeast coast of Sakhalin Island (Brownell and Chun 1977; Sobolevsky 1998, 2000, 2001; Weller *et al.* 1999, 2000, 2001a, 2002a; Würsig *et al.* 1999, 2000). Generally, gray whales feed in shallow (less than 20 m) waters close to the coast.

The western gray whale is listed as a Category I (endangered) species in the Red Data Book of the Russian Federation (Red Book of the Russian Federation 2000). The population was recently reclassified as Critically Endangered (extremely high risk of extinction) by the IUCN-World Conservation Union (Hilton-Taylor 2000; Weller and

Brownell 2000). The IUCN Red List criteria (Criteria D) used to support the reclassification were as follows: (1) the population is geographically and genetically distinct, and (2) the population plausibly contains less than 50 reproductively-active individuals (Hilton-Taylor 2000; Weller and Brownell 2000).

It is estimated that there were initially 1,500-2,000, and possibly as many as 10,000 individuals in the western gray whale population (Rice and Wolman 1971; Yablokov and Bogoslovskaya 1984), but over-exploitation by commercial whaling decimated the population. The population was reported to be "probably extinct" in the early 1970s (Bowen 1974). Subsequent sporadic sightings, however, indicated that the western gray whale was not extinct (Brownell and Chun 1977). Initial aerial surveys indicated that small groups of gray whales were present at several locations in the Sea of Okhotsk, with regular sightings of feeding whales in shallow waters (i.e., generally within the 20 m isobath) up to five kilometers offshore of Piltun Bay (Berzin *et al.* 1988, 1990, 1991; Vladimirov 1994). There have been repeated observations of gray whales offshore of the Piltun area over the past two decades (Berzin *et al.* 1988, 1990, 1991; Blokhin *et al.* 1985; Votrogov and Bogoslovskaya 1986; Brownell *et al.* 1997; Sobolevsky 1998, 2000, 2001; Weller *et al.* 1999, 2000, 2001b, 2002b; Würsig *et al.* 1999, 2000), whereas sightings elsewhere in the Sea of Okhotsk have been infrequent (Weller *et al.* 2001a).

In the mid-1990s, estimates of the numbers of western gray whales ranged from 120 individuals (Blokhin 1996; Brownell 1999) to approximately 250 (Vladimirov 1994; Perlov *et al.* 1996). More recent estimates based on monitoring studies sponsored by Exxon-Neftegas Ltd. (ENL), SEIC, and others (Sobolevsky 2000, 2001; Weller *et al.* 2000, 2001b, 2002b; Würsig *et al.* 1999, 2000) indicate that the number summering off Piltun Bay, which likely represents a significant (though presently unknown) proportion of the population, is approximately 100 individuals. Photo-identification studies have indicated that recognisable individuals demonstrate strong site fidelity and return to the northeast coast of Sakhalin Island seasonally (Weller *et al.* 2001b, 2002b). However, the entire historical range of the western gray whale has not been surveyed, and therefore the size of the entire Sea of Okhotsk population of western gray whales and other areas where gray whales may occur are currently unknown.

4.4.1 Distribution

The historical centres of distribution of western gray whales in the Sea of Okhotsk included Sakhalinskaya Bay, Ulbanskii, Shelikhov, Akademiia, and Tugurskii bays, the coastal waters of Sakhalin Island, Penzhinskaya and Gizhiginskaya bays in the northern Sea of Okhotsk, and in the waters west of Kamchatka (Krupnik 1984; Yablokov and Bogoslovskaya 1984; Perlov *et al.* 1997). The long-held belief that their wintering grounds were along the south coast of the Korean Peninsula has not been recently substantiated (Rice 1998). Wintering grounds are now believed to be located in the South China Sea, possibly along the coast of Guangdong province and/or around Hainan Island (Rice 1998). However, specific calving sites have never been reported.

The gray whale is a long-range, seasonal migratory species. Western gray whales begin arriving off northeast Sakhalin Island in late May, after ice has left the area, and some remain until late November, when ice returns (Weller *et al.* 1999; Sobolevsky 2000). Migration routes used by western gray whales are presently unknown, but most specialists believe that the majority of animals migrate through La Perouse Strait, south of Sakhalin Island, and up the east coast (V. Vladimirov, pers. comm. 2002), whereas others believe that some

individuals migrate through Tartar Strait, west of Sakhalin Island, and past the north coast (Yablokov and Bogoslovskaya 1984; Sobolevsky 2000). If they migrate along the east coast of Sakhalin Island, they presumably would pass the Lunskoye area on their way north to their summer feeding grounds, mostly in May to June, and on their way south to their winter breeding grounds, mostly in October to November. Eastern gray whales usually stay in coastal waters during migration, except when crossing the mouths of bays, so they are likely to migrate inshore from, or perhaps through, the Lunskoye Licence Area.

A total of 315 western gray whale sightings were recorded during systematic surveys of a coast-wide extensive sampling grid and a nearshore intensive grid centred on Piltun Bay in 1999. Most (151 sightings in 1999 and 154 in 2000) were within the 20-m isobath, and most were within 5 km of shore.

Most western gray whales feed north of the mouth of Piltun Bay; fewer are encountered south of Piltun Bay (Figure 4-2). During the feeding period, western gray whales feeding near Piltun Bay do not form dense aggregations, but scatter along the coast. In July-August, the area near the mouth of Piltun Bay appears to be their preferred feeding area. However, during surveys in 2001 sponsored by ENL and SEIC, groups of western gray whales also were observed feeding in deeper waters (35-40 m water depth) southeast of Chayvo Bay. As many as 83 western gray whale sightings were recorded on one day of surveys in that offshore area, and during that day western gray whales were still present and feeding in the Piltun Bay area. Both feeding areas have been used by large numbers of whales during aerial surveys conducted in late July and late August 2002. Thus, the actual number of western gray whales present off northeast Sakhalin Island could be greater than 100 individuals.

The discovery of the deep-water feeding area off Chayvo in 2001 raises the possibility that there are other, as yet undocumented feeding areas. To date, there has been no strong evidence of regular feeding in the Lunskoye area, although aerial survey coverage there has not been good. The first year that aerial survey coverage extended as far south as Lunsky Bay was 2000; coverage on those extensive surveys was approximately 20%, transects extended from the coast to beyond the 50 m depth contour, and surveys were flown during 23-24 June, 19-20 July, 26 August, 6 September, 13 October, and 19-20 November. In 2001, similar surveys were flown; those that included the Lunskoye area were on 18 July, 13 September, 24 September, 9 October, 23 October, and 18 November. The 2002 surveys of the Lunskoye area included both extensive and intensive (100%) coverage once per month, although surveys did not begin until late July. Four whales were seen about 3 km inshore from the northwest corner of the Lunskoye Field on 28 July, and no whales were seen in subsequent months. There was no evidence of feeding for the four that were recorded in July.

4.4.2 Hearing

Behavioural evidence suggests that baleen whales, including gray whales, hear very well at low frequencies, below 1 kHz. Baleen whales have also been shown to react to sonar and other sounds between 3 to 4 kHz. Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars that emit sounds above 36 kHz. In addition, baleen whales produce sounds at frequencies up to 8 kHz. They may be able to hear low frequency sounds (possibly as low as 10 Hz) from sources many hundreds of kilometres away. Therefore, the hearing range of baleen whale, including gray whales, likely ranges from <1 to 8 kHz. Hearing damage could occur if a whale is exposed to sounds louder than 180 dB re 1 μPa (NMFS 2000a,b).

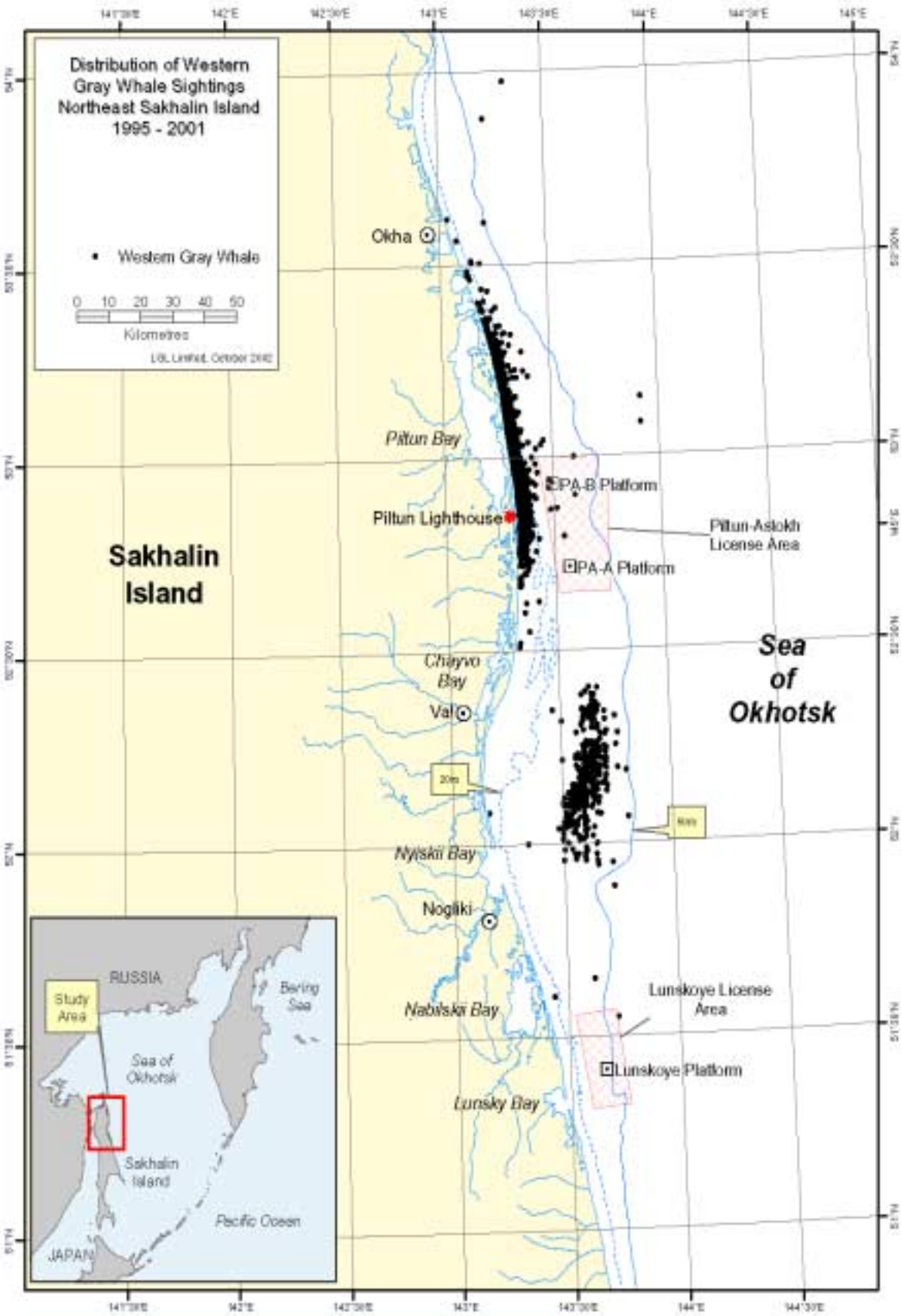

FIGURE 4-2. Distribution of western gray whales off northeast Sakhalin Island during 1995-2001, based on aerial, vessel, and shore-based surveys.

4.4.3 Condition of Gray Whales

Systematic photo-identification surveys of western gray whales present off Piltun Bay were conducted during 1997, 1998, 1999, 2000, and 2001 (Würsig *et al.* 1999, 2000; Weller *et al.* 2000, 2001b, 2002b). Those surveys were in addition to brief photo-identification surveys conducted during 1994 and 1995 (Brownell *et al.* 1997; Weller *et al.* 1999). Based on the photo-ID studies, about 106 different western gray whales have been identified (Weller *et al.* 2001b). The 1999, 2000, and 2001 photo-identification surveys also determined that some whales were emaciated, or "skinny" in all years, but no dead western gray whales were seen. During the photo-identification surveys in 1999, 2000, and 2001, 14% (10 of 70), 47% (27 of 58), and 26% (19 of 72) of whales, respectively, were judged to be skinny (Weller *et al.*, 2000, 2001b, 2002b).

In 2000, fewer than expected calves (based on the number of females with calves observed in 1998) were present in the population, possibly because of the poor condition of many females (Weller *et al.* 2001b). Seventy-two individual whales, including six calves, were identified in 2001. That number of calves was more than expected in the Piltun feeding area (Weller *et al.* 2002b). Six mother-calf pairs were identified, and ranked among some of the most frequently sighted whales. Of the six mothers identified, four had been observed with calves off Piltun in previous years. All of the mothers identified in 2001 were sighted in 2000 when they were pregnant. All six 2001 mothers, to varying degrees, were identified as being "skinny". Some "skinny" whales from 1999 and 2000 appeared to be recovering in 2001 (i.e. gaining weight) but other apparently healthy whales in 1999 and 2000 appeared "skinny" in 2001.

Similar signs of emaciation were displayed during the same period by eastern gray whales. Many apparently undernourished ("skinny") whales died during winter in the lagoons of Baja California and during their northward migration in 1999 (LeBoeuf *et al.* 2000). In 2000, nearly twice as many eastern gray whales died in the wintering lagoons of Baja California than in 1999 (LeBoeuf *et al.* 2000). Fortunately, high mortality in eastern gray whales was not documented during winter 2000-2001 or during the 2001 northward spring migration (Brownell *et al.* 2001).

The causes of emaciation in both North Pacific populations of gray whales are not clear, but several lines of evidence suggested over-exploitation of the food supply and/or a possible large-scale climatic/oceanographic regime shift that affected productivity in the North Pacific region (LeBoeuf *et al.* 2000). It is also possible that some other factor(s), such as disease or human-induced impacts during winter, migration, and/or the summer feeding period, may have simultaneously and similarly affected one or both of the populations of gray whale. The cause is considered most likely to be a complex cumulative time variable effect. It is highly unlikely that a population of approximately 100 whales has simply over-exploited its food supply.