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Volume 1: Objectives and Data

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Acoustic Studies on the North East Sakhalin Shelf
Volume 1: Objectives and Data

7 July to 7 October, 2005

Sakhalin, Russian Federation

A.N. Rutenko

Prepared for

Exxon Neftegas Limited
&
Sakhalin Energy Investment Company,

Yuzhno-Sakhalinsk, Sakhalin,

Russian Federation

March, 2006

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ОБЩИЙ
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March 2006

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

Executive Summary

Acoustic studies in support of the Korean-Okhotsk (western) gray whale monitoring program have been conducted on the NE Sakhalin shelf since 1999, and are designed to provide acoustic measurements to delineate the effects of NE Sakhalin oil and gas developments on the western gray whale population (*Eschrichtius robustus*). These whales are listed as endangered in the Russian Red Book and critically endangered by the International Union for the Conservation of Nature[1].

There are three key goals for the acoustic monitoring element of the western gray whale research program. The first goal is to monitor the ambient sound levels on the NE Sakhalin shelf and the temporal variation in anthropogenic noise levels due to oil and gas development activities. The second goal, in conjunction with the behavioral and observational biology programs, is to allow the effect of changes in anthropogenic sound on western gray whale behavior to be understood, proposing mitigation measures where appropriate. The third goal is to characterize the acoustic propagation on the NE Sakhalin shelf, allowing the changes in the acoustic field due to the development activities to be modeled and predicted. An additional goal for the 2005 field program was to monitor any sound propagating into the Piltun feeding area from Exxon Neftegas Limited (ENL) and Sakhalin Energy Investment Company (SEIC) development activities.

In addition to the acoustic studies, a comprehensive sampling program for bathymetry and hydrology was initiated in 2004 and continued in 2005. The goal of this program was to better understand the temporal and spatial variations in the hydrologic parameters on the NE Sakhalin shelf. This included the short-term and long-term (seasonal) variations as well as changes due to typhoons and strong storms. This data will be used to improve acoustic models and better understand acoustic propagation on the shelf.

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[1] Aerial surveys indicate that the gray whales spend most of the ice-free season feeding off the NE Sakhalin coast. They are predominantly located shoreward of the 20 m water depth contour, in an area from the mouth of Piltun bay northwards along the coast as well as south of the Arktun-Dagi license in 30-65 m of water.

Autonomous Underwater Acoustic Recorders (AUAR) and digital and analog sonobuoys developed by the Pacific Oceanological Institute (POI) were used to make these acoustic measurements.

1 Introduction

The acoustic program conducted on the NE shelf of Sakhalin Island in 2005 had two distinct components which were conducted simultaneously for much of the field season. These components were:

- An acoustic monitoring program designed to monitor sound propagating from the operations associated with the tow and installation of the Orlan and PA-B platforms, the construction of the pipeline from the Orlan platform to the Chayvo OPF and the Molikpaq engineering work. These studies were conducted between the PA-B, Molikpaq and Orlan locations and the inshore feeding area as well as the Chayvo area and the offshore feeding area.
- An acoustic monitoring program that broadened the program initiated in 2003 and extended in 2004. The monitoring program was designed to study temporal and spatial variations in the amplitude and frequency characteristics of ambient and anthropogenic sound at the edge of the Piltun and offshore gray whale feeding areas. In addition to the program monitoring, the background acoustic environment, both ENL and SEIC conducted detailed Transmission Loss (TL) studies between current and proposed facilities and key locations at the edge of the gray whale feeding areas.

In order to estimate the sound transmission from project activities it is necessary to understand the characteristics of sound propagation from the proposed production facilities to the borders of the known gray whale feeding areas. These are the areas where the gray whales are concentrated, predominantly feeding in water depths of 5-20 m in the Piltun feeding area and 30-65 m in the offshore feeding area. Mother-calf pairs have also been seen in the Piltun feeding area in water depths less than 10 m. These studies, in conjunction with the amplitude and spectral content of the background acoustic environment, will be used to assess any potential impacts from the construction and to design more effective mitigation measures.

The acoustic measurements were conducted using 14 digital Autonomous Underwater Acoustic Recorders (AUARs) developed at POI FEB RAS[2] (POI). Four of these AUARs were Transmit-AUARs (T-AUARs)[3]. An additional two mini-AUARs were constructed for the 2005 field season; these were smaller with a reduced (72 hours) record time and were used

[2] POI FEB RAS - The Pacific Oceanological Institute, Far East Branch of the Russian Academy of Sciences.
[3] The T-AUARs were equipped with a radio channel and were capable of simultaneously recording data on the AUAR hard drive and transmitting data (bandwidth 10 Hz to 5 kHz) to a receiving radio station. The transmission can be continuous or on a pre-programmed schedule.

for TL and source level measurements. The AUARs were designed to accurately record frequencies between 1-15,000 Hz and enable accurate, autonomous, synchronous acoustic measurements over a broad range of frequencies (including infrasounds[4]). Individually deployed acoustic sonobuoys also developed at POI (2 digital and 4 analog) were used to measure acoustic signals and to transmit them to a receiving station. Analog sonobuoys recorded frequencies from 10 Hz to 10 kHz and digital sonobuoys from 1 Hz to 2.6 kHz. When used together an analog and digital sonobuoy pair can record acoustic data from 1 Hz to 10 kHz. A detailed description of this equipment is given in volume 2 of this report [Borisov et. al, 2006].

The radio signals from the analog and digital sonobuoys and the T-AUARs were received either at a recording station at Piltun lighthouse or a recording station on the vessel *Academik Lavrent'ev* (Lunskoye program). The range of the digital radio channel was over 4 km when received by the non-directional antenna on the *Academik Lavrent'ev* and over 7 km when received at Piltun lighthouse. The range of the analog radio channel depended on the type of radio receiver used. Broadband (10-10,000 Hz) signals could be transmitted up to 12 km; narrowband (10-5000 Hz) signals could be transmitted more than 20 km if received by the station at Piltun lighthouse.

During the 2005 field season (7 July to 7 October), AUARs and sonobuoys were deployed from the research vessels *Academik Lavrent'ev and Academik Oparin* (Figures 1.1 and 1.2) which also accommodated the biology teams (Benthic, Marine Mammal Observers (MMO) and Photo-ID). Synchronous acoustic measurements were made at stations ranging from north of the Odoptu license area to the southern edge of the offshore feeding area (Figure 1.3), an area whose western edge extends 180 km along the NE Sakhalin shelf.

Previous work had shown that the results from acoustic modeling are very sensitive to the hydrologic, bathymetric and sea bottom parameters along the profile of interest. A comprehensive suite of bathymetric and hydrologic measurements was therefore taken using the vessel's sonar and a hydrologic sonde. The total number of measurements undertaken included 354 vertical hydrologic profiles (comprising sound velocity, temperature

[4] Infrasounds are sounds with a frequency of less than 20 Hz.

and salinity), and 7788 km of bathymetry data[5]. Figure 1.4 gives two maps showing the extent of the bathymetric grid and the points at which vertical hydrologic profiles were acquired. This plot shows the combined 2004 (323 vertical hydrologic profiles and 8400 km of bathymetry data) and 2005 data.

Figure 1.1 - The research vessel *Academik Oparin*.

Figure 1.2 - The research vessel *Academik Lavrent'ev*.

[5] Of the 354 vertical hydrologic profiles 48 were acquired in July, 185 in August and 121 in September. This includes 96 profiles at the benthic sampling stations

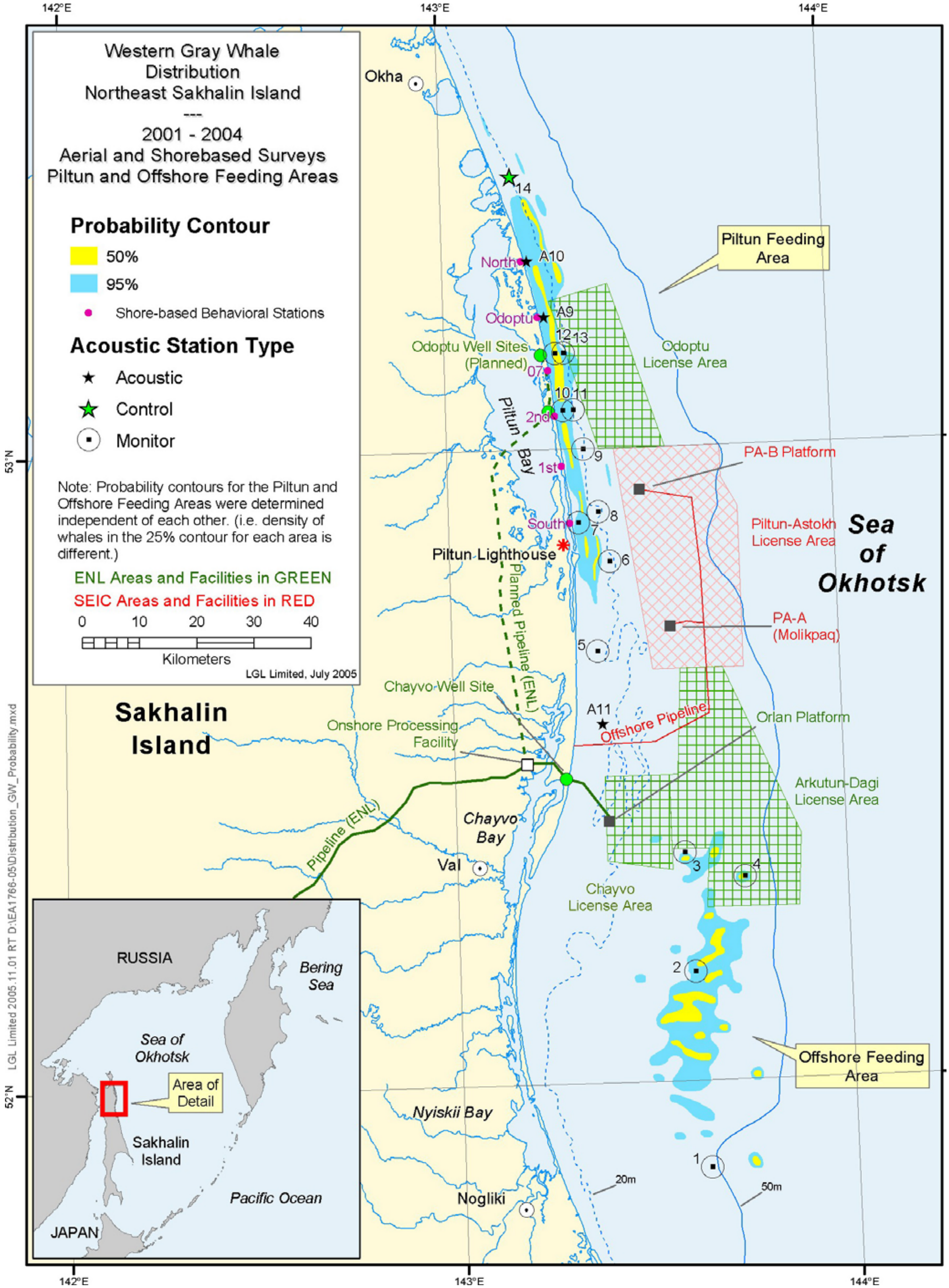

Figure 1.3 - Map of the NE Sakhalin Shelf showing the locations of the PA-B and Orlan platforms as well as the AUAR deployment locations.

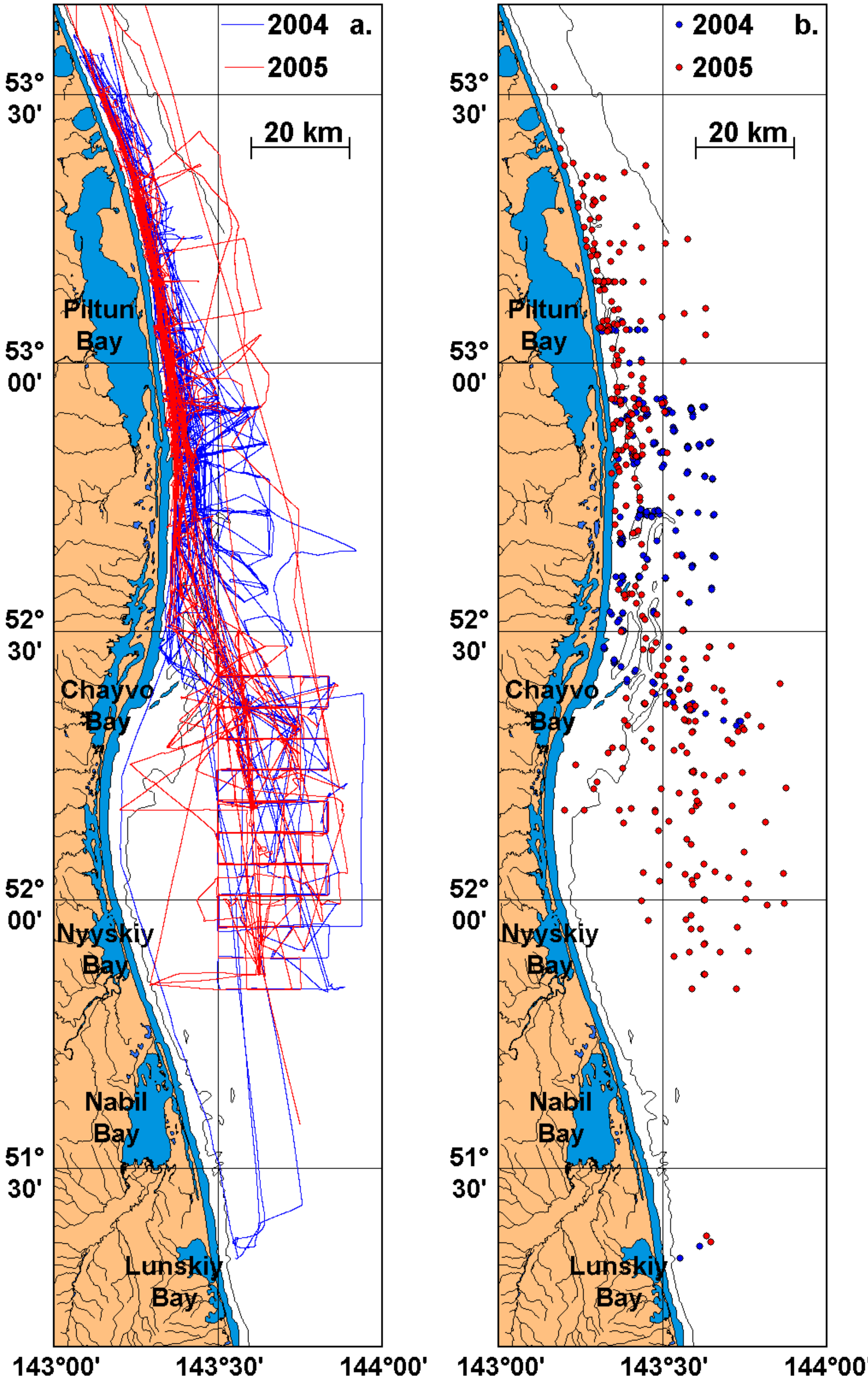

Figure 1.4 - Map of the NE Sakhalin Shelf showing (a) the 2004 & 2005 bathymetric grids and (b) the locations where vertical hydrologic profiles were acquired in 2004 & 2005.

The results of the 2005 acoustic program are presented in three separate reports. The first report describes the objectives of the 2005 program, the operational (including real time acoustic data acquisition) strategy and methodology as well as the data acquired during the 2005 field season. This includes a DVD containing the sonograms in 24-hour segments for all the acoustic data recorded in 2005 as well as the bathymetric and hydrologic data acquired during the field season. This data is listed in the Appendices. The second report describes the equipment used during the 2005 field season, its testing and calibration as well as the data processing and analysis methodology. The third report is dedicated to analysis of the data, conclusions and recommendations for future work. This analysis includes the following components:

Acoustic Monitoring

1. An analysis of the acoustic monitoring data recorded at six stations during construction operations and correlation of the acoustic data with construction operations.

Western gray whale research program – Acoustic studies

2. A quantitative spectral analysis of the variation in the ambient acoustic noise level with weather conditions (including cyclones).
3. The results of the comprehensive TL (spectral over the frequency range from 15 Hz to 15 kHz) experiments between the major facilities and key locations at the edge of the gray whale feeding areas.
4. A temporal, spectral and spectral-temporal analysis of the acoustic data recorded at different locations on the Sakhalin shelf[6].
5. The results of experiments to measure the acoustic output from the outboard motor on the Photo-ID zodiac and from the *Academik Lavrent'ev and Academik Oparin*.
6. A temporal analysis of acoustic energy levels (10 minute windows) at the 10 m contour directly offshore from the behavioral monitoring positions.
7. Analysis of the hydrologic data (including velocity, temperature, and salinity) recorded in 2004 and 2005.
8. An experimental study of the relationship between the distribution of benthos and the hydrology and bathymetry of the study area. This analysis includes hydrologic data acquired at 96 benthic sampling locations.

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[6] The use of AUARs for the 2005 program allowed an unprecedented characterization of the ambient noise at the monitoring stations. However, since the vessels used to house the scientists (*Academik Lavrent'ev and Academik Oparin*) were often a significant distance from the AUAR the identification and specific location of any transient anthropogenic noise source is generally unknown.

1.1 Objectives of the acoustic program

The acoustic program conducted on the NE shelf of Sakhalin Island in 2005 had seven main objectives:

1. The first was monitor sound propagating from the operations associated with the tow and installation of the Orlan platform and PA-B concrete gravity base, the construction of the pipeline from the Orlan platform to the Chayvo OPF and the Molikpaq engineering work. This real-time monitoring was designed to allow the construction operations to be conducted so as to minimize the impact on the western gray whale population.
2. The second objective was to study both temporal and spatial variations in the amplitude and frequency characteristics of ambient and anthropogenic sound at a series of monitoring stations located throughout the development area. These monitoring stations were positioned to be at the nearest outside edge of a gray whale feeding area to a proposed facility. The goal of this annual acoustic monitoring program is to estimate any increase in the cumulative acoustic level in the gray whale feeding areas due to the oil development and production activities.
3. The third objective was to study sound propagation and the variation in frequency dependent TL along a series of TL profiles from current or proposed facilities and pipelines to the nearest gray whale feeding area. The results of these TL profiles will allow the prediction of the potential acoustic footprint from a facility with a defined acoustic signature, installed at the proposed location.
4. The fourth objective was to acquire a comprehensive grid of bathymetric and hydrologic data across the study area, and to investigate the spatial and temporal variations in the hydrology due to weather events (e.g. typhoons). This data will be integrated with the 323 vertical hydrologic profiles and 8400 km of bathymetry data acquired in 2004.
5. The fifth objective was to measure the acoustic levels of the primary four-stroke outboard motor used for the Photo-ID zodiacs as well as the *Academik Lavrent'ev and Academik Oparin* (under different operational scenarios).
6. The sixth objective was to estimate the acoustic energy in 10 minute windows at locations approximately on the 10 m contour directly offshore from the behavioral monitoring stations.
7. The final objective was to acquire hydrologic data at 96 benthic sampling locations, and to study the relationship between the distribution and development of benthos and the hydrology and bathymetry of the study area[7] [Fadeev, 2005].

1.2 Operational strategy and methodology

The shallow water (5 - 15 m) part of the NE Sakhalin shelf starting south of the mouth of Piltun Bay and extending northwards up the Sakhalin coast is one of the most important summer feeding areas for the western gray whales.

[7] This study would be conducted in conjunction with the Benthos program led by Dr. V.I. Fadeev (IBM).

For this reason acoustic studies have been conducted in the area since 1999. In 2001 a second gray whale feeding area was discovered offshore in water depths of 30-65 m, approximately 20 km to the South East of the mouth of Chayvo Bay.

In 2005, as in the previous two years, the entire acoustic program was operated from a vessel. The vessels used in 2005 were the *Academik Lavrent'ev and Academik Oparin*[8]. The *Academik Lavrent'ev and Academik Oparin* were also the operational platform for all the vessel-based biology programs (Photo-ID, Benthic, MMO). Dr. Alexander Rutenko was the expedition leader for the biology-acoustics expedition on the *Academik Lavrent'ev*, and Dr. Yuri Yakovlev was the expedition leader for the biology-acoustics expedition on the *Academik Oparin*.

In 2005 16 AUARs designed and developed by POI were used to capitalize on the enhanced flexibility of a vessel-based program and to allow synchronous acoustic measurements to be conducted over a greatly enlarged spatial area. Fourteen (14) of these AUARs could be deployed at depths up to 50 m (2 to 100 m), could record continuously for 16 days and could measure the absolute acoustic amplitude of a signal over a frequency band from 1-15000 Hz. Two were low sensitivity mini-AUARs with similar recording characteristics, but only three days recording duration. A detailed description of this equipment is given in volume 2 of this report [Borisov et.al., 2006]. Two AUARs were lost during the 2005 field season.

One of the operational advantages of the *Academik Lavrent'ev and Academik Oparin* is that they can operate in water depths as shallow as 10 m. The AUARs were deployed from the stern of the *Academik Lavrent'ev or Academik Oparin* as the vessel sailed slowly along its course (Figure 1.5). AUARs were retrieved manually using a zodiac or boat deployed from the *Academik Lavrent'ev or Academik Oparin* (Figure 1.6). When a boat was used the AUAR was pulled to the surface and onto the boat by hand. If a zodiac was used the AUAR was pulled to the surface and towed to the *Academik Lavrent'ev or Academik Oparin*.

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[8] Two vessels were used for the 2005 field program because a single vessel was not available for the full 4 month season. The *Academik Lavrent'ev* was used from 7 July to 5 August and the *Academik Oparin* from 5 August to 7 October.

When the zodiac or boat returned to the *Academik Lavrent'ev or Academik Oparin* the AUAR was transferred to the vessel using its crane (Figures 1.1, 1.2, 1.6 and 1.7). The *Academik Lavrent'ev* used an electric winch and the *Academik Oparin* a hydraulic winch to deploy the hydrologic sonde and transducers to a depth of 8 m.

A low frequency (LF) resonant electromagnetic transducer and high frequency (HF) piezoelectric broadband transducer were deployed at 8 m from the *Academik Oparin* and used for sound propagation and TL studies at frequencies from 15-15000 Hz. The acoustic level of signals generated by the transducers was monitored using a calibrated hydrophone and recorded on the vessel. As for the previous two years, the hydrologic characteristics (salinity, velocity, and temperature) of the water layer were acquired using a hydrologic sonde[9] and were used to more accurately characterize the TL measurements. During the TL experiments the *Academik Lavrent'ev and Academik Oparin* proceeded at a constant speed along the defined acoustic profiles measuring the depth with a bottom profiler. The transducers were therefore quasi-stationary noise sources of known frequency content and location.

After the AUAR was recovered, acoustic data from the hard disk was downloaded onto a computer on the *Academik Lavrent'ev or Academik Oparin* and backed up to DVDs. The batteries were re-charged prior to redeployment. If a fast turnaround was required (e.g. the AUAR was being re-deployed at the same location) a spare disk and batteries were used.

The Received Level (RL) of an acoustic signal depends on the water depth and the distance between the potential noise source and the AUAR. The gain coefficients of the AUAR must be set to maximize the dynamic range of the recording system[10]. Since the goal of the 2005 season was to measure ambient or low level anthropogenic noise, the gain (and thus sensitivity) of the 14 standard AUARs was high. The two mini-AUARs were designed to

[9] Model SVXtra manufactured by Valeport Limited, England.
[10] The minimum acoustic signal that can be measured depends on the gain. The higher the gain the smaller the signals measured, but higher signals are clipped.

measure stronger signals, such as those generated by the near field of a transducer and the system sensitivity was lower.

Figure 1.5 - Deployment of an AUAR from the stern of the *Academik Oparin*.

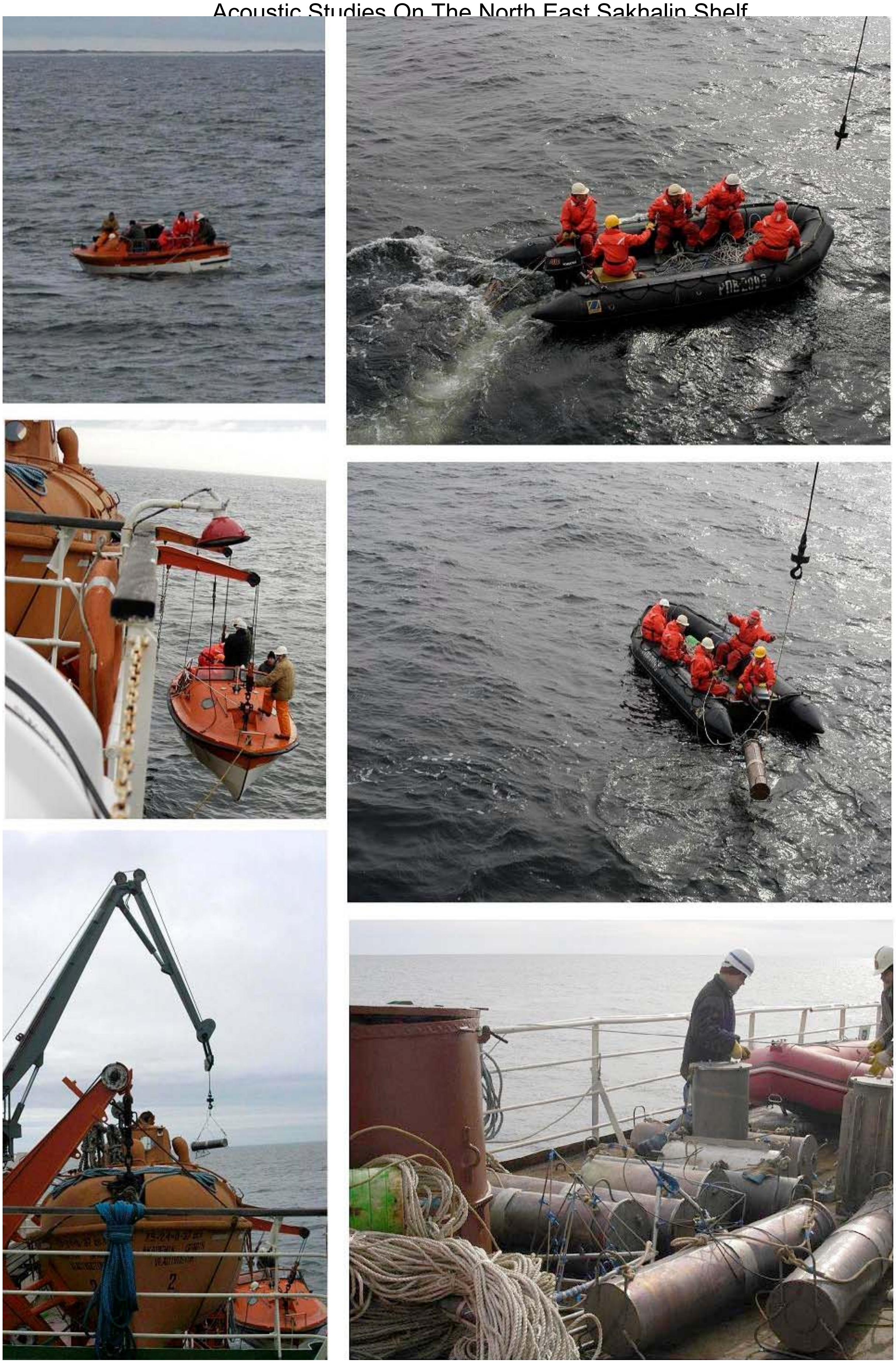

Figure 1.6 - Retrieval of an AUAR by a boat, zodiac and the *Academik Oparin*

Figure 1.7 - Deployment of the hydrologic sonde from the *Academik Oparin.*

During the 2005 field season AUARs were deployed and synchronous acoustic measurements recorded at stations ranging from near the Odoptu well pads to the southern edge of the offshore feeding area (Figure 1.3). The distance between the northern and southern edges of the area extended 180 km up the NE Sakhalin shelf. Before each AUAR is deployed its computer is programmed for the desired recording schedule. Computers on the *Academik Lavrent'ev or Academik Oparin* were used for acoustic data storage, processing and analysis.

To compute TL from acoustic measurements made by different AUARs, the data has to be calibrated to an absolute pressure standard. The hydrophones were manufactured with nominal sensitivities and the gains were set in the field. Field cross-calibrations conducted in 2005 confirmed the absolute calibration of the data. Further details of the AUARs used, their location, deployment depth and recording settings can be found in Appendix A. A detailed description of the characteristics and calibration of the 2005 acoustic recording equipment is provided in volume 2 of the report [Borisov et. al., 2006].

In order to more accurately characterize the 2005 TL measurements, the hydrological characteristics (velocity, temperature, and salinity) of the water layer were acquired using a hydrological sonde. The sonde is powered by a set of D cells, providing approximately 180 hours of continuous operation. Three hundred and fifty-four (354) vertical hydrologic profiles were acquired in 2005.

1.3 Terminology and algorithms used in the report

Ambient and anthropogenic acoustic data recorded by the AUARs was written to the AUAR disc in a raw format and converted to microPascals (μPa)[11] after downloading to the computer on the *Academik Lavrent'ev or Academik Oparin* (or during analysis). Acoustic spectra in decibels will be used to describe the variation in acoustic power as a function of frequency. In this report sound pressure power density spectra *G(f)* ($\mu Pa^2/Hz$)[12] will be used when spectral data are plotted. The sonograms *G(f,t)* are plots of power spectral

[11] The data was scaled (after incorporating hydrophone sensitivity, system instrument response and system gain), to convert the data to standard units of pressure (measured through an omni-directional hydrophone).
[12] Energy and power spectra are scaled to 1 Hz whatever the analysis length.

density vs. frequency and time and also include the variation in sound pressure level *D(Δf,t)* (μPa^2) with time over the annotated bandwidth[13]. Figure 1.8 shows a sonogram; the color scales generally run from ~37 to ~120 dB re 1 μPa^2/Hz.

The ***Spectral level*** of an acoustic signal relates to the level of acoustic power in a 1 Hz band. This term is only applied to sounds with continuous frequency spectra[14]. These spectra are often averaged over a number of one-second windows[15] to improve the statistical stability of the ambient noise data[16]; the number of one-second windows used in the averaging is given at the top of each plot (if the data is averaged over multiple windows).

A detailed description of the methodology used for normalizing and calculating both the amplitude and spectral data is given in Appendix D.

1.4 Units

During the course of this report a number of different unit notations have been used. This is due to differences in standard notation between different disciplines and nationalities.

The following are equivalent units using the different standard nomenclatures:
1 mkPa = 1 μPa and 1 mkV = 1 μV.

For spectral density plots - although the units for power spectral density are μPa^2/(s Hz), μPa^2/s/Hz or μPa^2, the units for power spectral density are sometimes defined as μPa^2/Hz or μPa/√Hz.

[13] Sound pressure level is the integral of the acoustic energy over the specified frequency band.
[14] A continuous frequency spectrum is a spectrum with signal present at all sampled frequencies.
[15] Average of X 1-second spectral estimates.
[16] Spectral averaging is used to obtain a lower variance spectral estimate.

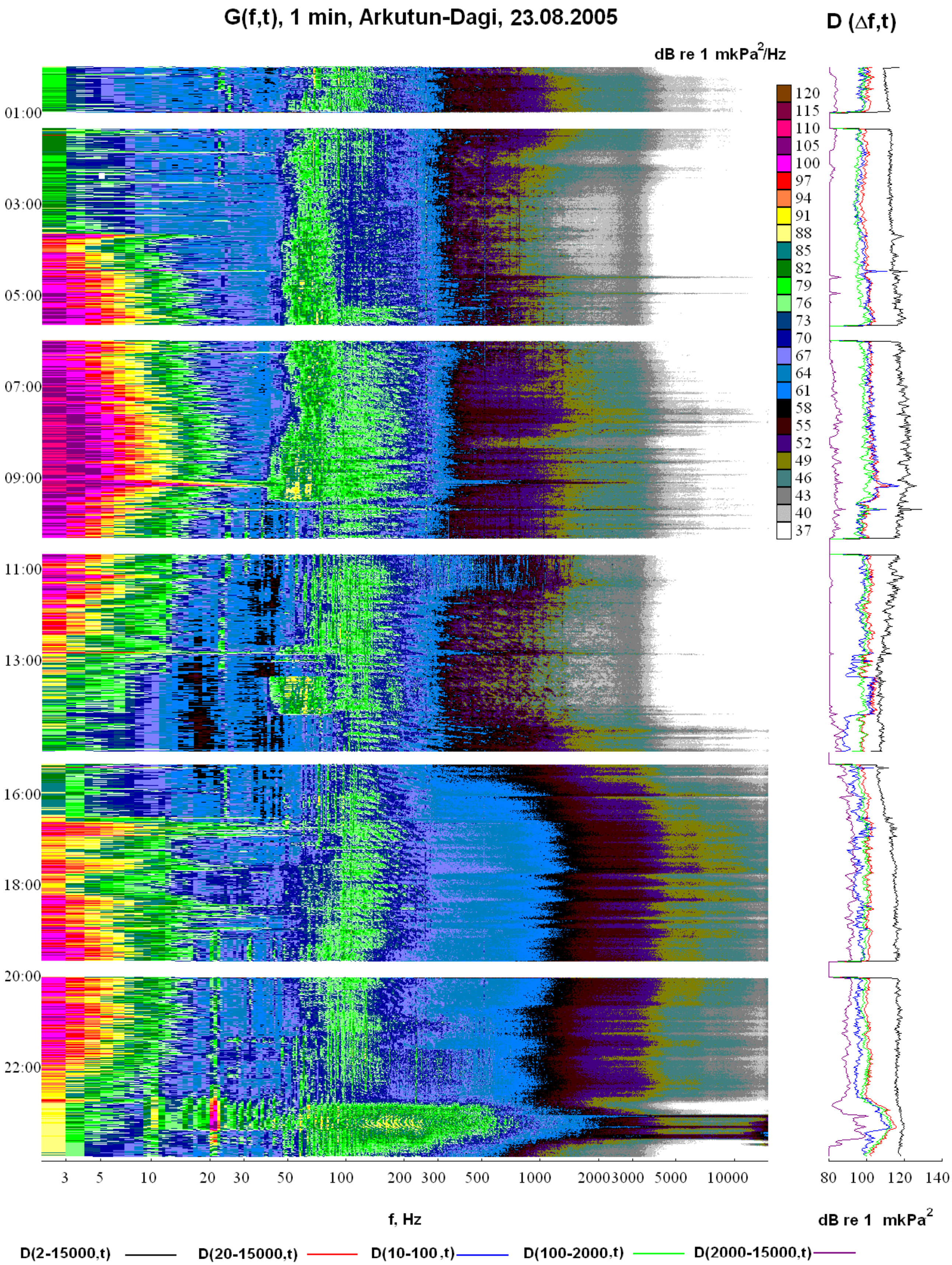

Figure 1.8 - Sonogram *G(f,t)* and plot of sound pressure level *D(Δf,t)* of acoustic energy recorded at the Arkutun-Dagi monitor station [4] on 23 August 2005.

2 Real-Time Acoustic Data Acquisition

This chapter discusses the implementation of a real-time acoustic monitoring program, developed to prevent anthropogenic sound generated by SEIC and ENL offshore construction activities from disturbing western gray whale feeding activities[17]. As the installation of the SEIC Concrete Gravity Based Structure (CGBS) at the PA-B platform location was the closest activity to the western gray whale feeding area, the most intense acoustic monitoring was during this specific offshore activity. The sections below contain a description of the objectives and methodology for the real-time acoustic monitoring program, plots of the real-time acoustic data recorded in the field and a comparison of the 10 Hz to 5 kHz transmitted data with the 2 Hz to 15 kHz data recorded on the T-AUARs, and processed after the field season.

2.1 Objectives of real-time acoustic monitoring program

The objective of the real-time acoustic monitoring program was to monitor any sound propagating from the operations associated with the tow and installation of the Orlan platform and PA-B concrete gravity base, the construction of the pipeline from the Orlan platform to the Chayvo OPF and the Molikpaq engineering work. This real-time monitoring was designed to measure the sound from construction operations so as to minimize the impact on the western gray whale population. This program had three main goals:

1. To record the acoustic field at four monitor stations located on the eastern and southern edges of the Piltun feeding area[18]. During times of nearby development activity (e.g. PA-B CGBS tow out) extra monitor stations were deployed. These broad band acoustic records will be used to identify any anthropogenic sounds associated with SEIC and ENL offshore construction activities. This data will be correlated with concurrent western gray whale behavioral and distribution studies to further understand any reaction to these sounds and to assist in the design and planning of future offshore development and production operations.

---

[17] The real-time received sound levels at the edge of the feeding area were considered to be the most reliable and quantifiable indicator of disturbance, as they are independent of environmental conditions such as reduced visibility and high sea states. However, field data of gray whale behavior, distribution and abundance were also considered important in determining the potential impact on a whale on a near real time basis. For this reason daily and weekly maps of whale distribution were generated and evaluated in an effort to assess real-time impacts, bearing in mind the high variability and other limitations of these data. Also, close communications between the biological and acoustic teams were established, so as to obtain feedback on whale behavior and distribution and correlate it with data on received sound levels.

[18] These broad band acoustic recordings will be as continuous as operationally feasible during the construction season.

2. To determine the degree to which the received sound levels at monitoring points at the outer edge of the Piltun feeding area agree with predicted sound levels. These predictions were made during the design and planning phase of offshore construction activities, using an acoustic model calibrated with TL measurements [SEIC, 2005a].
3. To ensure that sound levels reaching the feeding ground are below SEICs predefined action criteria [SEIC, 2005b] and take appropriate mitigation measures if necessary.

2.2 Methodology for the real-time acoustic monitoring

In order to monitor the acoustic field on the eastern and southern edges of the Piltun feeding area a radio receiving station was set up at Piltun lighthouse. This station received radio transmissions from a total of seven acoustic monitoring stations deployed at the locations shown on Figure 2.1 and Table 2.1. The sound levels recorded by the monitoring equipment and transmitted to the Piltun lighthouse radio station were monitored 24 hours a day. The data was received and evaluated in near real-time to ensure that the sound levels at the outer edge of the Piltun feeding area did not exceed the SEIC real-time action criteria agreed before the start of the construction season[19].

2.2.1 Locations of the monitoring stations

The locations of the acoustic stations used for the monitoring program are plotted in Figure 2.1 and their coordinates are given in Table 2.1. Stations ARB1 (analog sonobuoy) and PA-B-20 (T-AUAR) were closest to the majority of the PA-B CGBS installation activities and were located to record the highest sound levels generated by these operations. Monitor stations Odoptu-PA-B, Piltun and Piltun-S (T-AUAR) were farther from the PA-B construction operations. These stations were located to monitor sounds generated from other development activities (e.g. near Molikpaq and Chayvo/Orlan), without being dominated by sounds produced by the CGBS installation.

2.2.2 Real-time monitoring equipment

Of the seven monitoring stations that were occupied during 2005, four used T-AUARs and three used analog sonobuoy (ARB). Both were deployed on the sea bottom using anchors and were connected to radio transmitters in a surface float. The main features of these systems were:

[19] SEIC representatives at Piltun lighthouse were in communication with both the POI Acoustics team and the construction operations to ensure that the action criteria were maintained.

- **T-AUAR**: These are radio-enabled AUARs and are capable of both continuously recording full bandwidth (1 Hz to 15 kHz) acoustic data on the hard drive and transmitting analog data (bandwidth 10 Hz to 5 kHz) on a pre-programmed schedule to the radio station at Piltun lighthouse. The transmission schedule was selected to optimize battery life; in 2005 data was transmitted on a 1-hour out of 3-hour duty cycle. The four T-AUARs were deployed at monitor stations Odoptu-PA-B (#9), PA-B-20 (#8), Piltun (#6) and Piltun-S (#5).
- **Analog sonobuoy:** (The Russian abbreviation for analog sonobuoy is ARB (Analog radio-buoy)). These sonobuoys have no on-board storage capabilities; they transmit analog data (bandwidth 10 Hz to 5 kHz) continuously to the radio station at Piltun lighthouse. The three sonobuoys were deployed at stations ARB-1, ARB-2 and ARB-3.

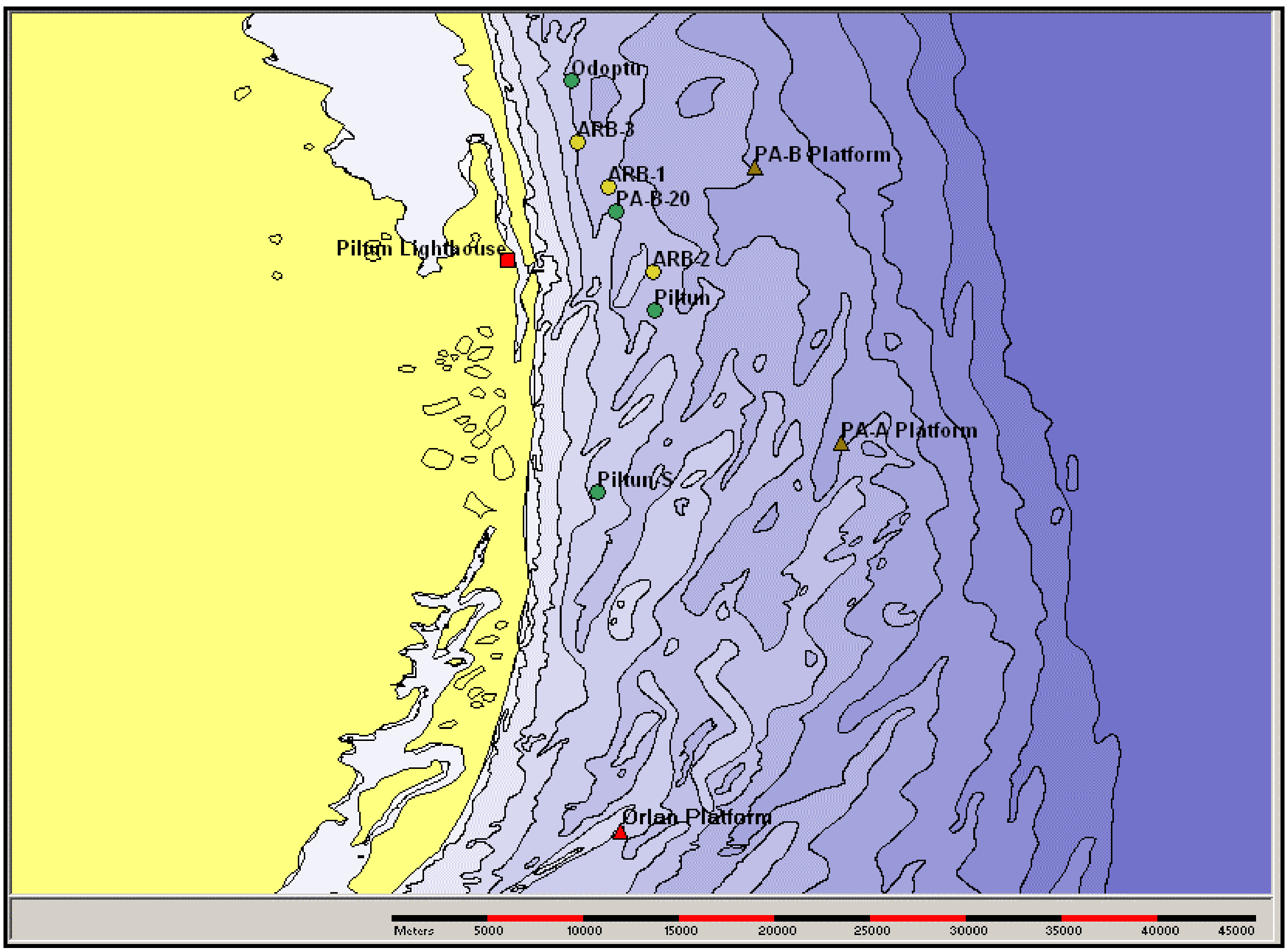

Figure 2.1 - Map of the monitor station locations and PA-B platform CGBS site. The green dots are T-AUAR stations Odoptu-PA-B, PA-B-20, Piltun and Piltun-S, the yellow dots are analog sonobuoy locations ARB1, ARB2 and ARB3.

Table 2.1 - Locations of the real-time monitoring stations (analog sonobuoys and T-AUARs).

Station	Latitude	Longitude
Sonobuoy locations from July 26 to August 8		
ARB1	52°55.0500	143°23.0167
ARB2	52°51.0667	143°25.1333
ARB3	52°57.1100	143°21.5333
T-AUAR locations from July 08 to July 23		
PILTUN-S	52°40.8969	143°22.6033
PILTUN	52°49.2950	143°25.2133
PA-B-20	52°54.1333	143°23.4667
ODOPTU-PA-B	52°59.9950	143°21.2850
T-AUAR locations from July 23 to August 08		
PILTUN-S	52°40.7083	143°22.5333
PILTUN	52°49.2333	143°25.2200
PA-B-20	52°53.9017	143°23.3450
ODOPTU-PA-B	53°00.0267	143°21.3100
ARB1 redeployed on August 4 (close to original position)		
ARB1	52°53.4936	143°23.7348
Sonobuoy locations after August 08. The locations are similar to the sonobuoy locations with the same number prior to August 08.		
ARB2	52°48.5436	143°25.4232
ARB3	52°55.2816	143°21.6918
ARB1	52°53.4936	143°23.7348
ODOPTU-PA-B	53°00.0336	143°21.2334
PILTUN-S	52°41.2182	143°22.5264
PILTUN	52°49.2432	143°25.0086

Use of these two recording systems provided the following primary benefits:

- Analog sonobuoys provided continuous real-time acoustic data that could be used for detailed real-time analysis during the critical construction periods.
- T-AUARs transmitted real-time acoustic data one hour in three for almost the entire construction season. These were used for real-time monitoring during this period and to complement the sonobuoys during critical construction periods.
- T-AUARs record continuous acoustic data on its hard drive; this is not subject to radio system noise and interference. This broader bandwidth data is available for post processing after T-AUAR retrieval, and to satisfy the third goal of the acoustic monitoring program.

The T-AUARs were deployed by 13 July to capture background sound levels prior to the start of construction activities (real-time monitoring at Piltun lighthouse commenced on 12 July). They were in almost continuous operation throughout the construction activities and continued to operate until 26 September (real-time monitoring at Piltun lighthouse ceased on 12 September, after that time the data was not transmitted, but was recorded by the AUARs). The continuous transmission sonobuoys were deployed on 26 July to optimize battery condition for critical times during the CGBS installation operations. The systems were fully operational at the start of the anchor deployments for the station keeping system on 27 July and were maintained operational through station keeping, ballasting down of the CGBS, anchor removal and decommissioning. Maintenance of the sonobuoys included replacing battery packs and repairing minor mechanical wave damage caused by high sea states. These high sea states also resulted in a limited number of physical displacements of the sonobuoys. The displaced sonobuoys were repositioned as quickly as possible.

2.3 Real-time acoustic data received at the Piltun lighthouse radio station

The radio receiving station at Piltun lighthouse was mobilized and fully operational by 12 July 2005 and started receiving data at 12:00. The T-AUARs at Odoptu-PA-B (#9), PA-B-20 (#8), Piltun (#6) and Piltun-S (#5) were deployed between 10 and 13 July and were operated continuously (except for maintenance operations) for four deployments until early September. The T-AUARs transmitted data to the lighthouse on a duty cycle of one hour in every three to optimize battery life. The T-AUAR at the PA-B-20 (#8) station had a mechanical failure for the first deployment (13 - 23 July)[20], but operated as programmed for the following two deployments. On 28 August, during the fourth deployment, the radio transmitter failed and was not repaired[21], as the radio transmission from the T-AUARs was being suspended in early September (the onboard disk continued to record data). For the fifth and final deployment, beginning on 10 September only AUARs were deployed at the four locations as the radio station at Piltun lighthouse was being demobilized and did not receive data after 12 September. Three sonobuoys were deployed by 27 July and were operational until 12 August. The sonobuoy closest to the PA-B platform was also monitored from 20 August until 12 September when the Piltun lighthouse radio station was demobilized. The sonobuoys transmitted data to the lighthouse continuously, not on an intermittent duty cycle like the T-AUARs. Figures 2.2 and 2.3 display the average one hour integrated broad band (10 Hz to 5 kHz) sound level values calculated from data transmitted by the T-AUARs and sonobuoys and received at Piltun lighthouse between mid July and mid September. Figures 2.2(a) to 2.2(d) display the data from the T-AUARs and Figures 2.3(a) to 2.3(d) the data transmitted by the sonobuoys.

2.4 Comparison of real-time and post processed sound levels

As a quality control check the data recorded on the hard disk of the four T-AUARs was compared to the data transmitted to the Piltun lighthouse radio station. Since the data received at Piltun lighthouse and the data on the AUAR were recorded using equipment that had been calibrated to an absolute acoustic standard, the data should be almost identical. There were expected to be small differences between the two data sets due to:

- Small time synchronization differences between data recorded on the AUAR and data received at Piltun lighthouse. The AUARs were synchronized to a clock on the vessel prior to deployment. However, this clock and the clock at Piltun lighthouse were not synchronized due to their physical separation.
- Clock drift; after the AUAR is deployed the clock will drift relative to the clock on the vessel. This drift is usually less than 15 minutes over the 16 day deployment and is not significant for long term acoustic monitoring. For exact data matching and synchronization this drift may have a small effect. For example, if a transient vessel was passing the T-AUAR at the start of a recording period and the de-synchronization between the AUAR and Piltun lighthouse was 15 minutes, part of the sound generated

[20] Acoustic data was transmitted via the radio channel, but not recorded on the hard drive of the AUAR.
[21] An analog sonobuoy was deployed nearby.

by the vessel may not be transmitted and a different average sound pressure level would be estimated.

There were also expected to be differences between the two data sets due to:

- The differences in bandwidth between the two data sets. The data received at Piltun lighthouse had a bandwidth of 10 Hz to 5 kHz and the data recorded on the AUAR was processed for a bandwidth of 2 Hz to 15 kHz. The contribution of frequencies above 5 kHz was expected to be insignificant; however, the contribution between 1 Hz and 20 Hz could be significant if flow noise was present on the data.
- The data recorded on the AUAR was not subject to the radio system noise and interference that is present on the data transmitted from the T-AUAR and received at Piltun lighthouse. Since the dynamic range of the radio channel is approximately 35 dB and the system gain was set to record sound pressure levels of up to 140 dB re 1 $\mu Pa^2/Hz$, sound pressure levels below 105 dB re 1 $\mu Pa^2/Hz$ would not be correctly recorded. Therefore, although the radio noise was not expected to be high, it could be the dominant acoustic level when the ambient noise levels were less than 105 dB re 1 $\mu Pa^2/Hz$. It is therefore expected that the broad band sound pressure level of the data received at Piltun lighthouse may be greater than that recorded on the AUAR during quiet periods due to contamination by radio noise.
- Strong weather and currents can have a mechanical influence on the hydrophone and thus the data, generating spikes and high amplitude, low frequency events. These can strongly bias a one hour average unless the data is quality controlled and edited.

The comparison between post-processed and real-time data has shown that the data received at Piltun lighthouse is a good representation of the sound levels recorded at the monitoring stations during offshore construction. Differences were seen due to de-synchronization and a different processing for high amplitude or low frequency events, but these differences did not substantially change the recorded and interpreted variations in the level of anthropogenic sound.

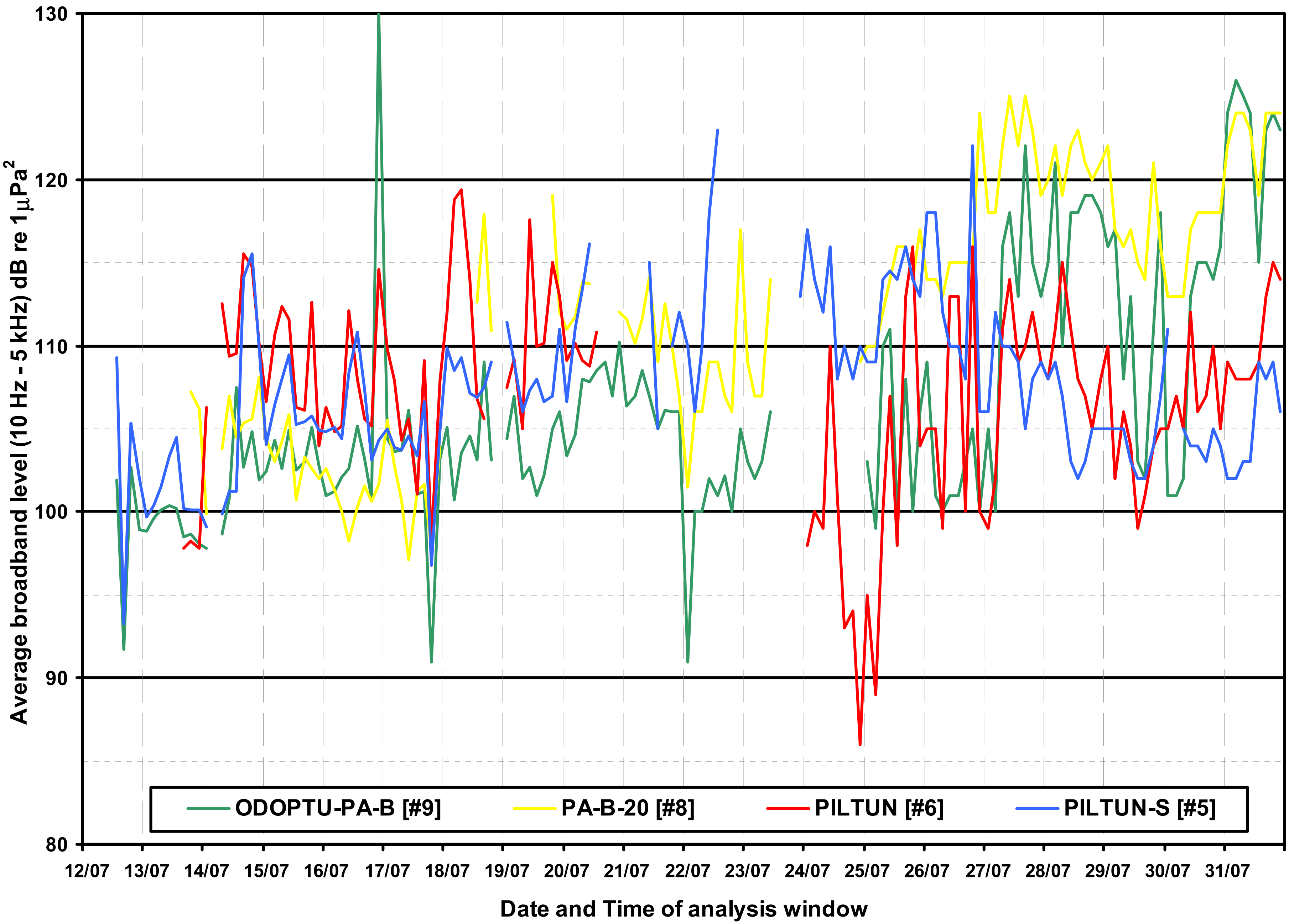

Figure 2.2(a) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 4 T-AUARs and received at the Piltun lighthouse radio receiving station from 12 to 31 July.

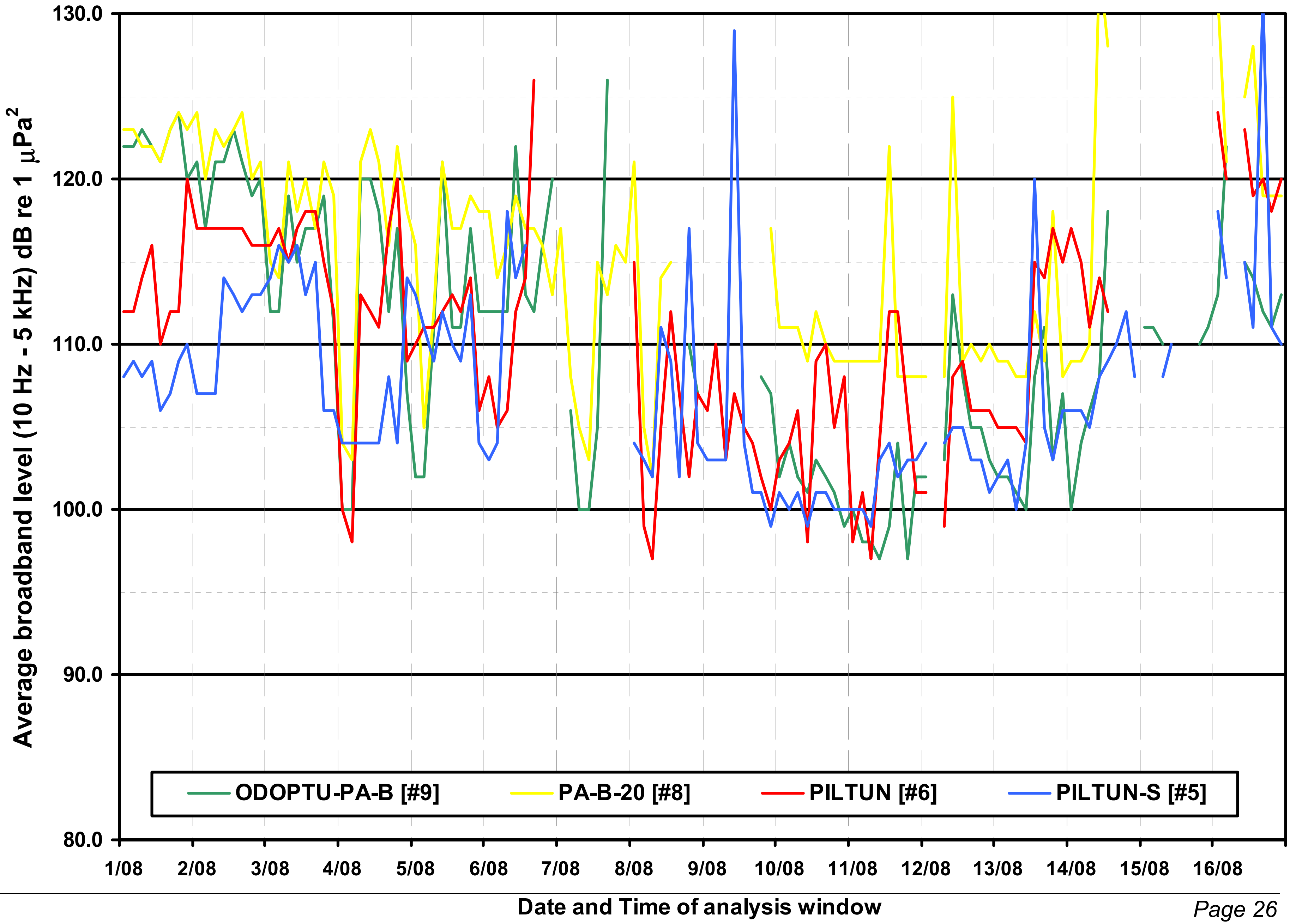
130.0
120.0
110.0
100.0
90.0
80.0
Average broadband level (10 Hz - 5 kHz) dB re 1 μPa²
ODOPTU-PA-B [#9]
PA-B-20 [#8]
PILTUN [#6]
PILTUN-S [#5]
1/08
2/08
3/08
4/08
5/08
6/08
7/08
8/08
9/08
10/08
11/08
12/08
13/08
14/08
15/08
16/08
Date and Time of analysis window

Figure 2.2(b)– Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 4 T-AUARs and received at the Piltun lighthouse radio receiving station from 1 to 16 August.

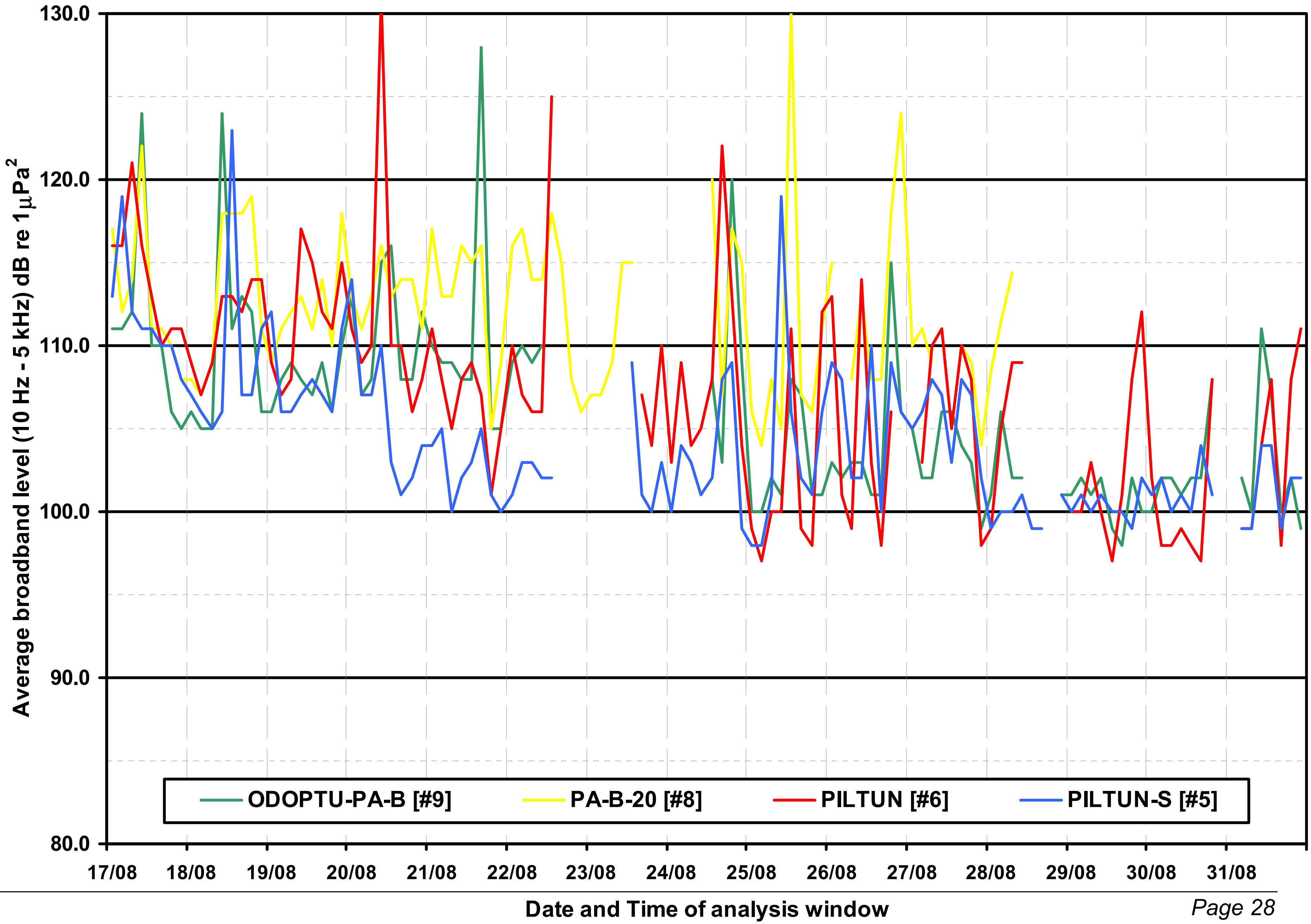
130.0
120.0
110.0
100.0
90.0
80.0
Average broadband level (10 Hz - 5 kHz) dB re 1μPa^2
ODOPTU-PA-B [#9]
PA-B-20 [#8]
PILTUN [#6]
PILTUN-S [#5]
17/08
18/08
19/08
20/08
21/08
22/08
23/08
24/08
25/08
26/08
27/08
28/08
29/08
30/08
31/08
Date and Time of analysis window

Figure 2.2(c) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 4 T-AUARs and received at the Piltun lighthouse radio receiving station from 17 to 31 August.

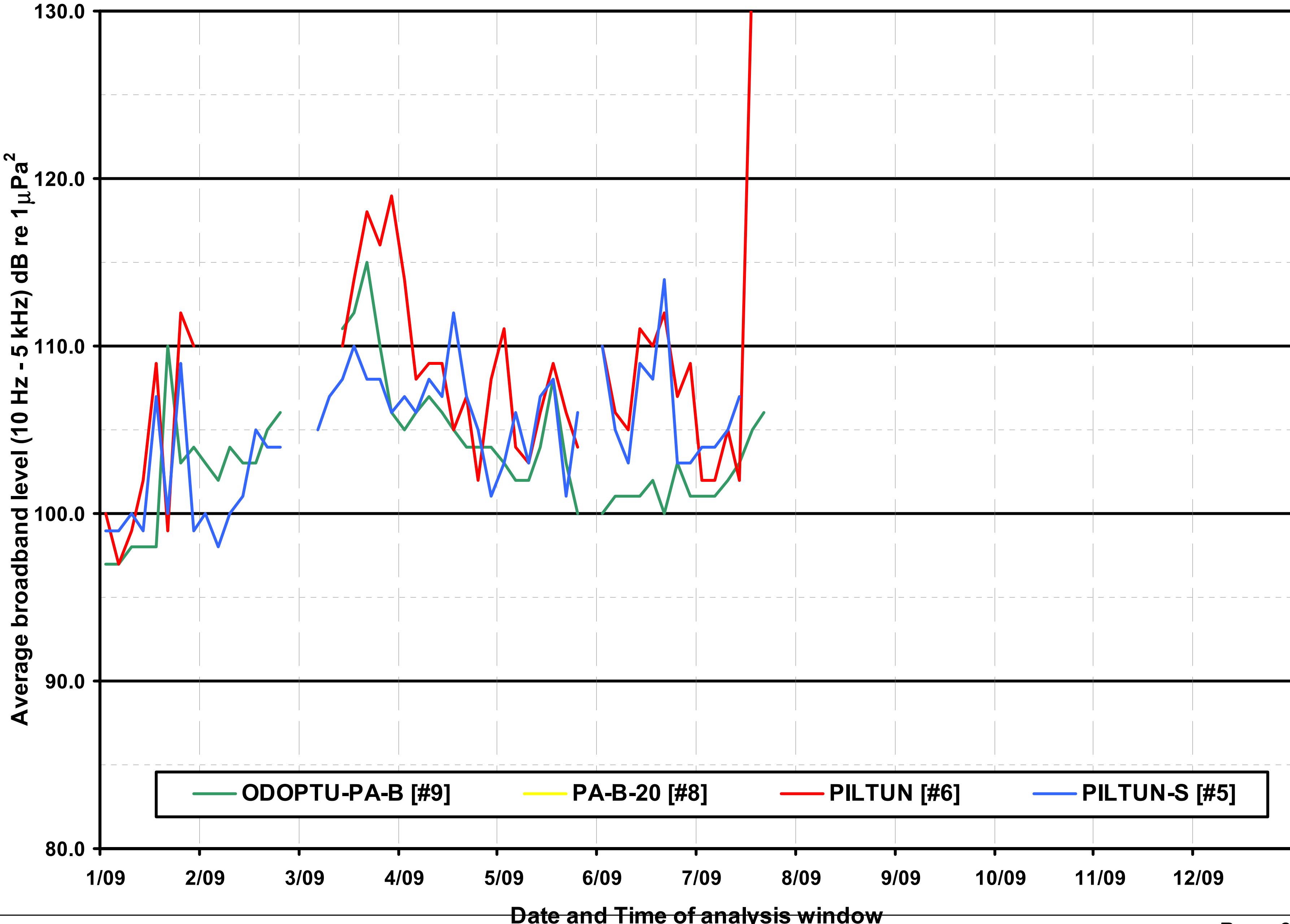
130.0
120.0
110.0
100.0
90.0
80.0
Average broadband level (10 Hz - 5 kHz) dB re 1μPa²
ODOPTU-PA-B [#9]
PA-B-20 [#8]
PILTUN [#6]
PILTUN-S [#5]
1/09
2/09
3/09
4/09
5/09
6/09
7/09
8/09
9/09
10/09
11/09
12/09
Date and Time of analysis window

Figure 2.2(d) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 4 T-AUARs and received at the Piltun lighthouse radio receiving station from 1 to 12 September.

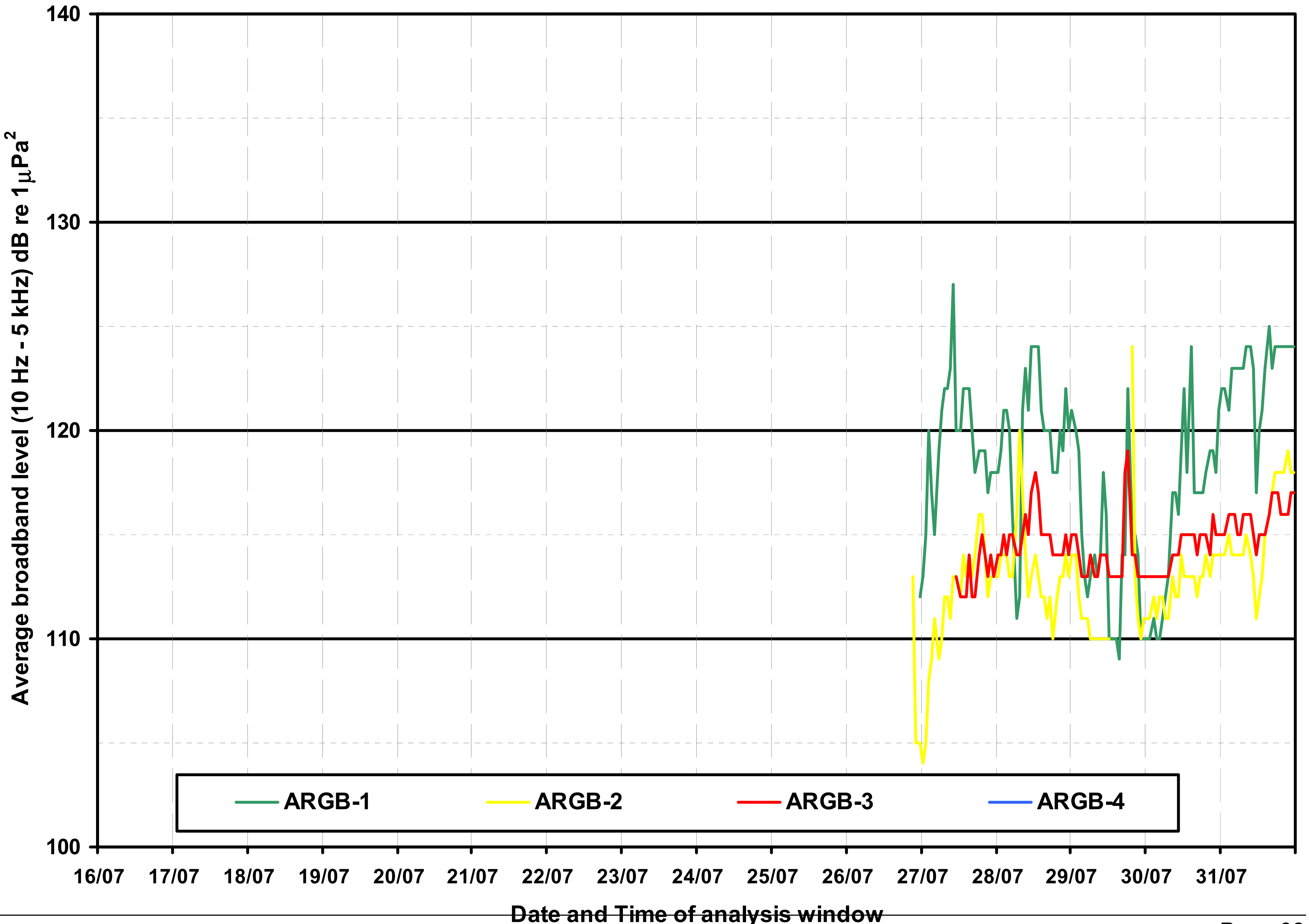
140
130
120
110
100
Average broadband level (10 Hz - 5 kHz) dB re 1μPa²
16/07
17/07
18/07
19/07
20/07
21/07
22/07
23/07
24/07
25/07
26/07
27/07
28/07
29/07
30/07
31/07
Date and Time of analysis window
ARGB-1
ARGB-2
ARGB-3
ARGB-4

Figure 2.3(a) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 3 sonobuoys and received at the Piltun lighthouse radio receiving station from 16 to 31 July.

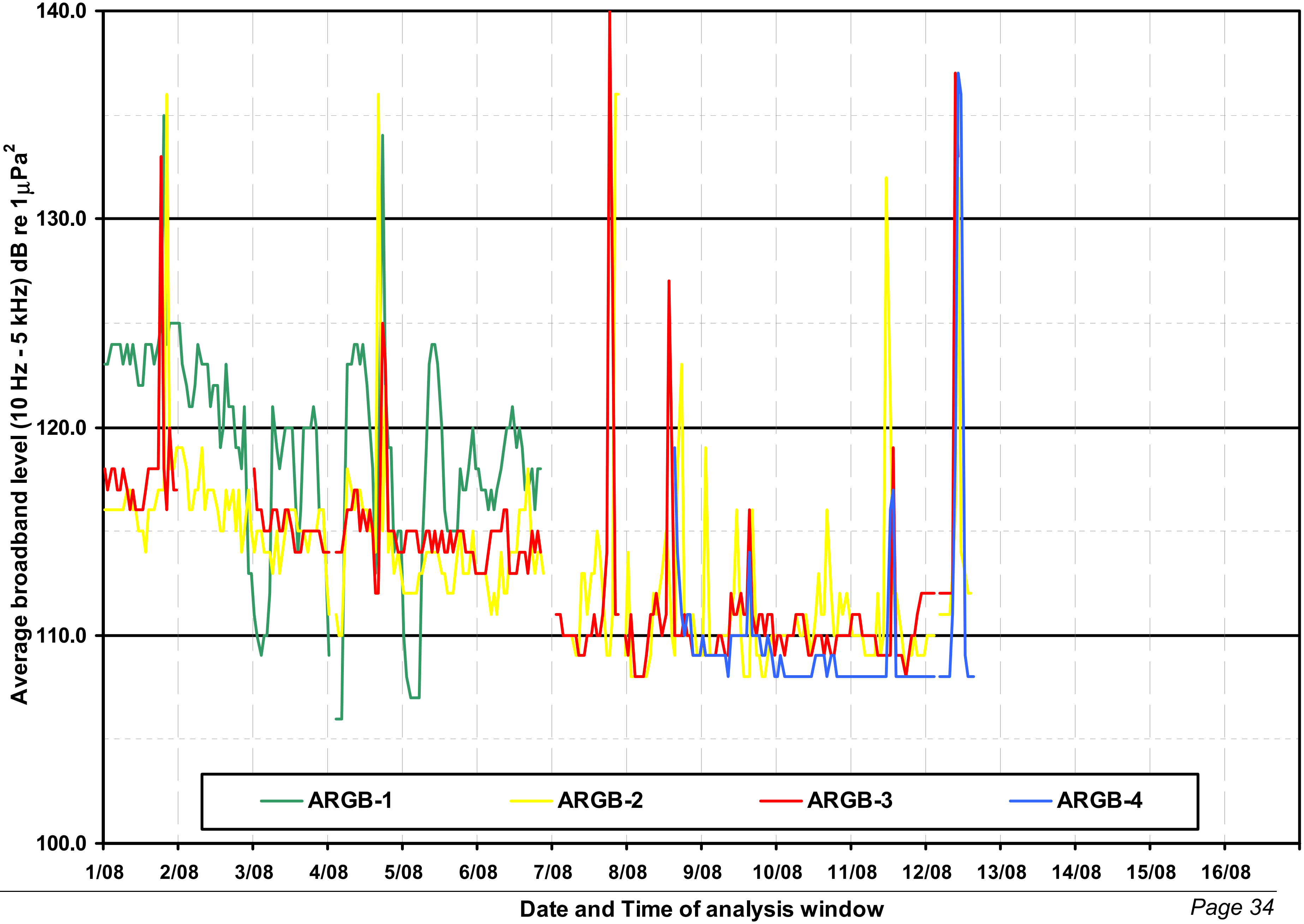
140.0
130.0
120.0
110.0
100.0
Average broadband level (10 Hz - 5 kHz) dB re 1μPa²
1/08
2/08
3/08
4/08
5/08
6/08
7/08
8/08
9/08
10/08
11/08
12/08
13/08
14/08
15/08
16/08
Date and Time of analysis window
ARGB-1
ARGB-2
ARGB-3
ARGB-4

Figure 2.3(b) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 3 sonobuoys and received at the Piltun lighthouse radio receiving station from 1 to 16 August.

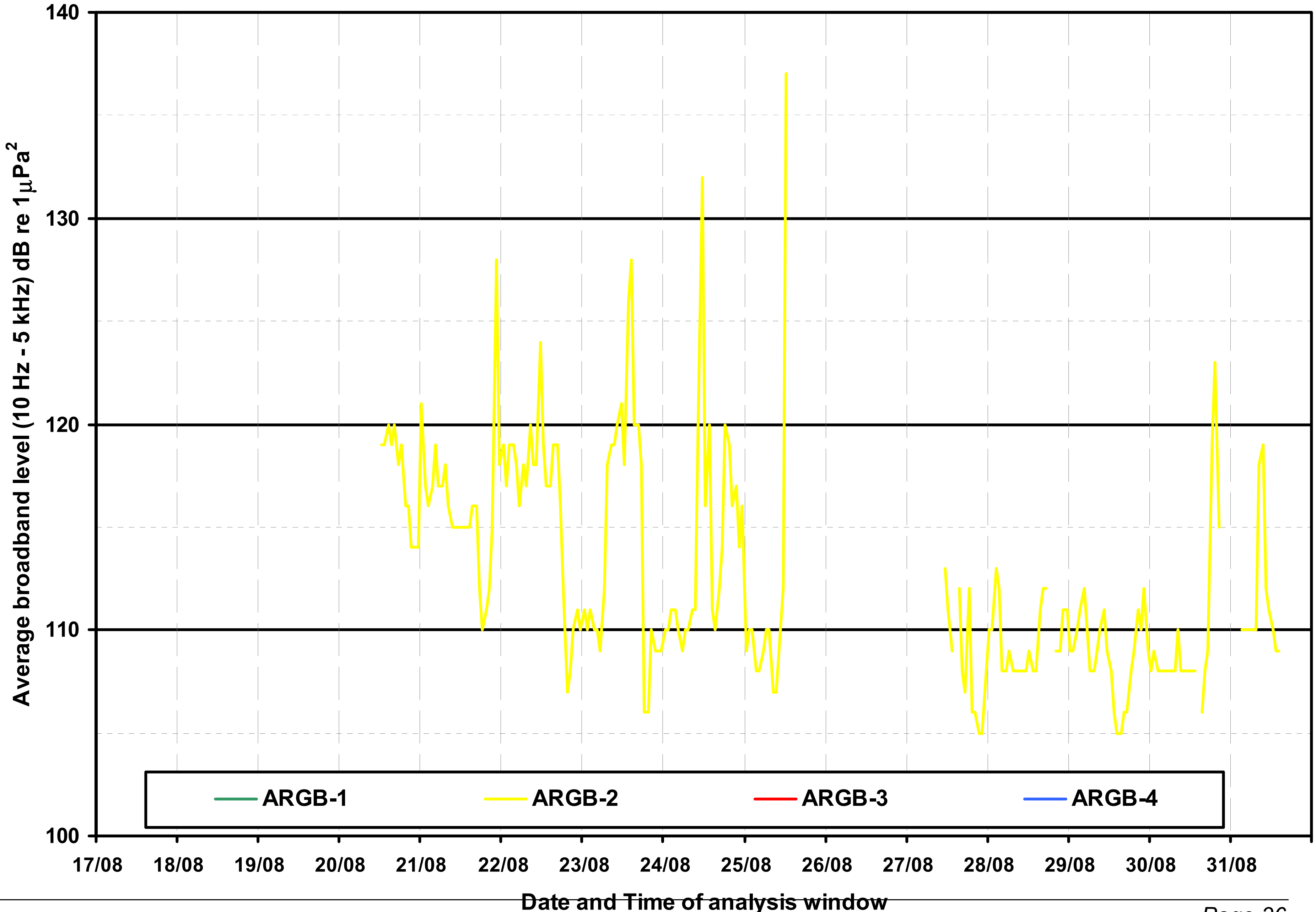
Average broadband level (10 Hz - 5 kHz) dB re 1μPa²
140
130
120
110
100
ARGB-1
ARGB-2
ARGB-3
ARGB-4
17/08
18/08
19/08
20/08
21/08
22/08
23/08
24/08
25/08
26/08
27/08
28/08
29/08
30/08
31/08
Date and Time of analysis window

Figure 2.3(c) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 3 sonobuoys and received at the Piltun lighthouse radio receiving station from 17 to 31 August.

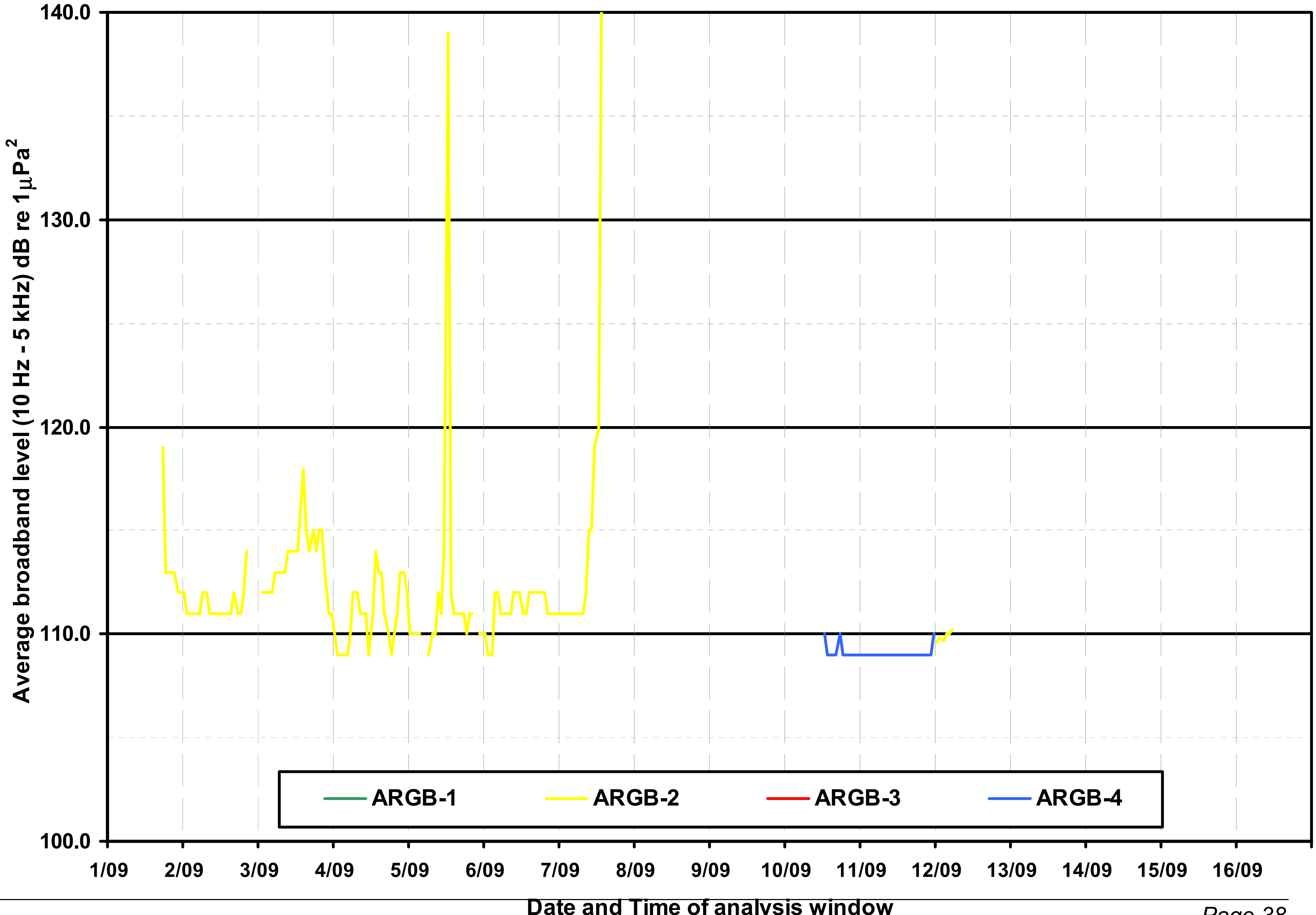
Average broadband level (10 Hz - 5 kHz) dB re 1μPa²
140.0
130.0
120.0
110.0
100.0
ARGB-1
ARGB-2
ARGB-3
ARGB-4
1/09
2/09
3/09
4/09
5/09
6/09
7/09
8/09
9/09
10/09
11/09
12/09
13/09
14/09
15/09
16/09
Date and Time of analysis window

Figure 2.3(d) – Plot showing the average 1-hour broadband (10 Hz to 5 kHz) received level transmitted by the 3 sonobuoys and received at the Piltun lighthouse radio receiving station from 1 to 12 September.

3 Data Recorded on the NE Sakhalin Shelf during the 2005 Field Season

This section discusses the data recorded on the NE Sakhalin shelf during the 2005 field season. It describes the deployment dates, recording times, hydrophone depths and locations of the AUARs as well as their operational characteristics. Tables 3.1 and 3.2 give these details for the 16 AUARs used in the study. The POI acoustic team undertook seven distinct studies in 2005:

1. Acoustic monitoring during construction operations.
2. Ambient noise measurements.
3. Anthropogenic acoustic measurements (especially from vessels involved in the western gray whale surveys such as the outboard motor on the Photo-ID zodiac as well as the *Academik Lavrent'ev and Academik Oparin*).
4. TL experiments along profiles from major facilities to the closest edges of the Piltun and offshore gray whale feeding areas.
5. Studies of sound levels near behavioral monitoring stations.
6. Bathymetric and hydrologic studies of the survey area.
7. Analysis of the relationship between benthos distribution and development and the hydrology and bathymetry of the area in partnership with the benthic team [Fadeev, 2005].

This volume will not discuss the analysis of these experiments, which will be the subject of the third volume of this report; it will however present all the acoustic data from the 2005 field program. This data will be presented as sonograms[22], where the spectral density values *G(f,t)* are represented by different colors[23], one sonogram representing the acoustic data for one AUAR for one day. The spectral density plots *G(f,t)* cover a broad (2 Hz to 15 kHz) band of frequencies and are plotted with a logarithmic frequency axis to aid in the visual analysis of the data (e.g. Figure 1.8). These sonograms *G(f,t)* show the variation in the spectral levels of ambient and anthropogenic sound with frequency and time due to changing meteorological conditions, vessel movements and industrial activity. All sonograms *G(f,t)* will be in absolute amplitude (dB re 1 $\mu Pa^2/Hz$), all instrument and sensor corrections having been applied to the data. Appendix A shows the days on which data was acquired at each station. Sonograms for all the data are available on a DVD at the back of this report.

[22] A sonogram is a plot showing the variation in acoustic power spectral density level with frequency and time.
[23] The scale of the sonograms varies from 37 to 100 dB re 1 $\mu Pa^2/Hz$ in 3 dB increments.

Table 3.1(a) - Operational times, parameters and locations of AUARs at monitor stations 1 to 6.

Station		Date		Time		Time	AUAR	Location		Depth	Gain	Sens.
Name	#	Start	End	Start	End	(hr)	#	Latitude	Longitude	(m)		(mV/Pa)
Lunskoye	1	15-Sep	30-Sep	16:15	12:30	356.3	№ 11	52°51'47"	143°37'.29'	48	40	56.5
OFA	2	3-Aug	19-Aug	10:15	16:30	390.3	№ 9	52°10'20"	143°36'02"	42	40	48.0
OFA	2	19-Aug		17:00		FAIL	№ 11	52°10'19"	143°36'03"	40	40	56.5
OFA	2	6-Sep	23-Sep	13:30	09:00	403.5	№ 10	52°10'18"	143°36.05"	42	40	49.5
Orlan	3	9-Jul	22-Jul	14:35	17:30	314.9	№ 8	52°21'35"	143°35'01"	33	40	50.0
Orlan	3	22-Jul	6-Aug	18:00	10:00	352.0	№ 5	52°21'35"	143°34'59"	33	40	51.5
Orlan	3	9-Aug	24-Aug	20:10	20:15	360.1	№ 5	52°21'41"	143°34'58"	33	40	49.0
Orlan	3	24-Aug	11-Sep	20:40	09:00	420.3	№ 8	52°21'37"	143°34'59"	33	40	50.0
Orlan	3	10-Sep	26-Sep	15:00	16:30	385.5	№ 9	52°22'21"	143°34.58"	31	40	48.0
Arkutun-Dagi	4	3-Aug	19-Aug	09:00	10:00	385.0	№ 10	52°19'12"	143°44'01"	47	40	49.5
Arkutun-Dagi	4	19-Aug	5-Sep	10:00	17:30	415.5	№ 6	52°19'15"	143°43'54"	45	40	50.0
Arkutun-Dagi	4	14-Sep	30-Sep	14:04	09:00	378.9	№ 8	52°19'15"	143°44'06"	46	40	50.0
Piltun-S	5	11-Jul	22-Jul	18:00	13:00	259.0	№ 4	52°40'54"	143°22'36"	16	10	49.0
Piltun-S	5	23-Jul	6-Aug	22:00	14:30	328.5	№ 4	52°40'43"	143°22'32"	17	10	49.0
Piltun-S	5	7-Aug	22-Aug	23:20	13:00	349.7	№ 4	52°41'13"	143°22'32"	17	10	49.0
Piltun-S	5	23-Aug	7-Sep	11:00	10:30	359.5	№ 4	52°41'17"	143°22'42"	19	10	49.0
Piltun-S	5	10-Sep	26-Sep	12:15	13:30	385.3	№ 4	52°40'26"	143°22'17"	15	10	49.0
Piltun	6	13-Jul	22-Jul	11:00	10:00	215.0	№ 3	52°49'18"	143°25'13"	20	10	50.0
Piltun	6	23-Jul	6-Aug	21:00	16:00	331.0	№ 3	52°49'14"	143°25'13"	21	10	50.0
Piltun	6	7-Aug	22-Aug	22:20	16:30	354.2	№ 3	52°49'15"	143°25'01"	22	10	50.0
Piltun	6	23-Aug	7-Sep	13:10	12:00	358.8	№ 3	52°49'12"	143°24'57"	22	10	50.0
Piltun	6	10-Sep	26-Sep	10:55	11:30	384.6	№ 3	52°49'19"	143°25'13"	21	10	50.0

Table 3.1(b) - Operational times, parameters and locations of AUARs at monitor stations 7 to 12.

Station		Date		Time		Time	AUAR	Location		Depth	Gain	Sens.
Name	#	Start	End	Start	End	(hr)	#	Latitude	Longitude	(m)		(mV/Pa)
PA-B-10	7	13-Jul	27-Jul	13:40	09:30	331.8	№ 6	52°53’03”	143°20’10”	11	40	50.0
PA-B-10	7	27-Jul	14-Aug	9:20	13:00	435.7	№ 7	53°03’54”	143°18’17”	12	40	50.0
PA-B-10	7	16-Aug	1-Sep	12:15	17:00	388.8	№ 7	52°53’06”	143°20’13”	9	40	50.0
PA-B-20	8	13-Jul		13:00		FAIL	№ 2	52°54’08”	143°23’28”	20	10	49.0
PA-B-20	8	24-Jul	8-Aug	19:20	15:40	356.3	№ 2	52°53’54”	143°23’21”	18	2	49.0
PA-B-20	8	9-Aug	23-Aug	16:00	15:00	335.0	№ 2	52°54’00”	143°23’17”	20	10	49.0
PA-B-20	8	24-Aug	5-Sep	11:30	12:40	289.2	№ 2	52°54’03”	143°23’20”	20	10	50.8
PA-B-20	8	10-Sep	26-Sep	10:15	10:00	383.8	№ 2	52°54’05”	143°23’21”	20	10	49.0
Odoptu-PA-B	9	10-Jul	23-Jul	16:30	11:00	306.5	№ 16	53°00’00”	143°21’17”	22	10	50.0
Odoptu-PA-B	9	24-Jul	7-Aug	18:30	16:30	334.0	№ 16	53°00’02”	143°21’19”	21	10	50.0
Odoptu-PA-B	9	8-Aug	23-Aug	10:00	14:00	364.0	№ 16	53°00’02”	143°21’14”	21	10	50.0
Odoptu-PA-B	9	24-Aug	7-Sep	10:00	15:00	341.0	№ 16	53°00’01”	143°21’13”	21	10	50.0
Odoptu-PA-B	9	10-Sep	26-Sep	09:00	08:30	383.5	№ 16	53°00’03”	143°21’10”	22	10	50.0
Odoptu-S-10	10	10-Jul	27-Jul	17:00	12:00	403.0	№ 11	53°03’53”	143°18’25”	11	40	49.0
Odoptu-S-10	10	27-Jul		11:40		LOST	№ 1	53°03’54”	143°18’17”	12	40	49.0
Odoptu-S-20	11	30-Jul	17-Aug	09:30	11:00	433.5	№ 8	53°03’43”	143°19’55”	21	40	50.0
Odoptu-S-20	11	23-Aug	7-Sep	16:22	16:30	360.1	№ 9	53°03’42”	143°19’33”	18	40	48.0
Odoptu-S-20	11	9-Sep		21:35		FAIL	№ 13	53°03’40”	143°20’03	23	40	50.8
Odoptu-N-10	12	10-Jul	27-Jul	17:30	13:00	403.5	№ 9	53°08’57”	143°17’24”	10	40	48.0
Odoptu-N-10	12	28-Jul	13-Aug	21:35	15:30	377.9	№ 11	53°09’06”	143°17’25”	12	10	56.5

Table 3.1(c) - Operational times, parameters and locations of AUARs at monitor station 13 and the control station, as well as acoustic stations A9 to A11.

Station		Date		Time		Time	AUAR	Location		Depth	Gain	Sens.
Name	#	Start	End	Start	End	(hr)	#	Latitude	Longitude	(m)		(mV/Pa)
Odoptu-N-20	13	20-Aug	5-Sep	18:30	09:00	374.5	№ 10	53°08'58"	143°18'33"	18	40	49.5
Odoptu-N-20	13	5-Sep	22-Sep	09:50	12:00	410.2	№ 7	53°09'12"	143°18'53"	22	40	50.0
Control	14	25-Aug	20-Sep	20:50	14:00	617.2	№ 5	53°25'58"	143°11'00"	20.5	40	49.0
BEH-Odoptu	A.9	11-Jul		13:30		LOST	№ 12	53°12'32"	143°16'12"	11	40	49.0
BEH-north	A.10	11-Jul	27-Jul	15:00	17:20	386.3	№ 10	53°18'00"	143°13'48"	10	40	52.8
BEH-north	A.10	28-Jul	13-Aug	20:30	12:30	352.0	№ 6	53°17'57"	143°13'47"	11	40	52.4
Chayvo-4	A.11	9-Jul	22-Jul	16:00	14:20	310.3	№ 7	52°33'56"	143°23'09"	16	40	50.31
Chayvo-4	A.11	22-Jul	6-Aug	15:30	12:10	332.7	№ 13	52°34'02"	143°23'00"	16	40	52.8
Chayvo-4	A.11	9-Aug	22-Aug	18:15	17:00	310.8	№ 13	52°34'06"	143°23'00"	18	40	52.3
Chayvo-4	A.11	23-Aug	7-Sep	10:05	08:30	334.4	№ 13	52°34'11"	143°22'56"	15	40	50.31
Chayvo-4	A.11	7-Sep	24-Sep	09:40	10:50	409.2	№ 6	52°34'09"	143°22'56"	17.5	40	52.1

Table 3.2 – Plot showing the days when AUARs were active at each monitoring station (by station).

Stations	July																							August																															Stations
	9	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	
Odoptu-PA-B		TAUAR #1														TAUAR #1																TAUAR #1																TAUAR #1								Odoptu-PA-B
PA-B-20					TAUAR #2											TAUAR #2																	TAUAR #2															TAUAR #2								PA-B-20
Piltun					TAUAR #3										TAUAR #3																TAUAR #3																TAUAR #3									Piltun
Piltun-S			TAUAR #4												TAUAR #4																TAUAR #4																TAUAR #4									Piltun-S
PA-B-10					AUAR #6															AUAR #7																					AUAR #7																PA-B-10
Orlan	AUAR #8													AUAR #5																			AUAR #5															AUAR #8								Orlan
Odoptu-N-10		AUAR #9																		AUAR #11																																				Odoptu-N-10
Odoptu-S-10		AUAR #11																		AUAR #14																																				Odoptu-S-10
Odoptu-N-20																																												AUAR #10												Odoptu-N-20
Odoptu-S-20																						AUAR #8																								AUAR #9									Odoptu-S-20
OFA																										AUAR #9																	AUAR #11												OFA
Arkutun-Dagi																										AUAR #10																AUAR #6													Arkutun-Dagi
A9			AUAR #12																																																				A9
A10			AUAR #10																	AUAR #6																																				A10
A11	AUAR #7														AUAR #13																		AUAR #13														AUAR #13									A11
Lunskoye																																																							Lunskoye
Control																																																	AUAR #5						Control

Stations	September																													Stations
	1	2	3	4	5	6	7	8	9	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	
Odoptu-PA-B										TAUAR #1																					Odoptu-PA-B
PA-B-20										TAUAR #2																					PA-B-20
Piltun										TAUAR #3																					Piltun
Piltun-S										TAUAR #4																					Piltun-S
PA-B-10																															PA-B-10
Orlan												AUAR #9																			Orlan
Odoptu-N-10																															Odoptu-N-10
Odoptu-S-10																															Odoptu-S-10
Odoptu-N-20						AUAR #7																									Odoptu-N-20
Odoptu-S-20									AUAR #13																						Odoptu-S-20
OFA						AUAR #10																									OFA
Arkutun-Dagi														AUAR #8																	Arkutun-Dagi
A9																															A9
A10																															A10
A11								AUAR #6																							A11
Lunskoye															AUAR #11																Lunskoye
Control																															Control

- Deployment #1
- Deployment #2
- Deployment #3
- Deployment #4
- Deployment #5
- No data
- LOST

Table 3.2 – Plot showing the days when AUARs were active at each monitoring station (by AUAR #).

July: 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 — August: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

	July – August				
TAUAR #1	Odoptu-PA-B	Odoptu-PA-B	Odoptu-PA-B	Odoptu-PA-B	TAUAR #1
TAUAR #2	PA-B-20	PA-B-20	PA-B-20	PA-B-20	TAUAR #2
TAUAR #3	Piltun	Piltun	Piltun	Piltun	TAUAR #3
TAUAR #4	Piltun-S	Piltun-S	Piltun-S	Piltun-S	TAUAR #4
AUAR #5	Orlan	Orlan	Control		AUAR #5
AUAR #6	PA-B-10	A10	Arkutun-Dagi		AUAR #6
AUAR #7	A11	PA-B-10	PA-B-10		AUAR #7
AUAR #8	Orlan	Odoptu-S-20	Orlan		AUAR #8
AUAR #9	Odoptu-N-10	OFA	Odoptu-S-20		AUAR #9
AUAR #10	A10	Arkutun-Dagi	Odoptu-N-20		AUAR #10
AUAR #11	Odoptu-S-10	Odoptu-N-10	OFA		AUAR #11
AUAR #12	LOST (A9)				AUAR #12
AUAR #13	A11	A11	A11		AUAR #13
AUAR #14	LOST (Odoptu-S-10)				AUAR #14

September: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

	September	
TAUAR #1	Odoptu-PA-B	TAUAR #1
TAUAR #2	PA-B-20	TAUAR #2
TAUAR #3	Piltun	TAUAR #3
TAUAR #4	Piltun-S	TAUAR #4
AUAR #5	Control	AUAR #5
AUAR #6	A11	AUAR #6
AUAR #7	Odoptu-N-20	AUAR #7
AUAR #8	Arkutun-Dagi	AUAR #8
AUAR #9	Orlan	AUAR #9
AUAR #10	OFA	AUAR #10
AUAR #11	Lunskoye	AUAR #11
AUAR #12		AUAR #12
AUAR #13	Odoptu-S-20	AUAR #13
AUAR #14		AUAR #14

- Deployment #1
- Deployment #2
- Deployment #3
- Deployment #4
- Deployment #5
- No data
- LOST

3.1 Ambient noise studies

One of the key goals of the acoustic studies in the western gray whale research program has been to measure and characterize the ambient noise field on the NE Sakhalin shelf. This long-term program commenced in 2003, and is currently ongoing. This data, in conjunction with the measurement of the acoustic signature of present and future facilities will allow the cumulative effect of oil development and production operations on the acoustic background in the area, as well as on the gray whale population to be more effectively estimated.

3.1.1 Western gray whale core areas[24]

In order to strategically plan the location of the monitoring stations for the 2003 to 2005 and future programs it was critical to estimate the core areas for the gray whales on the NE Sakhalin shelf. In 2003, the core areas were estimated and the acoustic monitoring locations selected using the sightings from all of the 2001 and 2002 aerial surveys [Borisov et. al., 2004]; however, in 2001, many more aerial surveys were acquired and they were concentrated in a reduced seasonal range. Further, no correction was made for survey effort. For 2004 the core areas were determined using whale densities estimated from the 2003 and 2004 aerial survey data taking the survey effort into account[25].

In these analyses, probability contours are used to visualize areas with the greatest likelihood of encountering gray whales, and examine shifts in the 'centers of activity' of gray whales over time[26]. Cumulative probability contours of 50% and 95% were generated to visualize the distribution of gray whales. The 50% contour represents the area within which 50% of the whales sighted are expected to be found. In 2003 the probability contours were estimated using a conventional kernel density method[27]. This kernel density method employed a square-gridding process, which is robust for small sample sizes unless the

---

[24] This section is based on work performed by LGL Ltd (Robin Tamasi, Peter Wainwright, Judy Muir, Sergei Yazvenko, Sonya Meier, and Steve Johnson).

[25] Density is the number of whales per unit area; multiple surveys over a grid cell result in larger densities within that cell if densities are not compensated for survey effort and average densities computed.

[26] Cumulative probability contours were computed independently for the Piltun and offshore feeding areas.

[27] The kernel density contours were mapped using the ArcView© 3.1 extension Animal Movement 2.04 [Hooge et. al., 1997]. Kernel density contours are an estimator that assesses an animal's probability of occurrence at each point in space using a utilization distribution.

variances of the north-south and east-west components of the distribution are very different, which is the case for the Piltun feeding area.

For the Piltun feeding area the distribution of whale sightings is oriented parallel to the coast with significantly greater variance in the along-shore direction than in the perpendicular-to-shore direction. For this reason, in 2004, a grid was constructed for the Piltun feeding area that was oriented along-shore and with an along-shore grid cell dimension greater than the perpendicular-to-shore dimension, (i.e. each cell was 4 km by 0.5 km). Density was then computed for each cell as the number of whales divided by the cumulative area surveyed within the cell. The same methodology was employed for the offshore feeding area except that, in this case, the conventional assumptions about distribution were satisfied and a regular grid of 1 km by 1 km cells was employed.

There was significant variation between the 2003 and 2004 estimates of the western gray whale core areas. In 2005 this analysis was updated using all available systematic survey data. These included data from the 2001 to 2004 aerial surveys, 2001 to 2004 scan stations, and the 2004 vehicle-based surveys. The details of this analysis are given in Appendix C.

3.1.2 Monitor, control and acoustic station locations

A systematic acoustic monitoring framework was developed in 2003 and extended in 2004 and 2005. The goal is to monitor changes in the acoustic field on the NE Sakhalin shelf and most importantly those changes in the anthropogenic sound level that could cause a significant increase in the Received Level (RL) in either the Piltun or offshore feeding areas.

Three types of stations for recording acoustic data were designated:

- **Monitor stations** - These are locations that will be systematically monitored to gain an understanding of the changes in the acoustic field over time. They will be reoccupied multiple times in a season and over multiple seasons. The monitor stations will generally be located at the edge of a gray whale feeding area nearest to a proposed facility or in a location where the greatest cumulative impact from multiple facilities could be expected.
- **Control station(s)** - Dr. John Richardson (LGL) recommended that a control station or stations be set up far enough away from the proposed development operations that the anthropogenic acoustic field would not be expected to increase. This station would

reflect any changes to the ambient noise field unrelated to the oil development activities.

- **Acoustic stations** - These locations will be infrequently monitored; their purpose is to gain an understanding of the anthropogenic sound field from a known location at a specific time related to development activities or to conduct TL experiments.

Prior to the start of the 2003 field season, 11 stations were designated; seven were monitor stations, three were acoustic stations and one was a control station. For the 2004 season, a further six monitor stations and seven acoustic stations were designated. In 2005 one additional acoustic station was designated. Table 3.3 gives the proposed names, numbers and locations of these stations[28].

The locations of the monitor stations were determined with reference to the major gray whale concentrations in the area (Figure 3.1)[29]. For the offshore feeding area, the locations of the stations (except the OFA station) were chosen to be on the 95% probability contour at the point closest to a current or proposed facility. The location of the monitor stations remained constant between 2004 and 2005[30]. The western gray whale distribution in the Piltun feeding area varies with bathymetry, with most whales feeding in water depths between ~8-12 m. Mother-calf pairs have been seen in the Piltun feeding area, often in water depths of 5-10 m, and fewer whales have been seen outside the 20 m contour. Thus, the two key acoustic monitoring points are the 20 m and the 10 m contour (regarded as the edge and center of the whale distribution). The location of the monitor stations remained constant between 2004 and 2005[31].

[28] Where possible the numbers and names of the monitor stations will be maintained year to year for clarity.

[29] Various vessel based (MMO, Photo-ID, Benthic) and land based (vehicle surveys, behavioral) biology programs were being conducted over the same range, so an evaluation of the effect of any changes in the acoustic field on the distribution of gray whales can be evaluated.

[30] The Orlan station is on the 95% cumulative probability contour (from 2003) closest to the proposed location of the Orlan platform, the Lunskoye station at the southern edge of the offshore feeding area, the OFA (Offshore Feeding Area) station is approximately in the center of the offshore feeding area and the Arkutun-Dagi station is at the North Eastern edge of the offshore feeding area.

[31] The Odoptu-S-10, Odoptu-N-10, Odoptu-N-10 and Odoptu-S-10 stations were at the 10 m and 20 m bathymetry contours off the coast from the two proposed Odoptu well pads. The Piltun station is at the 20 m bathymetry contour between the Molikpaq platform and the major gray whale concentration off Piltun lighthouse. The PA-B stations were at the 10 m (PA-B-10) and 20 m (PA-B-20) bathymetry contours closest to the proposed PA-B location. The Piltun-S station is on the 95% cumulative probability contour at the southern bathymetry contour of the Piltun feeding area and the Odoptu-PA-B station at the 20 m bathymetry contour between the proposed locations of the Odoptu-S well pad and the PA-B platform.

Table 3.3 - Numbers, names, locations and depths of the proposed stations.

#	Station		Latitude	Longitude	Depth
Monitor Stations:					
1	Lunskoye	Лунское	51° 51' 45" N	143° 37' 27.3" E	50 m
2	OFA (Offshore Feeding area)	ГЗК (Глубоководная зона кормления)	52° 10' 18" N	143° 36' 1.8" E	~40 m
3	Orlan	Орлан	52° 21.6' N	143° 35.0' E	32 m
4	Arkutun-Dagi	Аркутун-Даги	52° 19' 9.6" N	143° 44' 4.6" E	~40 m
5	Piltun-S	Пильтун-Ю	52° 40' 51" N	143° 22' 34" E	10 m
6	Piltun	Пильтун	52° 49.3' N	143° 24.9' E	20 m
7	PA-B-10	ПА-Б-10	52° 53' 2.1" N	143° 20' 10.6" E	10 m
8	PA-B-20	ПА-Б-20	52° 54' 00" N	143° 23' 20.5" E	20 m
9	Odoptu-PA-B	Одопту-ПА-Б	53° 00' 00" N	143° 21' 18" E	20 m
10	Odoptu-S-10	Одопту-Ю-10	53° 03.7’ N	143° 18.3' E	10 m
11	Odoptu-S-20	Одопту-Ю-20	53° 03' 42" N	143° 19' 58" E	20 m
12	Odoptu-N-10	Одопту-С-10	53° 09.1' N	143° 17.4' E	10.5 m
13	Odoptu-N-20	Одопту-С-20	53° 09' 6" N	143° 18' 42' E	20 m
14	**Control**	**Контрольная**	**53° 25.95' N**	**143° 11.1' E**	**20 m**
Acoustic Stations:					
A1	#1 (Chayvo-1)	#1 (Чайво-1)	52° 27.8' N	143° 19.0' E	11 m
A2	#2 (Chayvo-2)	#2 (Чайво-2)	52° 25.9' N	143° 20.6' E	11 m
A3	#3 (Chayvo-3)	#3 (Чайво-3)	52° 26.8' N	143° 24.6' E	17 m
A4	#4 (Piltun-1)	#4 (Пильтун-1)	52° 43' 14.4" N	143° 22' 26.7" E	10 m
A5	#5 (Piltun-2)	#5 (Пильтун-2)	52° 43' 48" N	143° 25' 49" E	20 m
A6	#6 (Piltun-3)	#6 (Пильтун-3)	52° 49.3' N	143° 24.9' E	20 m
A7	#7 (PA-B-1)	#7 (ПА-Б-1)	52° 55' 54" N	143° 19' 39" E	10 m
A8	#8 (PA-B-2)	#8 (ПА-Б-2)	52° 55' 54" N	143° 21' 42.4" E	20 m
A9	#9 (BEH-Odoptu)	#9 (Одопту (Пов))	53° 12' 33.1" N	143° 15' 51" E	10 m
A10	#10 (BEH-north)	#10 (Пов-север)	53° 17' 52.4" N	143° 13' 25.4" E	10 m
A11	#11 (Chayvo-4)	#11 (Чайво-4)	52° 34' N	143° 23' E	~18 m

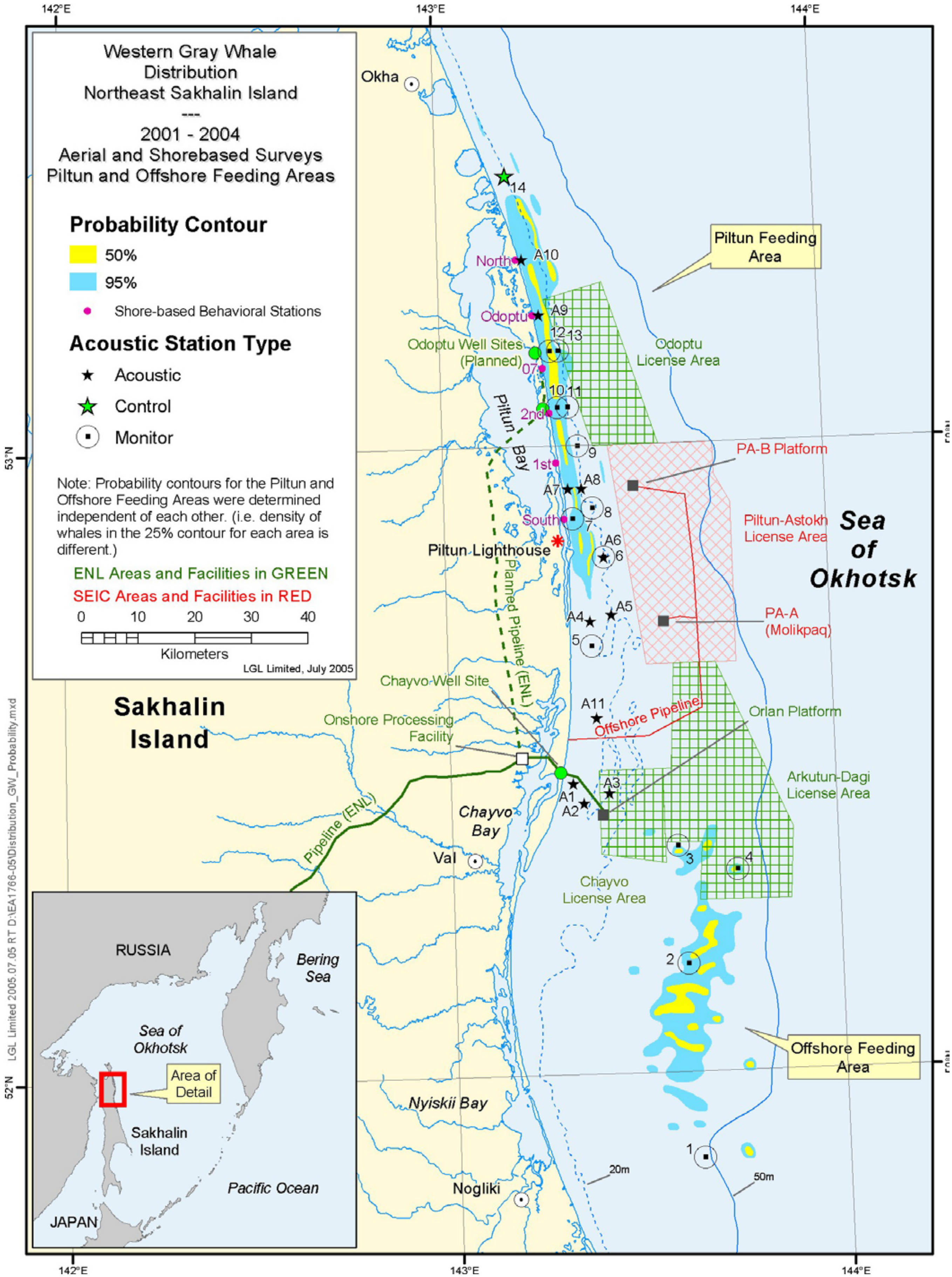

Figure 3.1 - Map showing the AUAR locations and cumulative probability contours showing the density distributions of western gray whales from the 2001 to 2004 aerial surveys, 2001 to 2004 scan stations and the 2004 vehicle-based surveys.

The control station location has remained the same since 2003[32]. This location has a similar hydrology and bathymetric character to the Piltun feeding area, is far enough away to serve as an acoustic control point, but close enough that operational support would not be difficult.

One new acoustic station was added in 2005 and was designated station A11, Stations A1 to A8 were not occupied in 2005. All the acoustic stations occupied in 2004 were used for TL experiments, most along the proposed pipeline routes from PA-B and Molikpaq.

The AUARs were deployed as shown in Table 3.1. This data represents acoustic data synchronously recorded over 180 km along the NE Sakhalin coast from the control station to the Lunskoye monitor station. Figures 3.2 and 3.3 show sonograms *G(f,t)* of acoustic measurements made by the AUARs at the Odoptu-S-20, Odoptu-N-20, Arkutun-Dagi and Lunskoye monitor stations. The full set of sonograms for the data is supplied on DVD and listed in Appendix A. The logarithmic scale on the frequency axis clearly shows the pseudo-noise signals below 16 Hz on Figure 3.3. This is flow noise caused by a tidal current with a velocity exceeding 3 m/s and recorded twice a day. The acoustic data for the infrasonic band should therefore be analyzed during slack tide periods when flow noise is absent (approximately 4 hours - Figure 3.3).

3.2 Anthropogenic acoustic studies

In addition to the monitoring of ambient noise, one of the goals of the 2005 program was to measure the acoustic signature of the 4-stroke outboard motor on the zodiac used by the Photo-ID team. The second goal was to determine the acoustic signatures of the *Academik Lavrent'ev and Academik Oparin*, the mother ships used to house the biology and acoustic teams.

[32] The control station was located on the 20 m bathymetry contour approximately 40 km north of the Odoptu North pad site.

3.3 Acoustic studies in conjunction with the behavioral stations

Figure 3.1 shows the location of the behavioral stations (marked with purple dots), as well as the acoustic monitor station locations. One of the goals of the 2005 program was to measure the acoustic levels at monitor stations synchronously with behavioral observations

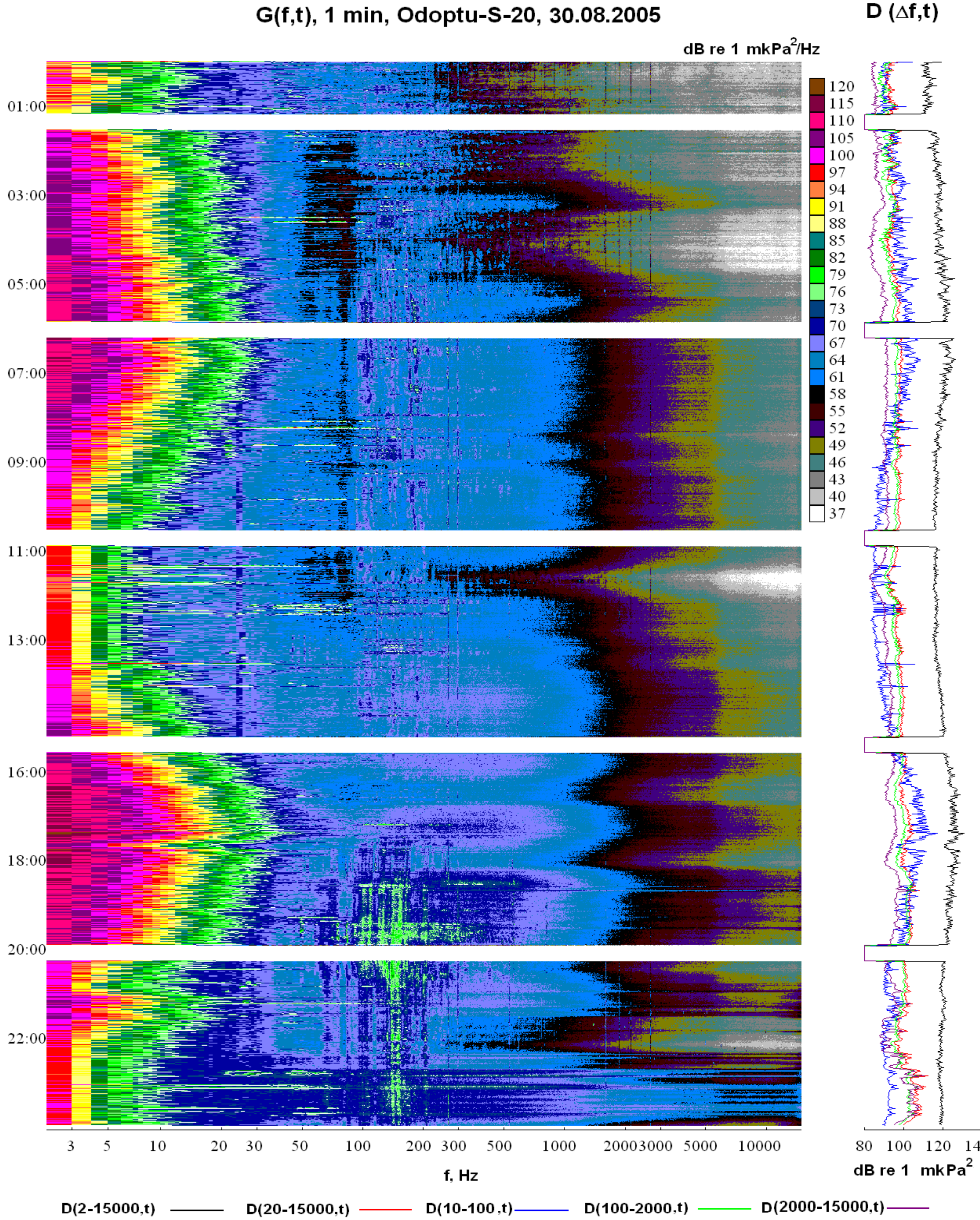

Figure 3.2 - Sonogram *G(f,t)* with plots of sound pressure level $D_{\Delta f}(t)$ of acoustic energy recorded at acoustic station Odoptu-S-20 [10] on 30th August 2005.

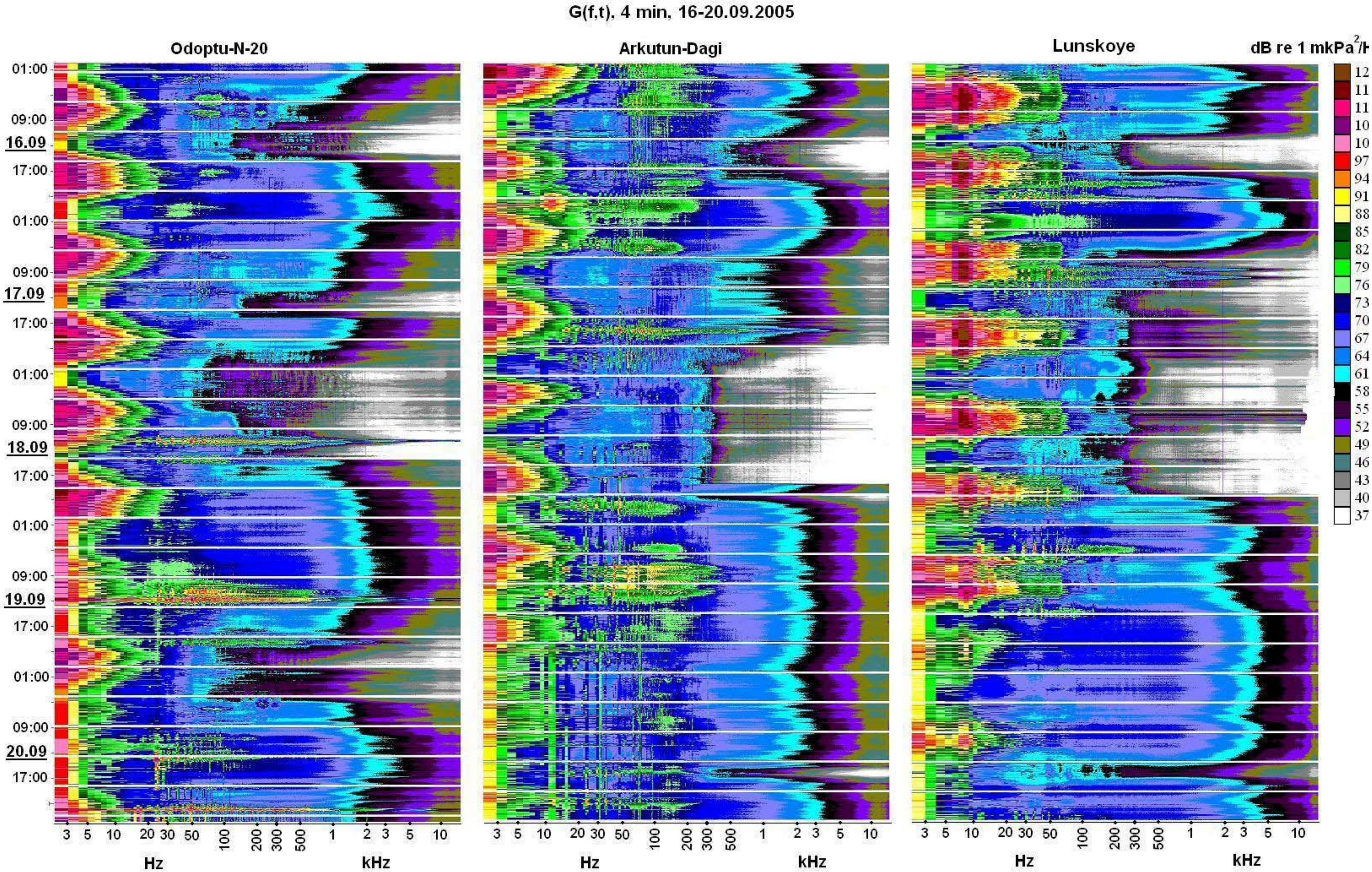

Figure 3.3 - Sonograms *G(f,t)* with plots of sound pressure level $D_{\Delta f}(t)$ of acoustic energy recorded at the Odoptu-N-20 [13], Arkutun-Dagi [4], and Lunskoye [1] monitor stations between 16 and 20 September 2005.

at the corresponding behavioral stations. The behavioral observations are listed in Table 3.4 with their corresponding acoustic observations if available. There were 17 days where synchronous behavioral and acoustic measurements were taken (27 stations)[33].

Table 3.4 – Relationship between behavioral observation times and acoustic recording at nearby stations[34].

Date	Behavioral Observations	Acoustic
12-Jul-2005	1st Station	#9
13-Jul-2005	South Station (11:00-15:00) / 1st Station	#7, #9
14-Jul-2005	2nd Station (08:00-16:30) / Station 07 (08:00-16:00)	#10, #12
15-Jul-2005	North Station (09:45-11:20) / Odoptu Station (09:45-12:20)	#A9, #A10
17-Jul-2005	1st Station	#9
18-Jul-2005	1st Station	#9
24-Jul-2005	North Station (11:30-5:30) / Odoptu Station (11:00-5:00)	#A9, #A10
26-Jul-2005	South Station (10:49-18:26) / 1st Station (09:10-19:02)	#7, #9
27-Jul-2005	2nd Station (09:30-18:30) / Station 07 (10:11-11:40; 15:20-18:00)	#10, #12
28-Jul-2005	2nd Station (10:50-18:10)	#10
29-Jul-2005	South Station (08:00-18:00) / 1st Station (7:40-18:50)	#7, #9
31-Jul-2005	South Station (08:00-9:00) / 1st Station (07:20-9:00)	#7, #9
6-Aug-2005	South Station (07:10-15:10) / 1st Station (07:07-15:10)	#7, #9
7-Aug-2005	2nd Station (07:40-18:00) / Station 07 (08:16-17:32)	#10, #12
8-Aug-2005	Odoptu Station (08:10-16:30) / North Station (08:47-16:48)	#A9, #A10
11-Aug-2005	South Station (11:35-18:20) / 1st Station (10:58-18:52)	#7, #9
18-Aug-2005	2nd Station (07:30-18:00) / Station 07 (07:30-17:30)	#10, #12
19-Aug-2005	Odoptu Station (09:00-16:30) / North Station (09:00-16:30)	#A9, #A10
20-Aug-2005	South Station (07:30-14:00) / 1st Station (07:30-14:00)	#7, #9
21-Aug-2005	2nd Station (07:30-14:00) / Station 07 (08:00-12:30)	#10, #12
23-Aug-2005	2nd Station (07:30-18:00) / Station 07 (08:20-18:30)	#10, #12
25-Aug-2005	1st Station (13:00-18:00)	#9
26-Aug-2005	South Station (11:20-16:40) / 1st Station (10:30-17:00)	#7, #9
31-Aug-2005	Odoptu Station (09:30-18:00) / North Station (10:00-17:15)	#A9, #A10
1-Sep-2005	2nd Station (08:30-17:30) / Station 07 (09:30-17:00)	#10, #12

For each of these days broad band sound pressure levels were estimated in 1-minute windows and energy levels were estimated in 10-minute windows (bandwidth 10 Hz to 15 kHz).

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[33] At the beginning of the field season two AUARs making sound measurements near two northern behavioral stations (stations A9 and Odoptu-N-10) were lost (presumed stolen). This limited the acoustic teams' ability to conduct monitoring studies near the northern behavioral stations.

3.4 Transmission Loss (TL) Experiments

A key component of the 2005 acoustic monitoring program was detailed Transmission Loss (TL) studies conducted from proposed facilities and pipeline routes to the western gray whale feeding areas[35]. This would allow ENL and SEIC to more effectively estimate the acoustic impact of construction activities at Molikpaq, PA-B, Orlan, and future facilities. These TL studies will be used to analyze any potential impacts from offshore construction and to design more effective mitigation measures if deemed necessary. The methodology for these TL studies is described in more detail in volume 2 of this report [Borisov et. al, 2006].

3.4.1 TL experiments acquired in 2005

A total of two TL profiles and six point-to-point measurements were acquired in 2005. One TL profile and six TL point-to-point measurements were acquired from the PA-B platform. TLP-4 was a 85 km profile from the PA-B platform to the Orlan and OFA stations at the northern edge and inside the offshore feeding area. The twelve source locations on this profile and associated hydrology were acquired from August 28-30 and 14 September 2005[36]. The six TL point-to-point measurements and associated hydrology were recorded from the PA-B platform to:

TLP-8 Piltun monitor station (#6) on 30 August 2005.
TLP-9 Acoustic stations #A7 and #A8 on 30 August 2005.
TLP-10 Odoptu-PA-B monitor station (#9) on 21 August 2005.
TLP-11 Odoptu-S-10 monitor station (#10) on 21 August 2005.
TLP-12 Odoptu-N-10 monitor station (#12) on 21 August 2005.
TLP-13 PA-B-20 (#8) and PA-B-10 (#7) monitor stations on 21 August 2005.
.

One TL profile was acquired from the Odoptu-N well pad. This TL profile (TLP-15) was 9.5 km long and extended from source locations seaward of the Odoptu-N-20 station to the Odoptu-N-20 station (#13) and Odoptu-N-10 station (#12) at the eastern edge and inside

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[34] For behavioral stations with a yellow background synchronous acoustic measurements were not available.
[35] The *TL(f,r)* was estimated as a function of frequency and range for the TL profiles. The *TL(f)* was estimated as a function of frequency for the TL points
[36] TLP-4L (85 km from OFA station), -4K (53 km), -4J (37 km), -4I (29 km), -4H (25 km), -4G (23), -4F (22 km, 1 km from Orlan station), -4E (16 km), -4D (8 km), -4C (4 km), -4B (2 km), -4A (1 km).

the Piltun feeding area. The seven source locations on this profile and associated hydrology were acquired on 21 September 2005[37].

To conduct the TL measurements, AUARs were deployed at the specified monitoring stations for each profile. Tonal and FM broadband acoustic signals were then transmitted from the source locations for each profile. At the beginning or on completion of the transmission, hydrologic measurements were taken from the *Academik Oparin* with the sonde. The profile was then sailed by the *Academik Oparin* with bathymetric and hydrologic data measurements being taken along the profile from the TL source locations to the recording station locations.

3.5 Bathymetric and hydrologic studies

F.F. Khrapchenkov (Храпченков Ф.Ф.), an oceanographer from the Oceanology department of POI was present on the *Academik Oparin,* and planned and acquired the bathymetry and hydrology data for the 2005 field season. He worked with the acoustics department of POI to process the data using the methods, algorithms and hydrological model developed in 2004. Volume 2 of the report [Borisov et. al., 2006] describes how the bathymetric and hydrologic data acquired on the NE Sakhalin shelf was processed to create a bathymetric map that was used for research on the temporal-spatial variations of hydrology in the study area. This data will be used to build acoustic models which will be used to model and predict the acoustic field generated by known sources and to analyze the impact of bathymetry and hydrology on the propagation of these fields. The data will also be used to investigate the impact of temperature and salinity variations on benthos distribution and development. The hydrology and tide-corrected bathymetry data for 2004 and 2005 is available on DVDs in this report.

3.5.1 Bathymetry map

Figure 1.4 shows the profiles along which the bathymetric data was acquired using the echo sounder on the *Academik Oparin*. The bathymetry data acquired in 2004 and 2005 were

[37] TLP-15G (9.5 km from the Odoptu-N-10 station), -15F (5.5 km), -15E (3.5 km), -15D (2.5 km), -15C (1.5 km, Odoptu-N-20 station), -15B (1 km), -15A (0.5 km).

combined to build the 3D map in Figure 3.4[38]. A notable feature of the bathymetry is the NE orientation of the bathymetric channels in the area; this will be discussed further in the third volume of this report [Kruglov et. al, 2006].

[38] There was a 4.5 m depth correction from the echo sounder transducer to the sea surface; it was also tide corrected.

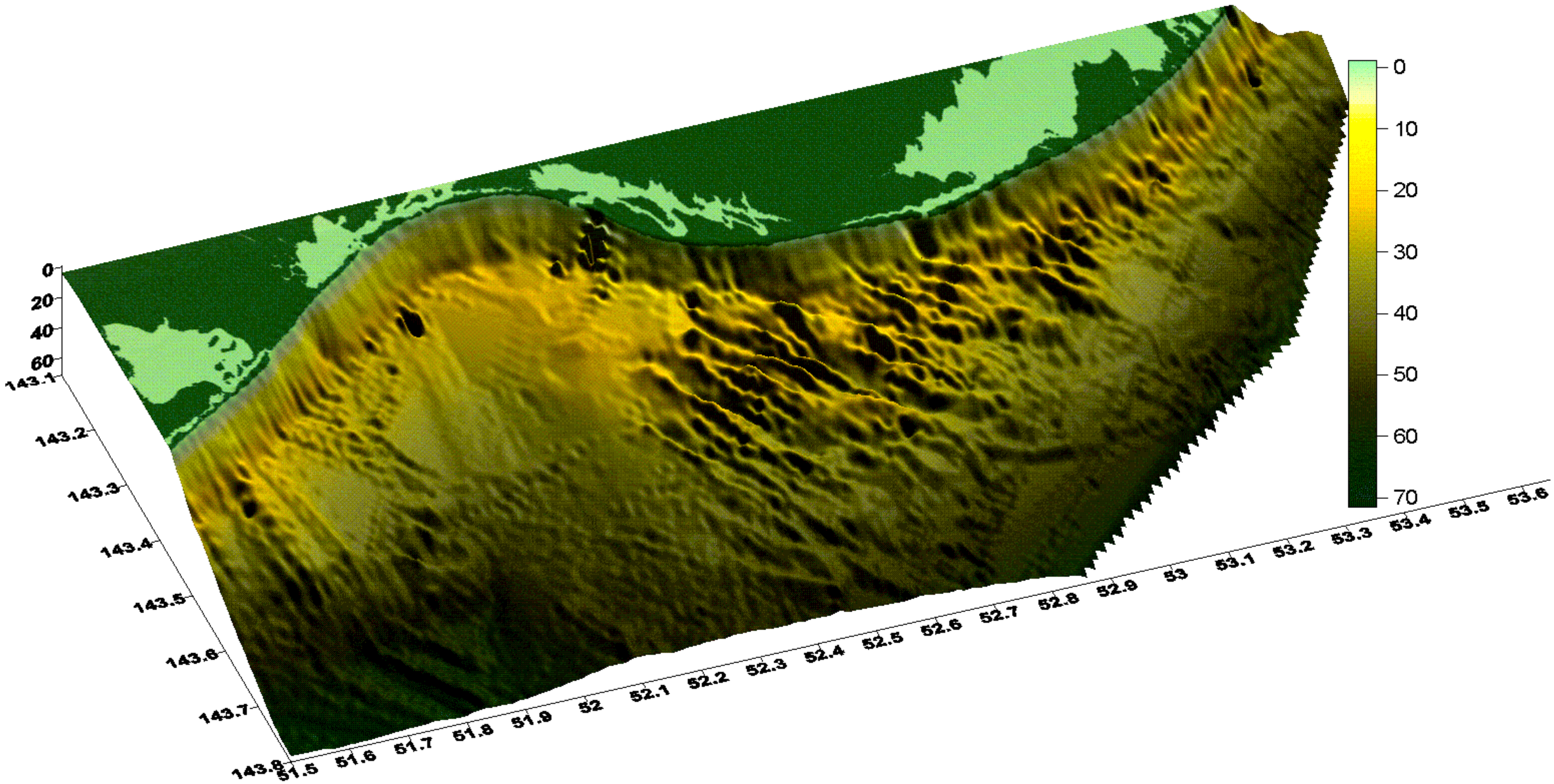

Figure 3.4 - 3D bathymetric map of the study area generated from 2004 and 2005 data (tide corrected).

4 Acknowledgements

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6 Bibliography

1. Bondar` L.F., Gritsenko A.V., Zakharov V.A., Kovzel` D.G. and Rutenko A.N. (1993). Digital radio telemetry system for the collection and results of its application in studies of sea reverberation characteristics // Acoustical Physics, Vol.39, no.2, pp.118-122.
2. Borisov S.V., Gritsenko A.V., Jenkerson M.R., Rutenko A.N., and Hodzevich A.V. (2002) Evaluating and Monitoring Acoustic Transmission from the Odoptu 3D seismic Survey 5 August - 9 September, 2001; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd.

   Борисов С.В., Гриценко А.В., Дженкерсон М.Р., Рутенко А.Н., Ходзевич А.В. (2002). Оценка и наблюдение распространения акустических сигналов, при проведении трехмерной сейсморазведки в районе Одопту с 5 августа по 9 сентября 2001 г. на о.Сахалин, Россия // Отчет Тихоокеанского океанологического института ДВО РАН для компании Эксон Нефтегаз Лимитед.
3. Borisov S.V., Gritsenko A.V., Rutenko A.N., and Hodzevich A.V. (2003) Results of Acoustic Studies Within and Adjacent to the Piltun-Astokh License Area 1-6 August, 2001 and 17-24 September, 2001; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

   Борисов С.В., Гриценко А.В., Рутенко А.Н., Ходзевич А.В. (2003). Результаты акустических исследований, проведенных с 1 по 16 августа 2001 г. и с 17 по 24 сентября 2001 г. в акватории Пильтунско-астохской лицензионной зоны, а также прилегающей к ней акватории на о.Сахалин, Россия / Отчет Тихоокеанского океанологического института ДВО РАН для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компани.
4. Borisov S.V., Gritsenko A.V., Kruglov M.V., Korotchenko R.A., and Rutenko A.N. (2003) Results of Acoustic Studies between Molikpaq and Piltun and Near Chayvo Bay, 12 September to 23 September, 2002; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

   Борисов С.В., Гриценко А.В., Круглов М.В., Коротченко Р.А., Рутенко А.Н. (2003). Результаты акустических исследований, проведенных с 12 по 23 сентября 2002 г. на акваториях между платформой Моликпак и заливом Пильтун, и прилегающей к заливу Чайво, на о.Сахалин, Россия / Отчет Тихоокеанского океанологического института ДВО РАН, г. Владивосток, для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компании .

5. Borisov S.V., Gritsenko A.V., and Rutenko A.N. (2004) Acoustic Studies on the North East Sakhalin Shelf, Volume 1: Equipment, Methodology and Data; 15 August to 20 September, 2003; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

   Борисов С.В., Гриценко А.В., Рутенко А.Н. (2004). Результаты акустических исследований, проведенных с 15 августа по 20 сентября 2003 г. на северо-восточном шельфе о. Сахалин, Россия. Том 1: «Оборудование, методика и данные» / Отчет Тихоокеанского океанологического института ДВО РАН, г. Владивосток, для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компании.

6. Borisov S.V., Gritsenko A.V., Dmitrieva A.V., Karnauhov A.A., Kruglov M.V. and Rutenko A.N. (2005) Acoustic Studies on the North East Sakhalin Shelf, Volume 1: Equipment, Methodology and Data; 30 July to 7 October, 2004; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

   Борисов С.В., Гриценко А.В., Дмитриева А.В., Карнаухов А.А., Круглов М.В., Рутенко А.Н. (2005). Результаты гидро-акустических исследований, проведенных с 30 июля по 07 октября 2004 г. на северо-восточном шельфе о. Сахалин, Россия. Том 1: «Оборудование, методика и данные» / Отчет Тихоокеанского океанологического института ДВО РАН, г. Владивосток, для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компании.

7. Borisov S.V., Gritsenko A.V., Korotchenko R.A., Kovzel D.G., Kruglov M.V., Rutenko A.N. and Solovyev A.A. (2006) Acoustic Studies on the North East Sakhalin Shelf, Volume 2: Equipment, Calibration and Methodology; 7 July to 7 October, 2005; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

   Борисов С.В., Гриценко А.В., Коротченко Р.А., Ковзель Д.Г., Круглов М.В., Рутенко А.Н., Соловьев А.А. (2006). Гидроакустические есследования, проведенные с 07 июля по 07 октября 2005 г. на северо-восточно шельфе о,Сахалин, Россия. Том 2:

«Обороудование, калибровка и методика» / Отчет Тихоокеанского океанологического института ДВО РАН для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компани.

8. Borland Paradox for Windows, version 1.0, User's Guide. USA: Borland International, Inc., 1993. 640 p.
9. Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas. L. (2001). Introduction to Distance Sampling. Oxford University Press. New York.
10. Fadeev V.I. (2005). Benthos and food supply studies in feeding areas of the Okhotsk-Korean gray whale population. // Institute of Marine Biology (FEB RAS), Vladivostok, Russia. Final report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co. 150 p.
Фадеев В.И. (2005) Исследования бентоса и кормовой базы в районах питания охотско-корейской популяции серого кита. // Заключительный отчет Института биологии моря ДВО РАН для компаний Сахалин Энерджи и Эксон Нефтегаз. Владивосток. 150 с.
11. Hooge P.N. and Eichenlaub B. (1997). Animal movement extension to arcview. Ver. 1.1. Alaska Science Center - Biological Science Office // U.S. Geological Survey, Anchorage, AK, USA.
12. Karnauhov A.A., Kruglov M.V. and Rutenko A.N. (2005) Acoustic Studies on the North East Sakhalin Shelf, Volume 2: Analysis, Conclusions and Recommendations; 30 July to 7 October, 2004; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.
Карнаухов А.А., Круглов М.В., Рутенко А.Н. (2005). Результаты гидроакустических исследований, проведенных с 30 по 07 октября 2004 г. на северо-восточном шельфе о. Сахалин,Россия. Том 2: «Оборудование методика и данные» / Отчет Тихоокеанского океанологического института ДВО РАН, г. Владивосток, для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компании.
13. Kruglov M.V., A.N. Rutenko, and F.F. Khrapchenkov. (2006) Acoustic Studies on the North East Sakhalin Shelf, Volume 3: Analysis, Conclusions and Recommendations; 7 July to 7 October, 2005; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

Круглов М.В., Рутенко А.Н., Храпченков Ф.Ф. (2006). Гидроакустические исследования, проведенные с 07 июля по 07 октября 2005 г. на северо-восточном шельфе о.Сахалин. Том 3: «Анализ, выводы, рекомендации». / Отчет Тихоокеанского океанологического института ДВО РАН для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компани.

14. Kruglov M.V., and Rutenko A.N. (2003) Transmission Loss Studies on the North east Sakhalin Shelf 2001 and 2002; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.
    Круглов М.В., Рутенко А.Н. (2003). Исследования потерь акустических шумов, проведенные в 2001, 2002 гг. На северо-восточном шельфе о.Сахалин, Россия / Отчет Тихоокеанского океанологического института ДВО РАН для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компани.
15. Kruglov M.V., and Rutenko A.N. (2004) Acoustic Studies on the North East Sakhalin Shelf, Volume 2: Analysis, Conclusions and Recommendations; 15 August to 20 September, 2003; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.
    Круглов М.В., Рутенко А.Н. (2004) Результаты акустических исследований, проведенных с 15 по 20 сентября 2003 г. на северо-восточном шельфе о.Сахалин, Россия. Том 2: «Анализ, выводы и рекомендации» / Отчет Тихоокеанского океанологического института ДВО РАН для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компани.
16. Powell R. A. (2000). Animal home ranges and territories and home range estimators // Research techniques in animal ecology: controversies and consequences. Edited by Boitani L. and Fuller T.K. // Columbia University Press, New York. pp. 65-110.
17. Richardson W.J., Greene C.R., Malme C.I. and Thomson D.H. (1995). Marine mammals and noise. Academic Press Limited. 576 p.
18. Rutenko A.N. (2006) Acoustic Studies on the North East Sakhalin Shelf, Volume 1: Objectives and Data; 7 July to 7 October, 2005; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.
    Рутенко А.Н. (2006) Гидроакустические исследования, проведенные с 07 июля по 07 октября 2005 г. на северо-восточном шельфе о.Сахалин, Россия. Том 1: «Цели

и полученные данные». / Отчет Тихоокеанского океанологического института ДВО РАН для компаний Эксон Нефтегаз Лимитед и Сахалин Энерджи Инвестмент Компани.

19. SEIC (2005a). Actions criteria definition - 1000-S-90-04-P-0048-00-03 – Marine Mammal Protection Plan.
СЭИК (2005) План защиты морских млекопитающих - 1000-S-90-04-P-0048-00-03.
20. SEIC (2005b). PA-B CGBS install noise monitoring - 0000-S-90-04-T-0240-00-01 - Noise Monitoring of Piltun CGBS Installation.
21. Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H. and Bishop, J.R.B. (2004). Distance 4.2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/
22. Worton B.J. (1989). Kernel methods for estimating the utility distribution in home-range studies // Ecology, Vol.70, pp. 164-168.

Appendix A - Daily Sonograms for AUAR Data.

	Station																
July	Lunskoye	OFA	Orlan	Arkutun-Dagi	Piltun-S	Piltun	PA-B-10	PA-B-20	Odoptu-PA-B	Odoptu-S-10	Odoptu-S-20	Odoptu-N-10	Odoptu-N-20	Control	BEH-Odoptu	BEH-North	Chayvo-3
#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A9	A10	A11
6																	
7																	
8																	
9			✓														✓
10			✓						✓			✓					✓
11			✓		✓				✓	✓		✓				✓	✓
12			✓		✓				✓	✓		✓				✓	✓
13			✓		✓	✓	✓		✓	✓		✓				✓	✓
14			✓		✓	✓	✓		✓	✓		✓				✓	✓
15			✓		✓	✓	✓		✓	✓		✓				✓	✓
16			✓		✓	✓	✓		✓	✓		✓				✓	✓
17			✓		✓	✓	✓		✓	✓		✓				✓	✓
18			✓		✓	✓	✓		✓	✓		✓				✓	✓
19			✓		✓	✓	✓		✓	✓		✓				✓	✓
20			✓		✓	✓	✓		✓	✓		✓				✓	✓
21			✓		✓	✓	✓		✓	✓		✓				✓	✓
22			✓		✓	✓	✓		✓	✓		✓				✓	✓
23			✓		✓	✓	✓		✓	✓		✓				✓	✓
24			✓		✓	✓	✓	✓	✓	✓		✓				✓	✓
25			✓		✓	✓	✓	✓	✓	✓		✓				✓	✓
26			✓		✓	✓	✓	✓	✓	✓		✓				✓	✓
27			✓		✓	✓	✓	✓	✓	✓		✓				✓	✓
28			✓		✓	✓	✓	✓	✓							✓	✓
29			✓		✓	✓	✓	✓	✓			✓				✓	✓
30			✓		✓	✓	✓	✓	✓		✓	✓				✓	✓
31			✓		✓	✓	✓	✓	✓		✓	✓				✓	✓

	Station																
August	**Lunskoye**	**OFA**	**Orlan**	**Arkutun-Dagi**	**Piltun-S**	**Piltun**	**PA-B-10**	**PA-B-20**	**Odoptu-PA-B**	**Odoptu-S-10**	**Odoptu-S-20**	**Odoptu-N-10**	**Odoptu-N-20**	**Control**	**BEH-Odoptu**	**BEH-North**	**Chayvo-3**
#	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**A9**	**A10**	**A11**
1			✓		✓	✓	✓	✓	✓		✓	✓				✓	✓
2			✓		✓	✓	✓	✓	✓		✓	✓				✓	✓
3		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
4		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
5		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
6		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
7		✓		✓	✓	✓	✓	✓	✓		✓	✓				✓	
8		✓		✓	✓	✓	✓	✓	✓		✓	✓				✓	
9		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
10		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
11		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
12		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓
13		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					✓
14		✓	✓	✓	✓	✓		✓	✓		✓						✓
15		✓	✓	✓	✓	✓		✓	✓		✓						✓
16		✓	✓	✓	✓	✓	✓	✓	✓		✓						✓
17		✓	✓	✓	✓	✓	✓	✓	✓								✓
18		✓	✓	✓	✓	✓	✓	✓	✓								✓
19		✓	✓	✓	✓	✓	✓	✓	✓								✓
20			✓	✓	✓	✓	✓	✓	✓				✓				✓
21			✓	✓	✓	✓	✓	✓	✓				✓				✓
22			✓	✓	✓	✓	✓	✓	✓				✓				✓
23			✓	✓	✓	✓	✓	✓			✓		✓				✓
24			✓	✓	✓	✓	✓	✓	✓		✓		✓				✓
25			✓	✓	✓	✓	✓	✓	✓		✓		✓				✓
26			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓
27			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓
28			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓
29			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓

30			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓
31			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓

	Station																
September	Lunskoye	OFA	Orlan	Arkutun-Dagi	Piltun-S	Piltun	PA-B-10	PA-B-20	Odoptu-PA-B	Odoptu-S-10	Odoptu-S-20	Odoptu-N-10	Odoptu-N-20	Control	BEH-Odoptu	BEH-North	Chayvo-3
#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A9	A10	A11
1			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓
2			✓	✓	✓	✓		✓	✓		✓		✓	✓			✓
3			✓	✓	✓	✓		✓	✓		✓		✓	✓			✓
4			✓	✓	✓	✓		✓	✓		✓		✓	✓			✓
5			✓	✓	✓	✓		✓	✓		✓		✓	✓			✓
6		✓	✓		✓	✓			✓		✓		✓	✓			✓
7		✓	✓			✓			✓		✓		✓	✓			✓
8		✓	✓										✓	✓			✓
9		✓	✓										✓	✓			✓
10		✓	✓		✓	✓		✓	✓				✓	✓			✓
11		✓	✓		✓	✓		✓	✓				✓	✓			✓
12		✓	✓		✓	✓		✓	✓				✓	✓			✓
13		✓	✓		✓	✓		✓	✓				✓	✓			✓
14		✓	✓		✓	✓		✓	✓				✓	✓			✓
15	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓			✓
16	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓			✓
17	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓			✓
18	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓			✓
19	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓			✓
20	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓			✓
21	✓	✓	✓	✓	✓	✓		✓	✓				✓				✓
22	✓	✓	✓	✓	✓	✓		✓	✓				✓				✓
23	✓	✓	✓	✓	✓	✓		✓	✓								✓
24	✓		✓	✓	✓	✓		✓	✓								✓
25	✓		✓	✓	✓	✓		✓	✓								
26	✓		✓	✓	✓	✓		✓	✓								
27	✓			✓													
28	✓			✓													
29	✓			✓													
30	✓			✓													

Appendix B – Monitoring Data Recorded.

Station	#	July														
		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Piltun-S	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Piltun	6			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PA-B-20	8			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Odoptu-PA-B	9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Orlan	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chayvo-4	A11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Station	#	July						August								
		26	27	28	29	30	31	1	2	3	4	5	6	7	8	9
Piltun-S	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Piltun	6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PA-B-20	8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Odoptu-PA-B	9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Orlan	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Chayvo-4	A11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
ARB-1			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
ARB-2		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ARB-3			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ARB-4															✓	✓

Station	#	August														
		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Piltun-S	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Piltun	6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PA-B-20	8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Odoptu-PA-B	9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Orlan	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chayvo-4	A11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ARB-2		✓	✓	✓								✓	✓	✓	✓	✓
ARB-3		✓	✓	✓												

ARB-4		✓	✓	✓													

		August							September							
Station	**#**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Piltun-S	**5**	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	
Piltun	**6**	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{green}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	
PA-B-20	**8**	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$			
Odoptu-PA-B	**9**	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	$\color{blue}\checkmark$	
Orlan	**3**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
Chayvo-4	**A11**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
ARB-2		$\color{red}\checkmark$		$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	$\color{red}\checkmark$	

		September														
Station	**#**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Piltun-S	**5**		$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
Piltun	**6**		$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
PA-B-20	**8**		$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
Odoptu-PA-B	**9**		$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
Orlan	**3**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
Chayvo-4	**A11**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$
ARB-2					$\color{red}\checkmark$											

		September						
Station	**#**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Piltun-S	**5**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$				
Piltun	**6**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$				
PA-B-20	**8**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$				
Odoptu-PA-B	**9**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$				
Orlan	**3**	$\color{green}\checkmark$	$\color{green}\checkmark$	$\color{green}\checkmark$				
Chayvo-4	**A11**	$\color{green}\checkmark$						

$\color{red}\checkmark$	**Radio-telemetry data acquired only**
$\color{blue}\checkmark$	**Radio-telemetry data and AUAR disk data acquired**
$\color{green}\checkmark$	**AUAR disk data acquired only**

Appendix C – Estimation of Western Gray Whale Core Areas[39].

In 2004, the core areas for gray whales on the NE Sakhalin shelf were determined using whale densities estimated from the 2003 and 2004 aerial survey data taking the survey effort into account[40].

In these analyses, cumulative probability contours are used to visualize areas with the greatest likelihood of encountering gray whales, and examine shifts in the 'centers of activity' of gray whales over time[41]. Probability contours of 50% and 95% generated to visualize the distribution of gray whales. The 50% contour represents the area within which 50% of the whales sighted are expected to be found. In 2003 the probability contours were estimated using a conventional kernel density method[42]. This kernel density method employed a square-gridding process, which is robust for small sample sizes unless the variances of the north-south and east-west components of the distribution are very different, which is the case for the Piltun feeding area.

For the Piltun feeding area the distribution of whale sightings is oriented parallel to the coast with significantly greater variance in the along-shore direction than in the perpendicular-to-shore direction. For this reason, in 2004, a grid was constructed for the Piltun feeding area that was oriented along-shore and with an along-shore grid cell dimension greater than the perpendicular-to-shore dimension, (i.e. each cell was 4 km by 0.5 km). Density was then computed for each cell as the number of whales divided by the cumulative area surveyed within the cell. The same methodology was employed for the offshore feeding area except that, in this case, the conventional assumptions about distribution were satisfied and a regular grid of 1 km by 1 km cells was employed.

[39] This section is based on work performed by LGL Ltd (Robin Tamasi, Peter Wainwright, Judy Muir, Sergei Yazvenko, Sonya Meier, and Steve Johnson).
[40] Density is the number of whales per unit area, multiple surveys over a grid cell can result in larger densities within that cell if the survey effort is not taken into account.
[41] Probability contours were computed independently for the Piltun and offshore feeding areas.
[42] The kernel density contours were mapped using the ArcView© 3.1 extension Animal Movement 2.04 [Hooge et. al., 1997]. Kernel density contours are an estimator that assesses an animal's probability of occurrence at each point in space using a utilization distribution. It is a non-parametric estimator that has no underlying assumptions of how animals use space.

There was significant variation between the 2003 and 2004 estimates of the western gray whale core areas. In 2005 this analysis was updated using all available systematic survey data. These included data from the 2001 to 2004 aerial surveys, 2001 to 2004 scan stations, and the 2004 vehicle-based surveys.

Because there are significant differences in these survey methods, it is necessary to calibrate the observations or bring them to a common standard, before performing density calculations. This was achieved by using Distance analysis [Buckland et al. 2001] to correct for differences in the ability to detect whales, and by applying an additional correction for the probability that whales were underwater during the period of the survey. Details of the density calculations are as follows:

- Distance 4.2 software [Thomas et al., 2004] was used to compute sightability functions and Effective Survey Width (ESW) for the aerial survey data sets, and to compute a sightability function and Effective Detection Radius (EDR) for the vehicle-based surveys. For the vehicle-based surveys, station elevation was used as a covariate in the sightability analysis. For the scan surveys, station elevation, sea state and visibility were used as covariates in the sightability analysis.
- Two grids were produced: one for the Piltun feeding area and one for the offshore feeding area.
- The Piltun feeding area grid consisted of a grid of cells conforming to the coastline with cell dimensions of 4-km alongshore by ½-km perpendicular to shore with an average area of 2.03 km^2 (standard deviation = 0.02 km^2).
- The offshore feeding area grid consisted of a grid of cells conforming to the coastline with cell dimensions of 1-km alongshore by 1½-km perpendicular to shore with an average area of 1.49 km^2 (standard deviation = 0.02 km^2).
- ArcView geographic information system (GIS) software was used to construct buffers around each aerial survey transect(s) flown to represent the surveyed swathes (1 km for surveys at 300 m altitude and 1½ km for surveys at 500 m altitude). For shore based stations, buffers with radius equal to the Effective Detection Radius were constructed to represent the area surveyed by each station.
- These resulting buffers were then overlaid on the grid and the area of the cell within the buffer ($Area_i$) was computed. Where less than 50% of the cell area fell within the buffer it was considered inappropriate to estimate density for that cell.
- The number of whales within the buffer within each grid cell was then computed. First, the number of whales for each sighting was inflated using the appropriate sightability function to compensate for the lower probability of sighting whales at greater distances from the observer.
- Next, the inflated whale sightings were overlaid on the result of the grid/buffer overlay. This resulted in an estimate of the number of whales within the surveyed area of each

grid cell (*Count$_i$*). Finally, density was estimated for each grid cell as the number of whales per unit area adjusted by the probability that whales were underwater during the period of the survey (*g(0)*):

$$Density = \frac{\left[\dfrac{Count_i}{Area_i}\right]}{g(0)}$$

g(0) was estimated based on the 2001-2003 behavioral data, the field of view and the speed of the aircraft or rate of scanning.

- Density estimates from individual surveys were then averaged to compute an overall average density for each grid cell.

Kernel Probability densities were then computed for the Piltun and offshore feeding areas separately as follows:

- A total *population* for each feeding area grid was computed by summing the densities for all cells.
- The cell data were then sorted by density in ascending order.
- *Cumulative densities* were then computed for each cell equal to the sum of the densities of all cells where the gray whale density was less than the density for that cell.
- Kernel probability densities were then assigned for each cell equal to the *cumulative density* divided by the *population* expressed as a percentage.
- For the offshore area, 50% and 95% probability contours (where the grid *x* and *y* dimensions are approximately equal) were computed using ArcView Spatial Analyst software and an inverse distance method with a distance threshold of 3-km. Exclusion areas (donuts) inside the probability contours were then eliminated and the resulting contours were smoothed using a spline method.
- For the Piltun feeding area (where the grid *x* and *y* dimensions are substantially different) polygons were created by selecting all grid cells of 50% and 95% probability classes. Gaps in the polygons of one grid cell width or length were filled and the resulting polygons were then smoothed using a spline method to produce the final 50% and 95% probability contours.

There are issues with using standard Distance methodology (Buckland et al. 2001) to develop sightability functions for the shore-based surveys. In particular, the assumption of uniform distribution of distances to whales from the survey point is violated, as whale density is correlated with water depth. This confounds sightability functions, as the variability in detections with distance may be due to effects of both changing density and sightability. The effect of this non-uniform distribution on the analysis is likely twofold:

(i) The Effective Detection Radius (EDR) is likely underestimated; and

(ii) The density of whales approximately 2½ to 3-km from shore is likely overestimated because decreasing whale density with depth is instead presumed to be decreasing sightability with distance from shore.