Marine Mammals Studies Offshore North East Sakhalin

(Final Report)

Science head of marine
mammal program
E. I. Sobolevsky, Ph.D.
Institute of marine biology
Far East Branch of Russian Academy of Sciences

List of main performers

1. E.I. Sobolevsky – performance of Introduction, The Study Subject and Methods (jointly with A.N. Rutenko), Sections 2, 2.1, 2.2, 3, Discussion, Conclusion.

2. A.N. Rutenko – performance of acoustic sections of report and designed program of acoustic studies and sonobuoys.

3. S.V. Borisov – design and exploitation of emissive complex.

4. A.V. Gritsenko – design of software support for input and analysis of information.

5. D.V. Antonenko and N.P. Ruznikova – performance of office studies.

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Introduction

The life and behavior of marine mammals of the northeastern sector of the Sakhalin continental shelf has been studied by many researchers. This information was mainly gathered during spring time aerial census of seals and observations from research vessels in the summer and autumn seasons (Fedoseyev, 1970; Fedoseyev et al., 1970; Kosygin et al., 1986; Sobolevsky, 1983, 1988, etc.). Lately, the efforts of Russian and foreign scientists were aimed at the study of gray whale distribution and population estimate (Berzin et al., 1986; Berzin, Vladimirov, 1996; Vladimirov, 1994; Blokhin, 1996; Brownell et al., 1997; Sobolevsky, 1998; Wursig et al., 1998; Weller et al., 1999). The research work and field studies were instigated by oil well drilling and platform construction operations offshore Sakhalin. There has been concern that offshore industrial activity has the potential to cause environmental damage, so a program of investigations has been developed to further characterize the environment in the Piltun-Astokhskoye area. Sakhalin Energy and Exxon Neftegaz oil companies have financed most of the recent studies of wildlife in the area of their operations. In particular, a study of marine mammals in the Piltun-Astokhskoye and Chaivo License Areas was carried out under the HAAER in 1999. A team of scientists took a census of marine mammals, studied their spatial distribution, population, main summer and autumn habitats and local migration routes. Besides these studies, an acoustic study to measure natural and industrial noise levels was carried out in the Piltun-Astokhskoye License Area (drilling, vessel, support operations, etc.).

The main purpose of the acoustic works which have been carried out in 1999 on northeast shelf of Sakhalin, in area traditional summer-autumn feeding of gray whales, there was research of levels of natural and industrial acoustic noise. The technical project did not stipulate frequency range, in which the measurements should be made, therefore we worked with frequencies from 5 Hz up to 7.5 kHz. The measurements were conducted under summer and autumn hydrological conditions of shelf of Okhotsk sea in coastal zone - area of concentration of gray whales, and in rather deep-water part of shelf – close to oil-extracting complex "Moliqpak" (see fig. 8). It was known, that the main sources of industrial acoustic noise on the given water area are the mechanisms from platform " Moliqpak ", "Sakhalinskaya" and tanker "Okha", and also noise generated by supplying vessels: «Smit Sibu», «Agat», «Rubin», «Smit Sakhalin», «Aquanaut», «Neftegas 16», «Neftegas 70», «Miss Sybil», «Anabar». In area of concentration of whales, source of short-term and high-frequency noise are engines of motor boats such as "Zodiacs", which use, for example, group of gray whale observers from Piltun lighthouse.

By the technical project was not stipulated research of acoustic signals generated by gray whales and other marine animals, but during long background measurements at platform "Moliqpak", and in coastal zone we repeatedly registered hydroacoustic signals of gray whales and killer whales. In section 6.4 the time realizations of such signals are presented.

1. The Study Subject and Methods

The study of sea mammals in the northeastern sector of the Sakhalin Island continental shelf was carried out in two phases. The first phase included the aerial census of whales and seals from a helicopter, from motor boats and from the shore.

The second phase included an acoustic study in the Piltun-Astokhskoye License Area.

I formed a task group, wrote bills for the pieces of equipment which we lacked, signed contracts for the lease of a helicopter and boats. We obtained relevant permits from Sakhalinrybvod, Goskomekologia and the frontier guards to carry out the studies. Copies of the permits were submitted to Sakhalin Energy we managed to deliver main pieces of equipment to the Piltun base only on July 6 by two helicopters.

We had the following equipment for the performance of out task:

“Zodiac” motor boats – 2

“Yamaha” boat motors –2

Power generators – 2

Sonobuoys – 8

Unitary wide-range transmitter – 1

“Burun-96” self-contained radio sounder - 1

«Pentium-PRO» computer – 1

FX-1000 Printer – 1

BACK-UPS PRO 1000 – 1

CD-Writer Plus 8100 – 1

A tape recorder 7005 – 1

U7-6 amplifier – 1

Б5-48 – 1 DC power unit

TEC42 - 2 power unit

GPS-12 – 1 portable satellite navigator

AX-400 «Standard» – 3 radios

P-313 – 1 radio

«Авио» -1 radio

HX 180VKA131 «Standard» – 2 radio stations

GX 2345S «Standard» - 1 radio station

RFT 03005 – 1 waveform generator

C1-112 – 1 oscillograph

A bathometer with two reversing mercury thermometers – 1

Accumulators – 2

«Sony» video camera – 1

Zenith photographic cameras – 3

Rubinar video camera lens – 1

Jupiter video camera lens – 1

Diving suits – 5

Field binoculars – 1

Life jackets - 5

The team which carried out the field study in the Piltun Feature:

1. E.I. Sobolevsky – Ph. D., head of the IBM laboratory (task manager)
2. A. N. Rutenko – research worker, TOI
3. V.V. Panchenko – research worker, IBM
4. D.V. Antonenko – IBM postgraduate
5. V.V. Zemnukhov – IBM postgraduate
6. S.V. Borisov – TOI research worker

7. E.A. Maslennikov – TOI engineer
8. A.V. Gritsenko – TOI research worker
9. S.N. Kovalenko – IBM engineer
10. I.I. Maximov – IBM engineer
11. L.A. Nurmukhametova – worker

IBM research workers N.P. Ruzhnikova, V.I. Deridovich, D.V. Antonenko performed all office studies.

Aerial surveys of marine mammals were taken on July 8, 17, 18, 26, August 4, 7, 30, September 21-22, October 8-9, November 18 and 20. Helicopters covered the distance from Okha to Nogliki, 20-50 km off the shoreline.

The survey was conducted by three observers (two at each side of the helicopter and one observer at the cockpit). Through the headphones, all observers could communicate between themselves and the helicopter pilot. Normally, we had three experienced marine mammal observers aboard the aircraft. The senior observer (E.I. Sobolevsky) was in the helicopter cockpit. Ahead of him and below him was the navigating officer who was responsible to stick to the heading and to follow the animal census gridline routes. The navigating officer announced any change of the heading and every new transverse section. The flight altitude depended on the weather conditions and visibility over the sea (150-180 meters). Observations were carried out through open portholes.

Mi-8 helicopter has two engines, is equipped by navigating devices and had a GPS-12 portable satellite navigator to ensure accurate navigation of the helicopter along the transverse grid sections and to identify the coordinates of locations in which marine mammals occurred.

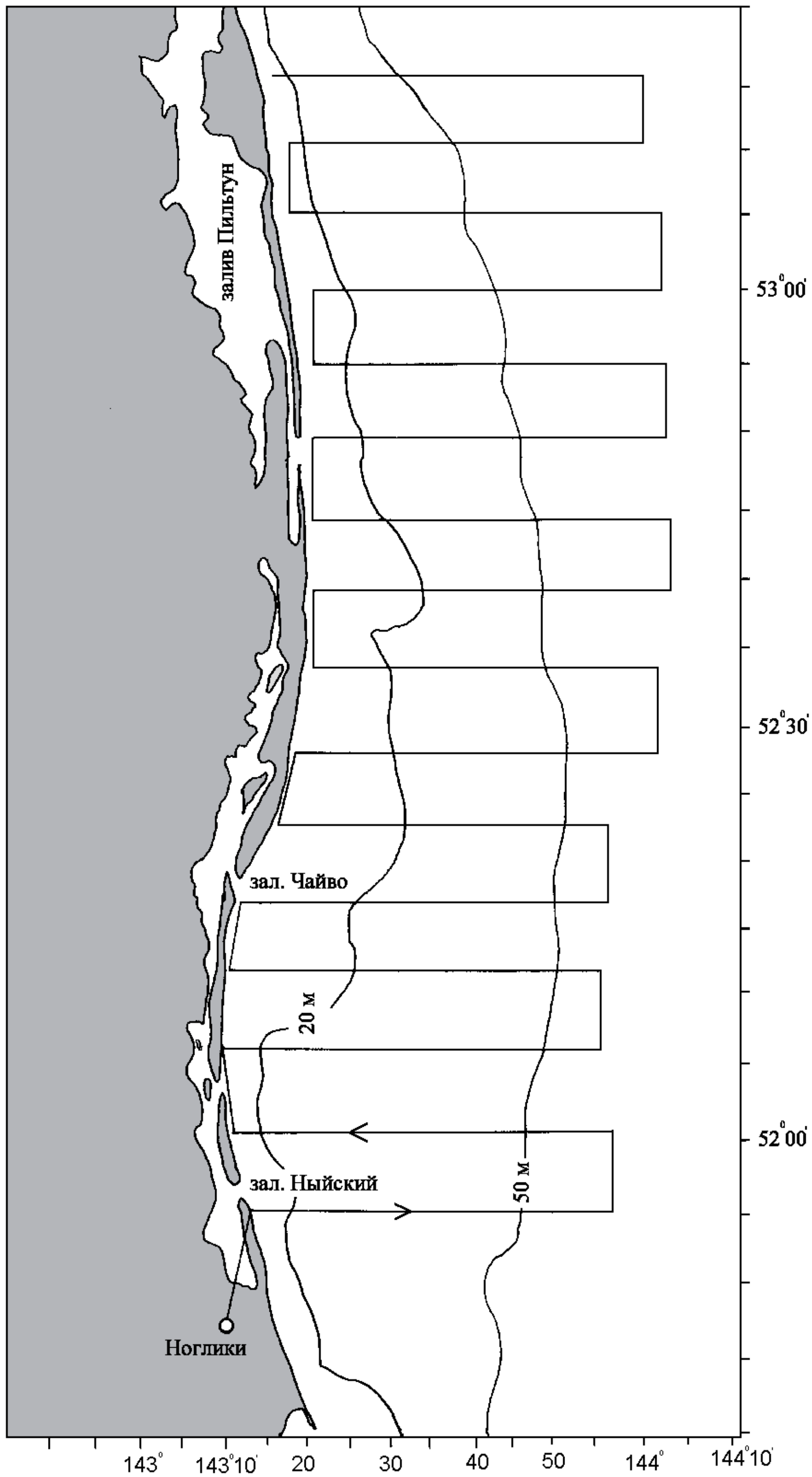


Fig. 1. Route schematic of the helicopter marine mammals survey offshore North-East Sakhalin (an extensive grid).

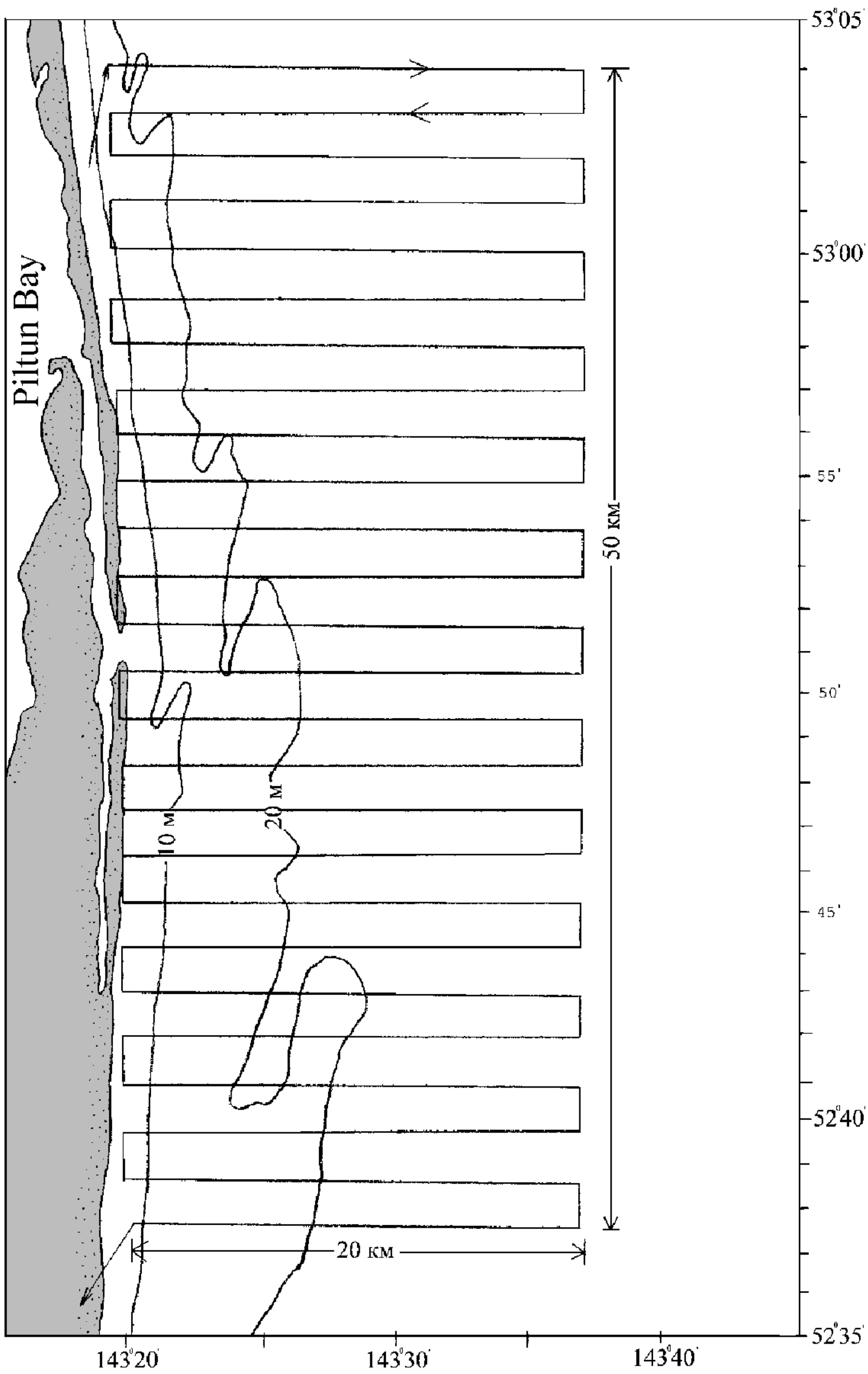


Fig. 2. Route schematic of the helicopter marine mammals survey offshore North-East Sakhalin (an intensive grid).

The helicopter was well heated and air conditioned which was important for the survey which was carried out in November when air temperature was below zero. The observers were quite comfortable and the helicopter portholes were free of ice and snow. The helicopter crew and the observers were equipped with life jackets. The helicopter carried an inflatable raft for 8 passengers, flare pots, a supply of fresh water, food and medicines. The observation band at the altitude of 150 m at normal visibility was two kilometers. In overcast weather and when the clouds were low, the observations sector was reduced to 500-800 m. No aerial census was taken in foggy and poor visibility weather. The records were registered in the observations log, including the time and place of encounter, the animals behavior, number and direction of movement. Whales and seals were filmed and photographed from the helicopter. In some cases, a Б8x30 field binocular was used to confirm the identification of animals.

Seal census was taken both from the helicopter and from motor boats. But seal rookeries along the Sakhalin Island coastline could be very well spotted from the helicopter. For this purpose, helicopter was flown along the coastline, where seal haul-out sites and rookeries were photographed. The photographs provide reliable basis for the estimate of the number of seals at some of the shoals and rookeries. Onshore census of seals is less reliable than the census taken from the helicopter by a video or a photographic camera.

Observations from small vessels and motor boats of Zodiak type were carried out in the area of the Piltun-Astokh License area. In some cases, the team landed onshore and near shoals to study the seals behavior, to estimate their population and to identify the species.

In the course of whales and seals observations, the team video filmed and photographed the feeding water area of gray whales. The gathered data was used later for the evaluation of turbid water patches in the whales' feeding area, the distribution of whales in groups and the population of seals at their rookeries.

The estimate of the overall gray whale population was adjusted for the frequency of occurrence at certain routes. We very well understood that it was not possible to extrapolate the population of gray whales over the whole of the surveyed area, which would be a very good pretext for any kind of criticism. Extrapolation is difficult in this case since there are a number of variables which must be taken into account. The difficulty lies in the fact that no whales at all were observed in some of the water areas, while in others, at the 20-m isobaths, they were observed more frequently. Gray whales were observed more often at the distance of 5 kilometers off the shore, but they were few out in the open sea. The distribution of gray whales along the stretch of the coastline was also non-uniform. Despite all the difficulties, we decided to take this step in order to get closer to the solution of the Sakhalin shelf gray whale population issue. A detailed description of the method which was applied for the whale and seal census is presented in Section 3 together with the data on the census of all marine mammals.

1.1. Acoustic Data-Recording Equipment

One type 5×10^{-7} mV/mkPa responsivity standard hydrophones were used on all radio sonar buoys as primary converters of acoustic pressure. The amplification paths of all buoys were identical. Figure 3 shows the amplitude-frequency response (AFR) of the through path “hydrophone – radio frequency discriminator terminal.” Radios of three types were used for the experiments, therefore, to compare the absolute values of acoustic signal levels, the estimates of their power spectrum $\hat{G}(\omega)$ were normalized and adjusted to the AFR of the measuring paths, shown in Figure 3. Sonograms $\hat{G}(\omega,t)$ were not normalized or adjusted.

Figure 4 shows three methods of installation of radio sonar buoys which were used in various experiments. The option of a freely drifting buoy (See Figure 4a) was used for the recording of ground noise near a visually observed whale. The buoy, in this case, is lowered in the water from the motor boat. The sea bottom buoy location (Figure 4c) turned out to be optimal since the survey area was characterized by shallow water and the current velocity exceeded 3 m/s. Option (b) was used for the installation of buoys at the distance of 1.2 km from the Molikpaq platform at the depth of 28 meters.

Energy was supplied to the radio buoy by Duracell alkaline batteries which could ensure independent operation of the buoy for three days (depending on the reception range). The range of stable radio signal reception was not less than 6 km.

Figure 5 shows the diagram of the onshore station data-recording equipment, while Figure 6 shows the equipment which was used onboard the helicopter or the motor boat.

A transmitter with an independent power source was used for the study of spatial and temporal characteristics of the acoustic noise of the surveyed area, as well as for the Molikpaq noise propagation loss.

The broad band transmitter is a cylindrical device made of piezoelectric rings which are joined up in parallel. To suppress the extraneous resonance and to broaden the frequency band of the transmitted signals in the low frequency band, each ring is placed in a damping shroud made of composite material (epoxy and glass microspheres filler). On both sides the cylinder is sealed by metal lids with airtight connectors. The weight of the transmitter is about 35 kg onshore, while in the sea it has insignificant negative buoyancy. This made it possible to tow the transmitter by the boat and to carry out manual vertical sounding from the boat. Power is supplied to the transmitter along a 50 m long cable. A 100 WA RFT LV-103 amplifier, equipped with a 20 transformation ration marching transformer, was used as a distribution amplifier. A 24 V and 75 Ah capacity accumulator was used to supply power to the amplifier. It ensured continuous operation of the transmitter during 12 hours. A multifrequency signal conditioner which generated 5 sequences of rectangular pulses with off-duty factor 2 and 10 Hz frequency difference (for the first harmonic) was used as the transmitter exciter. The frequency of the transmitter reference generator was stabilized by quartz. The frequencies of the transmitted signal first harmonics were chosen to be relatively low (about 500 Hz). Therefore, the harmonics amplitude of signals which are emitted in the marine environment is equalized by the AFR roll-off at low frequencies. Beside the multifrequency signal, the signal conditioner has additional outlets of pseudonoise signals (on the basis of digital pseudorandom maximum length sequence) and fixed 4000 Hz frequency signaling tone. Power is supplied to the digital signal conditioner by the same source as to the distributing amplifier. When the transmitter was operated onboard a vessel which was

equipped by a 220 V, 50 Hz power unit, any basic frequency generator can be used provided it shapes signaling tones and compound signals.
The functional design of the transmitter system is presented in Figure 7, where: 1 is the external basic frequency generator; 2 is the digital multifrequency signal conditioner; 3 is the LV-103 distributing amplifier; 4 is the matching transformer; 5 is the transmitter; 6 is the accumulator; 7 is the signal source switch. Figure 8 shows the AFR of the system: basic frequency generator – distributing amplifier – matching transformer – transmitter. Acoustic pressure is adjusted to the distance from the receiving hydrophone to the transmitter surface, which is 1 m. the transmitter can be towed at the speed of 15 km/hr.

The functional diagram of the survey instrumentation and equipment is presented in Figure 9 and includes the “L-card” L-1250 input board (IB) (16 channels, a ADSP-2105 signal processor, a 12-digit analog-to-digital converter and a digital-to-analog converter, and 128 Kb storage memory), an Intel “Pentium Pro” computer (233 MHz clock rate, 10.8 Gb hard disk, 98 Mb main memory, CD-Writer Plus) and a package of software for the acoustic data entry and processing.

Data from the acoustic buoys or from the tape recorder arrive to the input board (IB). Depending on the experiment objectives, one of the accumulation modes is used: no data processing or data reduction. In the first case, all data are converted to the digital code and then recorded on the hard disk. Data are continuously recorded from two channels at the 15 kHz sampling frequency to the 10 Gb disk during 46 hours. In the second case, the entered data were subjected to spectral processing (periodogram estimate) and quadrature spectrum components were stored in previously selected frequency bands. Data were not entered during data processing.

Since the capacity of the hard disk was limited, acquired data were recorded by CD-Writer Plus on laser 650 Mb disks. The time of full laser disk writing was about 20 minutes.

The processing program calculates periodograms $G(\omega)$ for each channel (on the basis of the fast Fourier transform, FFT, series length of 65536 values, graduation in the temporary realm by Hamming window). The imaging program displays the diagrams of power spectrum $\widehat{G}(\omega)$ or sonograms $\widehat{G}(\omega, t)$ (spectral path) of signals on the display and sends the image to the printer. The LkDat program is designed to study amplitude-to-time parameters of acoustic signals.

The L1250DMA program provides for the continuous entry and accumulation of data in real time. Prior to the survey, the IB operation mode is programmed from the computer menu (the number of channels, sampling rate) and the disk is chosen on which data is stored. To correctly specify the data interarrival time, the program defines the amount of free memory on the physical disk and estimates the maximum data entry time. The data area entered in the computer in the mode of direct memory access (DMA) with a dual buffer in the main memory and are stored as consecutive 12000000 bite files in real time (Vtime.dat).

The algorithm of the «Lacky» program is based on the cycle: data input from the IB to the buffer in the DMA mode, processing (calculation of periodograms), storage of quadrature components, visualization of the power spectrum. The user interface allows to program the IB operation mode, to specify the boundaries of cut frequency bands, parameters for the periodogram calculation and diagram imaging. The program was applied for the entry and processing of recorded signals, as well as for the adjustment of input channels.

The «Spectr» program is based on the same processing algorithm as the «Lucky» program, but it does not stop processing during data entry. The «SpRoud» program makes it possible to visualize power spectrum as a spectral track (sonogram) and to print it. The following parameters are specified by the computer program menu: the frequency bank width, the number of averagings, the vertical scale of spectral density in dB, the threshold level in dB.

All accumulated unprocessed data were processed by the «LkDat» program. It performs the following functions:

- data visualization;
- identification of amplitude values of signals in various channels;
- estimation of time intervals between any specified points;
- data thinning;
- data storage in a file;
- line bearing identification (for the multichannel system).

Programs «L1250DMA», «Lucky», «SpRoud» and «LkDat» were designed in the «Pascal 5» language for MS-DOS 6.22. The «Spectr» program was designed on the basis of the «Delphi 4» package for «Windows 98».

1.2. Specifics of Experimental Data Digital Processing

The accumulation and analysis of acoustic data was carried out by a computer. The continuous analog signal – electric tension (which corresponds to the acoustic pressure which is measured by hydrophones) is amplified in voltage in accordance with the AFR of the through measuring tract with the sampling frequency $f_Д$, is transformed by a 12 bit analog-to-digital converter to digital code which is entered in the computer. The power spectrum of these signals are estimated by the discreet Fourier transform. The Fourier discreet time series (FDTS) is a particular case of the Fourier continuous time series (FCTS), based on two basic signal processing operations: drawing of indications (discretization) and window weighting. We used uniform indications, at the time interval of T seconds. The frequency of indications was $f_Д = 1/T$. Weighting in the temporary real TW was done by the Hamming window. Suppose that we draw indications of continuous actual signal $x(t)$ of a limited spectrum, whose top frequency is equal to F_0 Hertz, then the signal FCTS $x(t)$ is equal to zero at $|f| > F_0$. The FCTS of the actual signal $x(t)$ is always a symmetrical function of the full emission bandwidth which is equal to $2F_0$, Hz. Signal indications $x(t)$ are estimated by way of multiplication of the signal by the indications function:

$$x_s(t) = x(t) \cdot TS = T \sum_{n=-\infty}^{\infty} x(nT)\delta(t - nT).$$

In accordance with the frequency domain convolution theorem, the signal FCTS $x(t)$ is simply a convolution of the signal spectrum and of the Fourier transformation of the temporal indications function (TS):

$$X_s(f) = X(f) * \Psi\{TS\} = \sum_{k=-\infty}^{\infty} X(f - kF).$$

The convolution of $X(f)$ with the Fourier transformation of the indications function simply regularly continues $X(f)$ at the frequency interval of $1/T$ Hz, which corresponds to the frequency interval between impulse functions.

To obtain spectral estimates in respective energy or power measure units (Marple, 1990), it is necessary to apply modified definitions and terminology of the usual discrete Fourier transform definitions which are quoted in any manual for digital signal processing. The pair of transforms for the usual calculation of DFT N – the point sequence of the DFT $X[k]$, is presented by the following expressions

$$X[k] = \sum_{n=0}^{N-1} x[n] \exp(-j2\pi kn/N), \qquad (1)$$

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] \exp(j2\pi kn/N). \qquad (2)$$

We complied with (Marple, 1990) and used a pair of Fourier discrete time series (FDTS)

$$X[k] = T \sum_{n=0}^{N-1} x[n] \exp(-j2\pi kn/N), \qquad (3)$$

$$x[n] = \frac{1}{NT} \sum_{k=0}^{N-1} X[k] \exp(j2\pi kn/N), \qquad (4)$$

defined for $0 \le k \le N-1$ и $0 \le n \le N-1$, since they show direct dependence from indications interval T. The FDTS can be treated as some sort of FCTS approximation, based on the use of the finite number of indications.

The limiting of band and time, which are required for the correlation between FDTS and FCTS shows that FDTS is a modification of the primary continuous signal $x(t)$ and transformation $X(f)$. Band limiting (BL) creates a filtered function of time

$$x_{BL}(t) = x(t) * \Psi^{-1}\{FW\},$$

while time limiting (TL) creates a filtered function of transformation (filtered spectrum)

$$X_{TL}(f) = X(f) * \Psi\{TW\}.$$

The indications of these functions are denoted as $x_{BL}[n] = x_{BL}(nT)$ and $X_{TL}[k] = X_{TL}(k/NT)$.

The power theorem for FCTS will be:

$$\int_0^{NT} |x(t)|^2 dt = \frac{1}{NT} \sum_{k=-\infty}^{\infty} |X_{TL}[k]|^2 . \qquad (5)$$

This formula characterizes the power of the signal at the interval of NT seconds.

The following pair of Fourier transforms can be formulated for the discrete time series $x[n]$ and for the continuous periodic frequency spectrum $X(f)$:

$$X(f) = T \sum_{n=-\infty}^{\infty} x_{BL}[n] \exp(-j2\pi fnT), \qquad -1/2T \le f \le 1/2T, \qquad (6)$$

$$x_{BL}[n] = \int_{-1/2T}^{1/2T} X(f) \exp(j2\pi fnT) df, \qquad n = 0, \pm 1, \pm 2, ..., \pm\infty . \qquad (7)$$

It should be noted that the first expression defines some periodic function which agrees with the primary transformed function only at the interval from $-1/2T$ to $1/2T$ Hz. For this FDTS, the energy theorem will be

$$T \sum_{n=-\infty}^{\infty} |x_{BL}[n]|^2 = \int_{-1/2T}^{1/2T} |X(f)|^2 df \qquad (8)$$

It characterizes power at the frequency period of $1/T$ Hz. Expression (6) is associated with z transform of some discrete series by the equation

$$X(f) = TX(z)\Big|_{z=\exp(j2\pi fT)},$$

where $X(z)$ - z - is the transform of the sequence $x_{BL}[n]$. It is assumed that the convergence domain of this $z-$transform includes a unit circumference. Thus, FDTS is simply a $z-$transform, calculated in the unit circumference in $z-$plane and multiplied by T. Thus, the following pair of transforms corresponds to the FDTS:

$$X_{TL}[k] = T \sum_{n=0}^{N-1} x_{BL}[n] \exp(-j2\pi kn/N), \qquad k = -\frac{N}{2}, ..., \frac{N}{2} - 1, \qquad (9)$$

$$x_{BL}[n] = \frac{1}{NT}\sum_{k=-N/2}^{N/2-1} X_{TL}[k]\exp(j2\pi kn/N), \qquad n = 0,...,N-1. \qquad (10)$$

The energy theorem for this FDTS is

$$T\sum_{n=0}^{N-1}|x_{BL}[n]|^2 = \frac{1}{NT}\sum_{k=-N/2}^{N/2-1}|X_{TL}|k\|^2,$$

which characterizes the energy of sequence from N indications.

Both sequences $x_{BL}[n]$ and $X_{TL}[k]$ are periodic in module N, therefore when $-N/2 \le k \le 1$, the equation $X_{TL}[-k] = X_{TL}[N-k]$ is valid. Expression (4) can be presented in the equivalent form

$$x_{BL}[n] = \frac{1}{NT}\sum_{n=0}^{N-1} X_{TL}[k]\exp(j2\pi kn/N),$$

where $0 \le n \le N-1$. Expressions (9) and (10) form a pair of Fourier discrete time series related to the basic pair: continuous time function $x(t)$ and continuous frequency function $X(f)$. The inherent difference between FDTS expressions and usual FDT expressions (1) and (2) is T, which characterizes the time interval between indications (seconds). Multiplier $1/NT$ characterizes the frequency interval between indications (hertz). The above multipliers are required to make expressions (9) and (10) valid approximation of the transformation integral in the integration domain

$$\sum_{n=0}^{N-1} x[n]\exp(-j2\pi nfT)T \approx \int_0^{NT} x(t)\exp(-j2\pi ft)dt. \qquad (11)$$

T and $1/NT$ here are scale multipliers of FDTS in relation to the indication frequency $f_Д$, which ensures the correctness of scale in energy and power estimates. It should be noted that FDTS will be identical to FCTS only in case of periodic signals which can be presented as a total of complex sinusoids with frequencies k/NT Hz, where $k = 0,...,N-1$.

Similar to the expression for the FCTS spectral power density, the expression for the FDTS spectral power density can be presented as:

$$S_{ДВПФ}(f) = |X(f)|^2 = \left| T \sum_{n=-\infty}^{\infty} x_{BL}[n] \exp(-j2\pi fnT) \right|^2, \qquad (12)$$

defined for $-1/2T \le f \le 1/2T$. On the basis of the energy theorem (5), one can present the following expression for the FDTS spectral energy density:

$$S_{ДВРФ}[k] = |X_{TL}[k]|^2 = \left| T \sum_{n=0}^{N-1} x_{BL}[n] \exp(-j2\pi kn/N) \right|^2, \qquad (13)$$

defined for $0 \le k \le N-1$.

FDTS is defined by time periodic functions with the period of NT seconds. Power is equal to energy related to a time unit. Therefore, if we divide energy spectral density (ESD) which is defined by expression (13), by NT, we shall receive the following expression for the deterministic power spectral density (PSD):

$$P_{ДВРФ}[k] = \frac{1}{NT} S_{ДВРФ}[k] = \frac{T}{N} \left| \sum_{n=0}^{N-1} x_{BL}[n] \exp(-2j\pi kn/N) \right|^2,$$

(14)

where $0 \le k \le N-1$. This density is expressed in power units per 1 hertz. It should be noted that its value depends on the indications interval T, therefore we use the estimate of the FDTS power spectral density (hereinafter “power spectrum”) $G[k]$

$$G[k] = a \cdot F \cdot P_{ДВРФ}[k] = a \left| \frac{1}{N} \sum_{n=0}^{N-1} x_{BL}[n] \exp(-j2\pi kn/N) \right|^2, \qquad (15)$$

where a - is the coefficient which compensates for the decrease in dispersion due to data weighting in the time domain. This value does not depend on the indications interval - T. The value which is defined by this expression at any k index will be equal to the sinusoid power of k/NT hertz frequency. However, unlike expression (14), expression (15) is not a correctly scaled PSD function.

Let us introduce physical terminology which we are going to use for the analysis of acoustic data. Definition reads that the term **spectral level** (SL) is related to the level of a sound wave in the **frequency band of 1 Hz.** This term is used only for signals with continuous spectrum, i.e. in those cases when the signal, even a small one, is present in any point of the analyzed frequency band. The term ***frequency band level*** (FBL) is related to the frequency band which is wider or narrower than 1 Hz.

1.3. Normalization and Correction of In-Situ Data

The measurements, carried out by self-contained radio sonar buoys, provided synchronous series of sampled data which help to study temporal and spectral parameters of the acoustic field and signals (in a limited frequency band). Normalization and adjustment of data were carried out by the following algorithms:

- normalization of basic data:

  A [mkPa] = $\mathrm{M} \times K_{TR}$, where M – is the analog-to-digital coder value, and

  $K_{TR} = \dfrac{\Delta U}{K_g \cdot K_{U,M} \cdot K_{U,REC}\big|_{\max}}$, where ΔU – is the quantization threshold of the analog-to-digital coder analog tension, equal to 2.5 mV; $K_{U,M}$ - is the gain on the scaling strengthener tension; $K_{u,REC}\big|_{\max}$ - is the maximum gain of a through "hydrophone-radio output" measuring tract in a given frequency band; K_g - is the hydrophone sensitivity, equal to 5×10^{-7} mV/mkPa.

- normalization of the power spectrum:

$$G_N(f) = G(f) \times (K_{TR})^2$$

- adjustment of the normalized power spectrum in accordance with the frequency response function of the through measuring tract:

$$G_{NA}(f) = \frac{G(f) \times (K_{TR})^2 \times (K_{U,REC}\big|_{\max})^2}{[K_{U,REC}(f)]^2}.$$

- adjustment of the power spectrum to *level 1 mkPa rms* в dB:

$$G_{1mkPa}(f) = 10LogG_{NA}(f) + 10Log(K_{TR})^2 \quad \text{[dB]}.$$

- development of the power spectrum estimate $\hat{G}(f)$ by way of averaging in consecutive realization without overlapping:

$$\hat{G}_{1mkPa}(f) = \frac{G_{1mkPa}(f)_1 + \ldots + G_{1mkPa}(f)_n}{n}.$$

All programs for the normalization, adjustment and spectral and temporal analysis are verified by tests based on the application of calibrated noise and electric signaling tones, transmitted by the through "hydrophone – output of radio frequency discriminator" tract, as well directly entered in the computer by way of a analog-to digital coder.

2. The Analysis of Species Composition and Distribution of Marine Mammals Offshore Eastern Sakhalin

Aerial observations survey covered the water area within 51º45' –53º40` N and 143º10` – 144º00`E. The survey data showed that among the whales population offshore northeastern Sakhalin gray whales (Eschrichtius gibbosus) are the most numerous. The population of Phoca largha seals is the most numerous among local pinnipeds. Ringed seals (Pusa hispida) and bearded seals (Erignathus barbatus)were observed in some of the rookeries, but do not gather in big numbers and are scattered along the coastline.

Killer whales (Orcinus orca) were observed during the survey. The helicopter survey data provided information on the major areas of mammals' summer habitats, on the gray whales distribution, their feeding areas, as well as showed the locations in which seals gathered for the salmon spawning season. The dates of the helicopter aerial surveys are presented in Table 2.1.

2.1. Distribution of Gray Whales in the Summer and Autumn Seasons (July-November)

Distribution of gray whales in the July-November period in the northeastern sector of the Sakhalin Island continental shelf had its own peculiarities in certain months, therefore we found it feasible to present the data for each of the survey months separately. The survey data are presented in Table 2.2.

July. The survey in July was carried out on the basis of the wide spacing grid (8 and 18) and on the basis of the densely spaced grid (17 and 26). Besides that, on July 12 the team on the helicopter surveyed the coastline from the Piltun Bay to Nogliki, but the survey along the coastline proved to be inefficient and no other mammals except seals in the Piltun Bay were observed. Therefore, the helicopter route of July 12 is not presented in the report.

On July 8 the survey on extensive grid was carried in sunny, quiet weather, in good visibility conditions. The helicopter was flown at the altitude of 150 m at the speed of 160-180 km/hr. No whales were observed in the 12 transects from the Nyiskiy Bay to the Piltun Bay (Figure 2.1.). The first single whales were observed near the shore, opposite the Piltun Bay. The whales appeared from time to time on the surface, released two or three blows, and dived back into the deeper water.

Most of the whales were observed on that day in the area between 52º58'8" – 53º00'2" N and 143º19'54" – 143º24'17" E at the 10-15 meter isobaths (Figure 2.1.). The most part of whales was actively feeding. Nearby there were observed patches of turbid water. The whales were staying close to the shore, at the distance of 1-2.5 km. Some of the whales reacted to the helicopter which was flying at the altitude of 150 m and tried to leave the survey area, heading away from the shore. The whales which were observed at the 15-20 m isobaths did not show any reaction to the helicopter noise, regularly appeared on the surface and did not attempt to leave the area.

Table 2.1.

Schedule of Helicopter Survey Offshore
North-East Sakhalin in July – November 1999.

Date of survey	Extensive (infrequent) grid	Intensive (frequent) grid	Piltun Bay	Offshore North-East Sakhalin	Chaivo Bay and Nyiskii Bay
July 8	+	-	+	+	+
July 12	-	-	+	+	+
July 17	-	+	+	+	-
July 18	+	-		+	+
July 26	-	+	-	+	-
August 4	+	-	-	-	-
August 7	+	-	-	+	+
August 30	-	+	+	+	-
September 21	+	-	-	+	+
September 22	+	-	-	+	+
October 8	-	+	+	+	-
October 9	+	-	+	+	+
November 18	-	+	+	+	-
November 20	+	-	+	+	+
Total number of flights	8	5	8	13	8

Table 2.2.

Gray Whales Aerial Survey Results Offshore North-East Sakhalin in July – November 1999

Date of survey	Number of gray whales identified (ind.)		Number of whales identified outside survey areas	Total number of identified whales (in parenthesis, %)
	using an extensive grid	using an intensive grid		
July				
8	15	-	0	15 (4.8)
17	-	8	0	8 (2.5)
18	29	-	5	34 (10.8)
26	-	23	1	24 (7.6)
Total in July	44	31	6	81 (25.7)
August				
4	45	-	2	47 (14.9)
7	28	-	0	28 (8.9)
30	-	28	1	29 (9.2)
Total in August	73	28	3	104 (33.0)
September				
21	33	-	0	33 (10.5)
22	27	-	13	40 (12.7)
Total in September	60	-	13	73 (23.2)
October				
8	-	4	0	4 (1.3)
9	22	-	10	32 (10.1)
Total in October	22	4	10	36 (11.4)
November				
18	-	6	1	7 (2.2)
20	14	-	0	14 (4.5)
Total in November	14	6	1	21 (6.7)
Total number of whales (July - November)	213	69	33	315 (100%)
% of total number of whales	67.6	21.9	10.5	100%

North of 53°N, at coordinates 53°05'3"N and 143°55'6"E we encountered a single whale at a relatively large distance from the coast (about 23 miles) at a water depth of 95-107m. We also encountered another whale at the same water depth on a different transect at coordinates 53°09'00"N and 143°55'00"E, it was going toward the coast. These two whales were likely to go to the summer feeding area, probably it was their first travel to the Piltun Bay this year. But this is only an assumption.

In the afternoon at coordinates 53°10'8"N and 143°32'15"E, a group of killer whales consisting of 25-30 individuals was observed. They were at a distance of more than 2 km from the helicopter and 9.7 km from the coast at a water depth of 40-45 m. The killer whales stayed close to each other in an area of about 50x60 m. When the helicopter approached, most killer whales were underwater, but their outlines and all their movements could be observed. Such aggregation of killer whales in a limited area may be associated with the beginning of the hunchback salmon run along the Sakhalin coast. On those days (July 6-8), we saw the approach of hunchback salmon. During the flight at a height of 150 m along the Sakhalin coast, salmon were observed jumping out of the water.

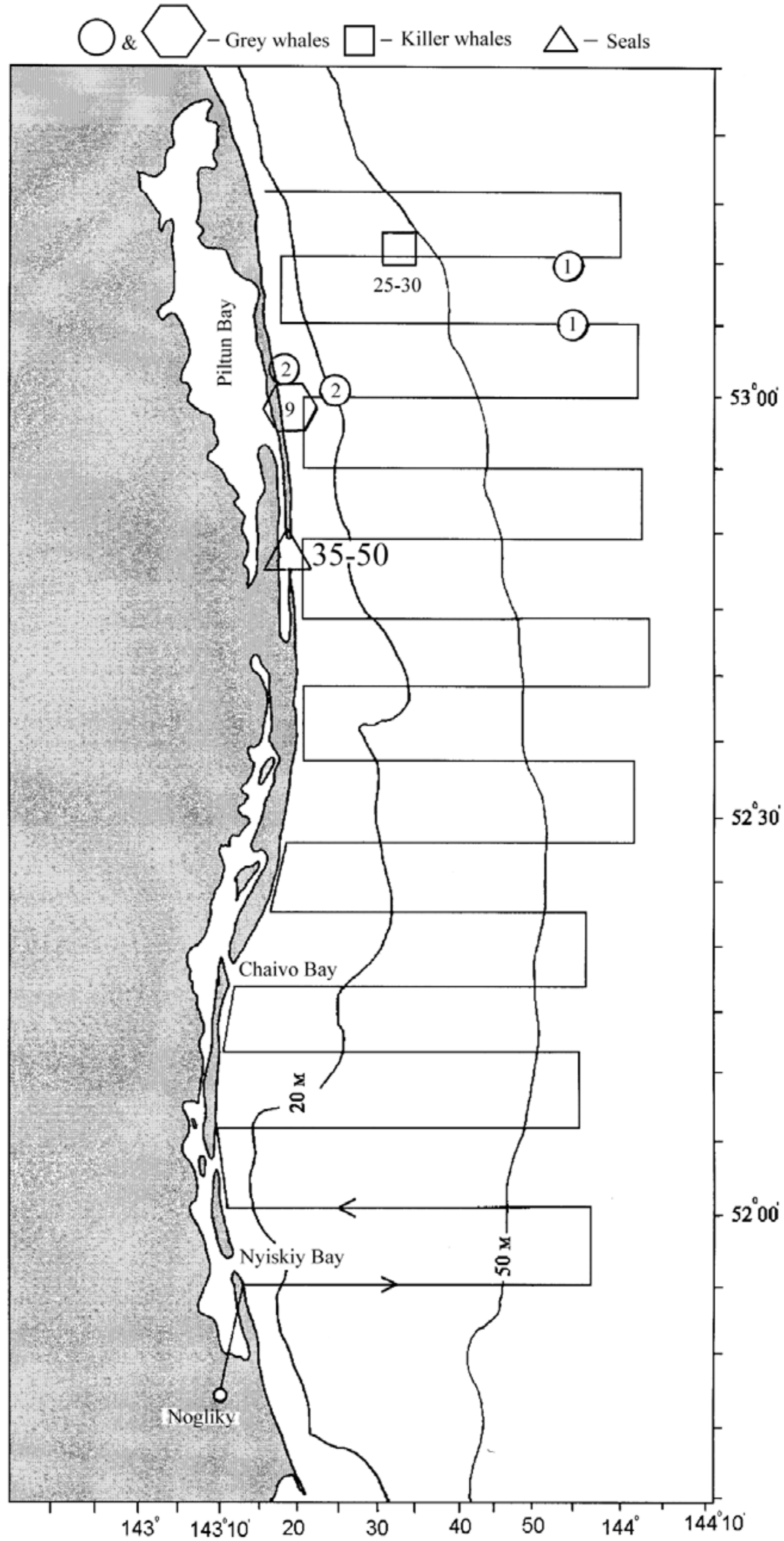


Fig. 2.1. Occurrence of mammals offshore Sakhalin based on aerial survey of 8 July 1999.

On July 17 we counted whales by the intensive grid from south to north. The weather was sunny, the sea was slight (1-2 points on international sea state standard scale). An area of about 1,000 km^2 was covered on 26 transects. We counted a total of 8 whales out of which 7 whales were in the coastal zone opposite the Piltun Bay and 1 whale was south of the Piltun bay (Fig. 2.2). The whales kept apart, we saw 3 groups of 2 individuals and 2 single whales. The whales mostly kept to the coastal zone on the 5-10-m isobaths. No whales were encountered beyond the 20-m isobath (Fig. 2.2). The behavior of the whales was calm, when the helicopter approached them the whales did show any anxiety and remained where they were. In the afternoon we saw only one feeding whale (Table 2.3). We did not see mud spots around the other whales.

On July 18 we counted whales by the extensive grid from the Nyiskiy Bay toward the north on 16 transects (Fig. 2.3). The weather was sunny, with a slight wind; the sea was calm (less than 1 point).

We counted 34 whales on that day, 5 of them were beyond the survey area (Fig. 2.3).

We did not encounter any whales on 11 transects located between 51°50′ - 52° 50′N. On the other transects whales were noticed in the coastal zone mainly on the 5-10-15-m isobaths. Two groups of whales (a total of 5) were seen at a water depth of 20-25 m.

On July 18 most gray whales were relatively far, about 17-30 miles to North from the Piltun lighthouse (Fig. 2.3), that is why they could not be seen by the observers on the lighthouse and the motor boats of the Zodiac type.

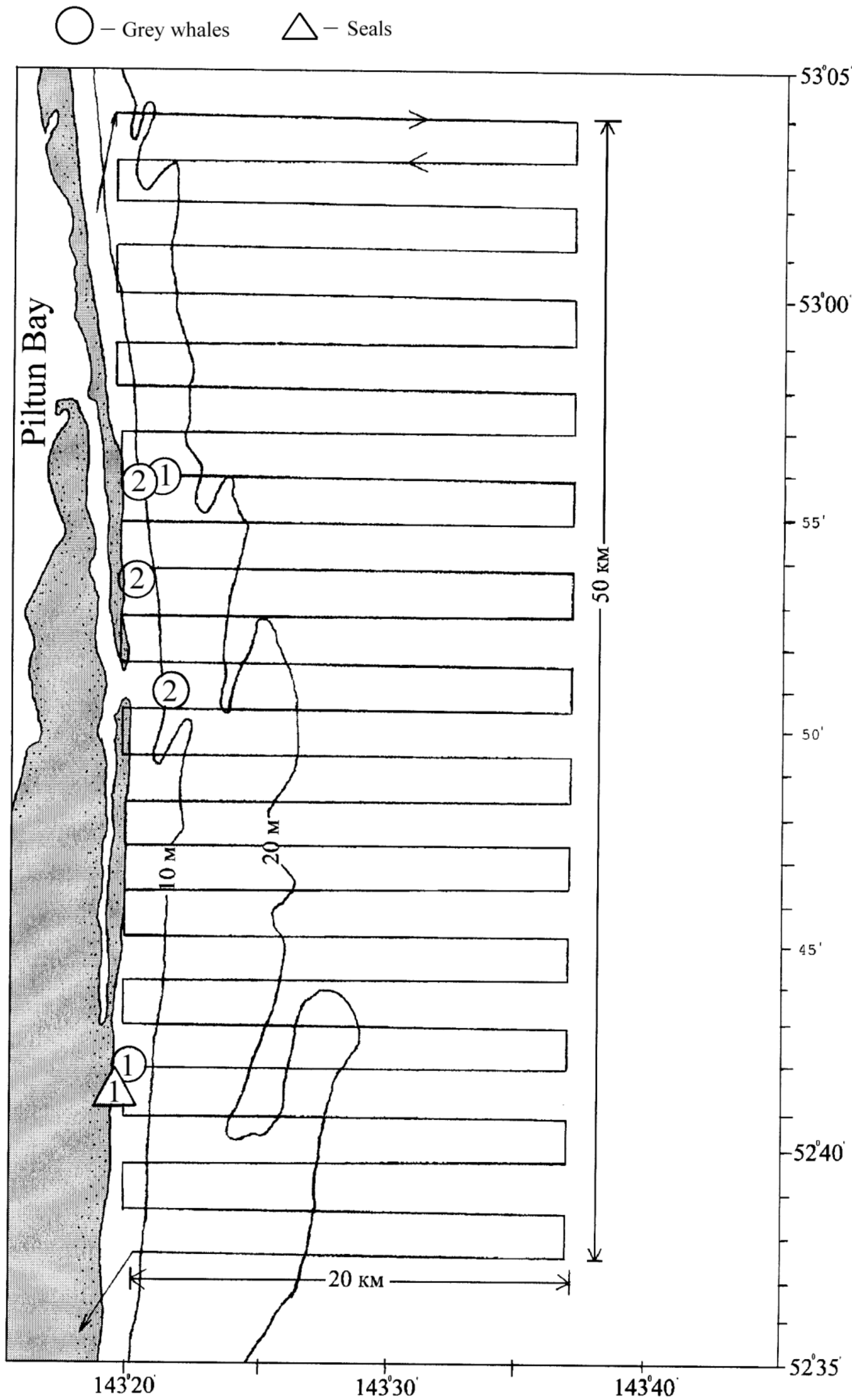


Fig. 2.2. Occurrence of mammals on shelf of Sakhalin by aerial survey at 17 July, 1999

Table 2.3

Occurrence of Mammals Offshore Sakhalin Based on Aerial Surveys in July 1999.

Date	Time	Location of sightings (longitude, latitude)	Mammals sighted, behavior
1	2	3	4
July 8	1:06 p.m.	52°48' 143°18'	35-50 (Seals)
	1:51 p.m.	52°58'8" 143°19'54"	1+1+1 (Gray whale)
	1:55 p.m.	52°58'42" 143°20'30"	1+1+2 (Gray whale)
	2:02 p.m.	53°00'00" 143°19'8"	2 (Gray whale)
	2:12 p.m.	53°02'7" 143°17'36"	2 (Gray whale)
	2:18 p.m.	53°00'2" 143°24'17"	2 (Gray whale)
	2:58 p.m..	53°05'3" 143°55'6"	1 (Gray whale)
	3:35 p.m.	53°10'8" 143°32'15"	25-30 (Killer whale)
	4:14 p.m.	53°09'00" 143°55'00"	1 (Gray whale)
July 17	1:45 p.m.	52°55'54" 143°20'30"	2 (Gray whale)
	1:46 p.m.	52°56'00" 143°20'48"	1 (Gray whale)
	2:06 p.m.	52°53'24" 143°20'31"	2 (Gray whale)
	2:40 p.m.	52°50'55" 143°21'48"	1+1 (Gray whale)
	3:46 p.m.	52°41'6" 143°19'47"	1 (Spotted seal)
	3:47 p.m.	52°41'8" 143°19'52"	1 (Gray whale)

1	2	3	4
	4:38 p.m.	52°22'6" 143°10'55"	35-40 (Seals)
July 18	11:23 a.m.	52°17'10" 143°12'16"	5 (Seals)
	1:07 p.m..	52°53'48" 143°21'00"	4 (Gray whale)
	1:10 p.m.	52°53'55" 143°21'12"	2 (Gray whale)
	1:13 p.m.	52°54'00" 143°21'18"	1+1 (Gray whale)
	1:19 p.m.	52°56'36" 143°20'18"	1 (Gray whale)
	1:20 p.m.	52°56'38" 143°20'22"	1 (Gray whale)
	1:21 p.m.	52°58'42" 143°19'12"	1+1 (Gray whale)
	2:22 p.m.	53°05'36" 143°18'35"	3 (Gray whale)
	2:25 p.m.	53°05'42" 143°19'00"	1+1 (Gray whale)
	2:42 p.m.	53°08'42" 143°17'12"	2 (Gray whale) The whales are feeding
	2:44 p.m.	53°09'00" 143°18'16"	1+1 (Gray whale)
	2:49 p.m.	53°11'6" 143°17'13"	2 (Gray whale)
	3:52 p.m.	53°12'36" 143°17'8"	1 (Gray whale)
	3:58 p.m.	53°12'35" 143°16'54"	1+1+1 (Gray whale)
	4:03 p.m.	53°14'49" 143°16'18"	1+1 (Gray whale)
	4:08 p.m.	53°20'30" 143°15'18"	3 (Gray whale)
	4:10 p.m.	53°22'54" 143°14'11"	1+1 (Gray whale)

1	2	3	4
July 26	4:20 p.m.	52°58'48" 143°20'58"	2+1 (Gray whale)
	4:45 p.m.	52°56'38" 143°20'17"	4 (Gray whale) The whales are sticking together in a group ranged from 30 to 50 m.
	5:10 p.m.	52°54'43" 143°20'53"	1+1 (Gray whale)
	5:17 p.m.	52°53'14" 143°21'49"	1+1 (Gray whale)
	5:19 p.m.	52°53'00" 143°21'06"	3 (Gray whale)
	5:40 p.m.	52°52'47" 143°20'53"	1+1+2 (Gray whale)
	5:51 p.m.	52°52'45" 143°21'13"	1 (Gray whale)
	6:02 p.m.	52°47'43" 143°21'59"	6 (Killer whale) 1 (Gray whale)
	7:02 p.m.	52°44'49" 143°21'58"	1 (Gray whale)
	7:18 p.m.	52°43'59" 143°21'58"	1 (Gray whale)
	7:58 p.m..	52°37'27" 143°21'39"	1 (Gray whale)
	8:12 p.m.	52°33'00" 143°22'19"	1 (Gray whale)

On that day we could observe whales practically all over the coastal zone and opposite Piltun Bay in an area lying between 52°53'48" - 52°54'00"N and 143°21'00"- 143°21'18"E (Table 2.3.). We saw small groups of 2-3 whales each and many single whales along the coast. The animals did not show any anxiety. They retained their location and practically did not react to the noise made by the helicopter.

The whale count made on July 18 proved more resulting than the count on July 8 when only 15 gray whales were counted. Most probably, some whales came to the summer feeding area in the second half of July, which affected the results of count.

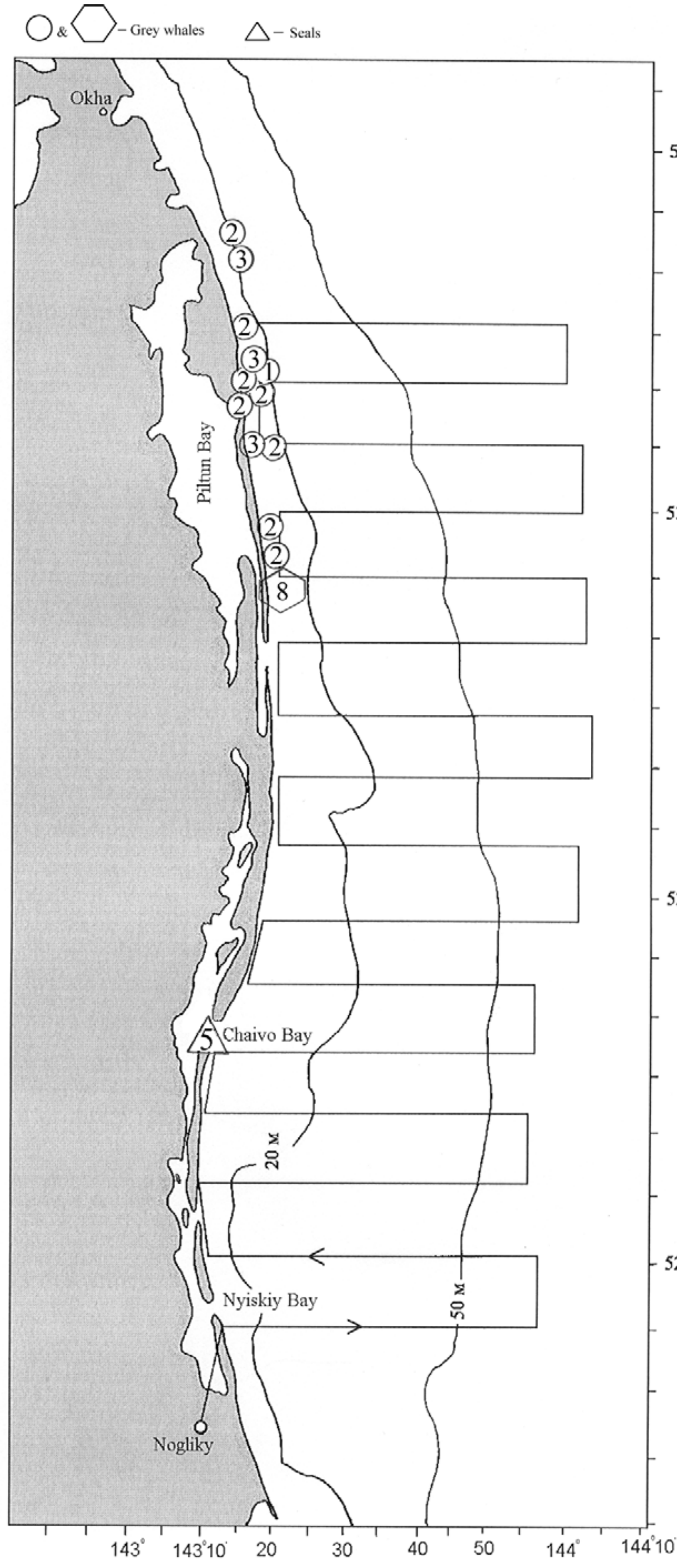


Fig. 2.3. Occurrence of mammals on shelf of Sakhalin by aerial survey at 18 July, 1999

On July 26 we counted whales by the intensive grid. The weather was good, the sea was slight (1-2 points). We counted whales from north to south. We counted 23 gray whales on the transects and one whale outside the survey area at coordinates 52°33'00"N and 143°22'19"E (Table 2.3.).

Most whales were observed off the mouth of the Piltun Bay and slightly north of it (Fig. 2.4). Unlike the previous flights in July, some whales were seen south of the Piltun Bay. We counted 5 single whales. On that day we could also see a group of killer whales consisting of 6 individuals chase a gray whale. One killer whale (large male) was swimming next to the whale the other 5 killer whales surrounded the whale blocking its way to the north. The killer whales did not show any aggressiveness during our observations, but the gray whale's behavior was unusual in that the whale was swimming on its back and tried to escape toward the coast. At that moment the whale was on the 10-m isobath.

The count on July 26 showed some difference in the whale distribution: whales were encountered south of the Piltun Bay. It was the only distinction. All whales were encountered on the 5-10-15-m isobaths. Not a single whale was seen beyond the 20-m isobath (Fig. 2.4).

Thus, the aerial count showed that most whales were located in the coastal zone at a water depth less than 20 m and north of the mouth of the Piltun Bay.

August. Three aerial counts of sea mammals were conducted in August.

On August 4 we counted whales by the extensive grid. Sergei Yazvenko (Canada) was present on board the helicopter to observe our work. The weather was sunny, the wind was slight, the sea was calm (at most 1 point). We flew on 8 transects from north to south at a height of 150 m and a speed of 160-180 km/h. between 53°20′ - 52°35′N.

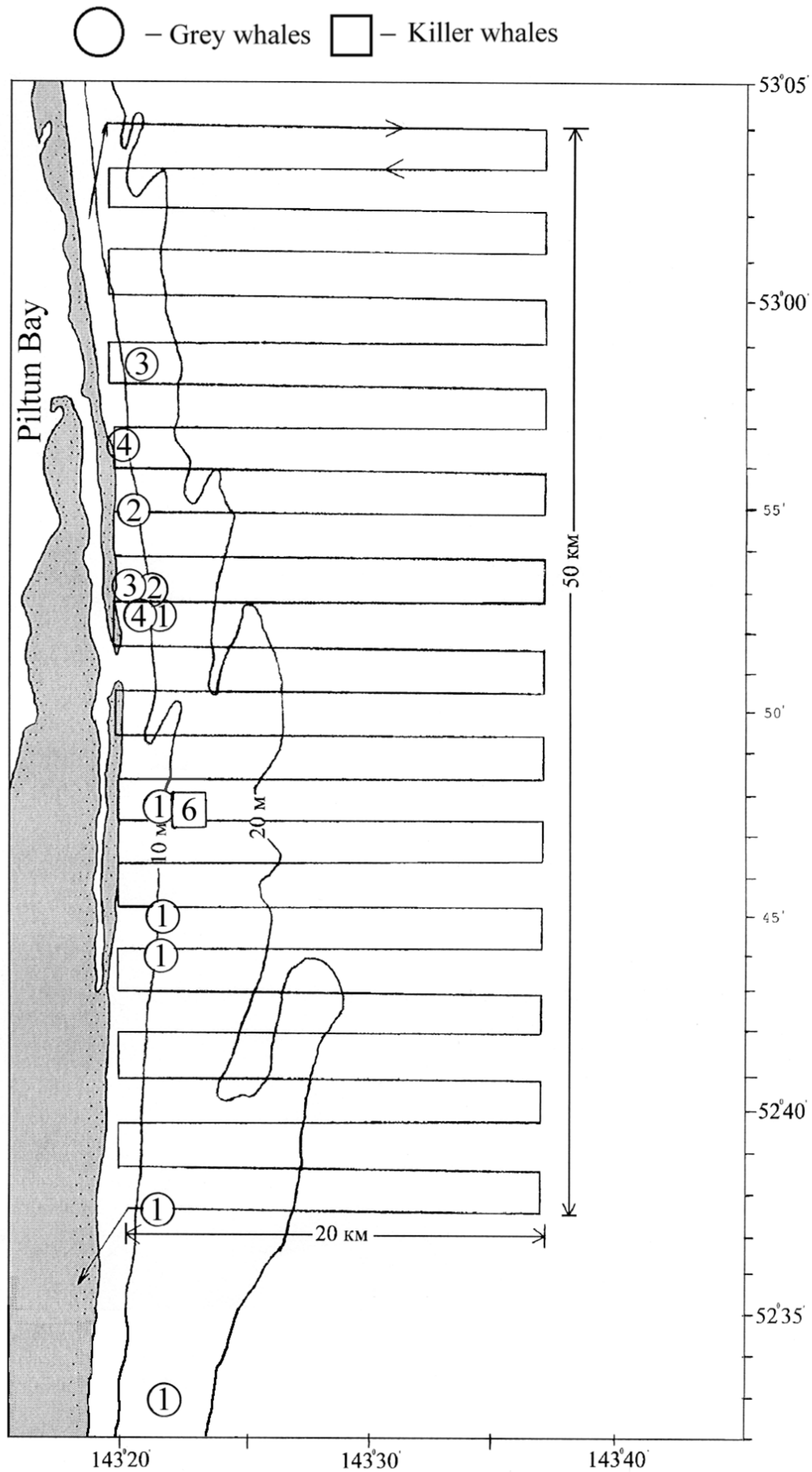


Fig. 2.4. Occurrence of mammals on shelf of Sakhalin by aerial survey at 26 July, 1999

The offshore most transect ended 50 km from the coast. A total of 47 whales were distributed along the coast offshore to a water depth of 20-m relatively uniformly (Fig. 2.5).

The behavior of the animals was calm; they did not practically react to the helicopter noise and stayed in one location. In some locations, five to six whales were observed simultaneously. The whales within these groups were at a distance of 20-50 m from each other. Small groups of whales (2-3 individuals) could be seen relatively often; the whales within such groups kept closer to each other. On that day, active feeding of whales was not observed, though in some locations a few mud spots were observed. The greatest number of gray whales was counted in the coastal zone near 53°N (Table 2.4). Only one whale was observed south of the mouth of Piltun Bay. Whales were absent beyond the 20-m isobath. The distribution of gray whales was similar to that observed on July 18, but on August 4 almost twice as many whales were counted to latitude of 53°N as on July 18.

Since on August 4 only 50% of the survey area was flown, the extensive grid was repeated on August 7. The survey was conducted in the afternoon when it was overcast (cloud 8-9 points), the visibility was 5-6 km, and the sea was slight (1-2 points). We covered 16 transects from the Nyisky Bay toward the north to 53°17′N (Fig. 2.6). Like the previous surveys, gray whales were not observed on 8 transects located south of 52°35′N. The first two gray whales were observed on transect 9 near the coast at coordinates 52°41'35"N and 143°20'36"E. The whales stayed together and were feeding actively, as evidenced by many mud spots. Later that day, whales could be seen on all transects except the last one. The whales were mostly observed on the 10-15-m isobaths.

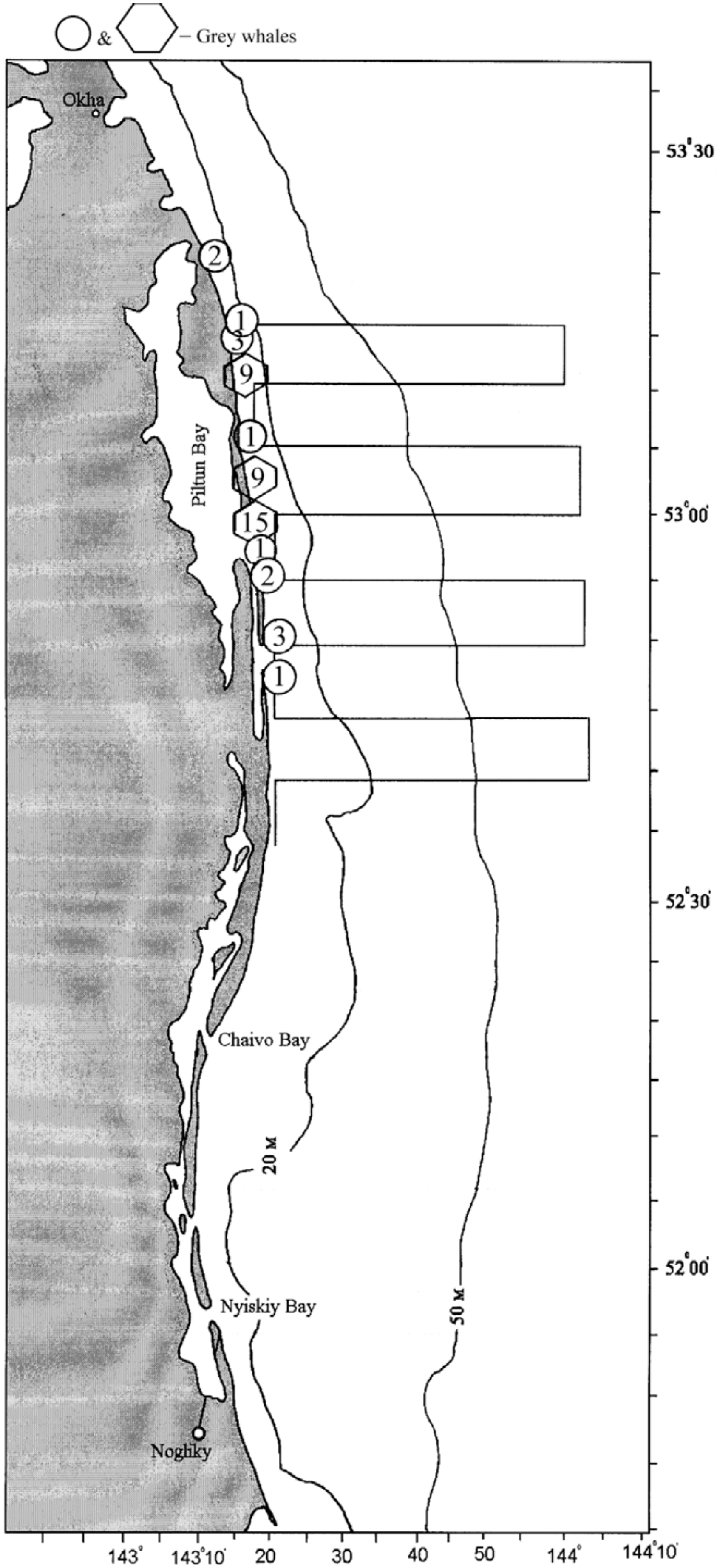


Fig. 2.5. Occurrence of mammals offshore Sakhalin based on an aerial survey on 4 August, 1999.

Table 2.4

Occurrence of mammals offshore Sakhalin based on aerial surveys in August 1999.

Date	Time	Location of sightings (longitude, latitude)	Mammals sighted, behavior
August 4	2:19 p.m.	52°47'42" 143°21'53"	1 (Gray whale)
	2:21 p.m.	52°50'48" 143°22'3"	2+1 (Gray whale)
	3:00 p.m.	52°55'48" 143°20'54"	2 (Gray whale) Behavior of the whales is calm
	3:02 p.m.	52°57'42" 143°20'35"	1 (Gray whale)
	3:03 p.m.	52°58'30" 143°20'06"	1 (Gray whale)
	3:04 p.m.	52°59'12" 143°18'54"	3 (Gray whale)
	3:08 p.m. 3:11 p.m. 3:25 p.m.. 3:58 p.m. 4:05 p.m. 4:13 p.m. 4:20 p.m.	52°57'12" 143°19'30" 53°00'2" 143°19'48" 53°01'31" 143°19'11" 53°02'47" 143°18'18" 53°04'55" 143°18'54" 53°05'42" 143°18'25" 53°05'48"	1 (Gray whale) 2+1+2 (Gray whale) The whales are distributed on area 100x70 m. 5 (Gray whale) The group of whales is not compact. The whales are located about 20-50 m from each to other 3 (Gray whale) 1+2 (Gray whale) Two whales are swimming together 2+1 (Gray whale) 1 (Gray whale)

		143°18'12"	
	4:23 p.m.	53°09'6" 143°16'5"	3 (Gray whale)
	4:25 p.m.	53°10'00" 143°17'18"	1+1 (Gray whale)
	4:29 p.m.	53°09'36" 143°16'30"	2 (Gray whale)
	4:33 p.m.	53°10'54" 143°16'23"	1+1 (Gray whale)
	5:28 p.m.	53°12'54" 143°16'06"	3 (Gray whale) The whales are sticking together
	5:42 p.m.	53°13'54" 143°15'23"	1 (Gray whale)
	6:08 p.m.	53°21'48" 143°12'35"	2 (Gray whale)
August 7	3:22 p.m.	51°59'40" 143°16'30"	2+11+3 (Seals)
	3:30 p.m.	51°59'53" 143°10'25"	1+6+3 (Seals)
	3:36 p.m.	52°01'35" 143°09'54"	2 (Spotted seal)
	3:42 p.m.	52°04'47" 143°09'12"	8 (Seals)
	3:45 p.m.	52°05'00" 143°16'36"	3 (Seals)
	4:30 p.m.	52°20'12" 143°12'11"	150-180 (Seals) The seals lay on the bank near Chaivo Bay
	5:03 p.m.	52°41'35" 143°20'36"	2 (Gray whale) The whales are feeding. There are many feeding plumes.
	5:38 p.m.	52°46'55" 143°21'24"	4 (Gray whale)
	5:46 p.m.	52°48'47" 143°22'55"	3 (Gray whale)
	6:20 p.m.	52°54'41" 143°22'54"	1+3 (Gray whale)
	6:25 p.m.	52°57'18" 143°20'6"	3 (Gray whale)

	6:39 p.m.	52°57'34" 143°20'09"	2 (Gray whale)
	6:44 p.m.	52°58'30" 143°18'36"	3 (Gray whale)
	6:47 p.m.	52°59'42" 143°19'8"	1 (Gray whale)
	6:53 p.m.	53°01'24" 143°18'35"	1+1 (Gray whale)
	7:46 p.m.	53°05'36" 143°18'48"	1 (Gray whale)
	7:53 p.m.	53°06'55" 143°16'54"	1 (Gray whale)
	7:59 p.m.	53°09'2" 143°16'24"	2 (Gray whale)
August 30	12:44 a.m.	52°40'48" 143°20'25"	1 (Gray whale)
	1:25 p.m.	52°44'36" 143°20'24"	2 (Gray whale)
	1:56 p.m.	52°47'42" 143°20'26"	3 (Gray whale)
	2:17 p.m.	52°49'36" 143°21'30"	1 (Gray whale)
	2:18 p.m.	52°49'48" 143°21'24"	1 (Gray whale)
	2:27 p.m.	52°51'12" 143°21'54"	1 (Gray whale)
	2:45 p.m.	52°52'54" 143°21'6"	2 (Gray whale)
	2:47 p.m.	52°53'24" 143°20'48"	2 (Gray whale)
	3:02 p.m.	52°55'6" 143°20'00"	2+1+2 (Gray whale)
	3:33 p.m.	52°57'54" 143°19'48"	1 (Gray whale)
	3:47 p.m.	52°59'12" 143°19'54"	2 (Gray whale)
	3:49 p.m.	52°59'13" 143°19'24"	2 (Gray whale)
	3:50 p.m.	52°59'25" 143°19'55"	3 (Gray whale)
	3:50 p.m.	52°59'24" 143°20'12"	1 (Gray whale)
	4:03 p.m.	53°04'25"	1 (Gray whale)

		143°17'49"	
	4:17 p.m.	53°17'30" 143°14'6"	1 (Gray whale)
	4:59 p.m.	52°50'46" 143°19'12"	Herd of seals (more than 90 individuals)
	5:28 p.m.	52°19'6" 143°11'20"	Herd of seals (more than 500 individuals)
	5:28 p.m.	52°19'28" 143°11'06"	Herd of seals (more than 1000 individuals)
	5:30 p.m.	52°19'30" 143°10'54"	Herd of seals (more than 200 individuals)

On that day the whales formed small groups of 2-3 individuals, single whales were rare. The majority of gray whales were observed near latitude 53°N. Unlike August 4, fewer whales were encountered north of 53°N. Whales were mainly encountered south of 53°N; 9 whales were south of the mouth of the Piltun Bay on the 8-15-m isobaths.

On the whole, the distribution on August 4 and 7 was similar with the only distinction that fewer whales were counted on August 7 (Table 2.4), but the occurrence of whales south of Piltun Bay was much higher (32.1% of the total number) than on August 4 (8.5%).

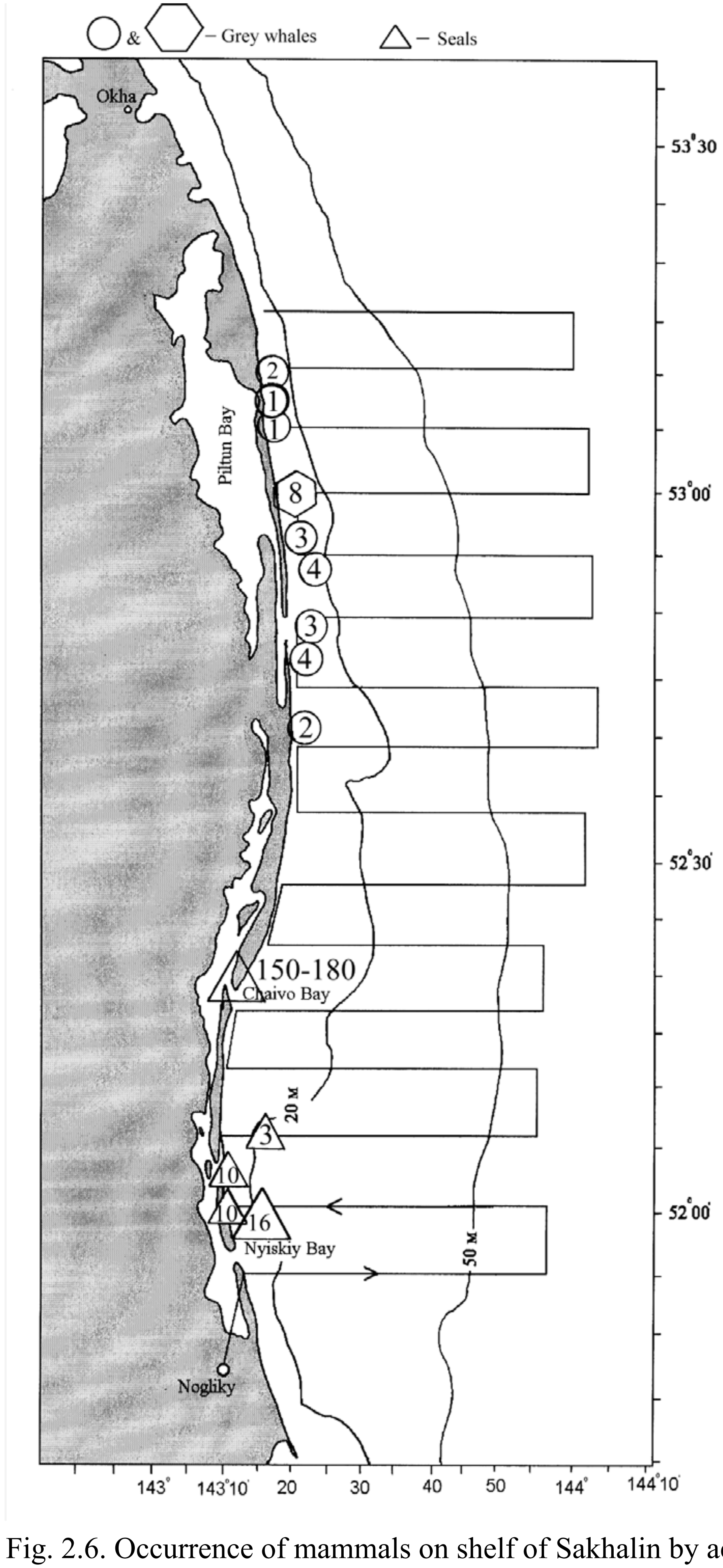


Fig. 2.6. Occurrence of mammals on shelf of Sakhalin by aerial survey at 7 August 1999.

On August 30, the intensive grid was surveyed. In the morning, the weather was not favorable for work: it was fog and drizzling. Fog dispersed by 11 o'clock. In the afternoon, the weather became sunny, but the sea was slight (2 points). The survey was run from south to north on 26 transects. Twenty-eight gray whales were observed with one of them observed on the north, beyond the survey area at coordinates 53°17'30"N and 143°14'6"E (Table 2.4.). Whales were observed on 13 transects (50%) out of 26. Most whales were observed north of the mouth of Piltun Bay (71.4%) on the 10-12-m isobaths. Not a single whale was observed in water deeper than 15 m. The whales were feeding actively at the mouth of Piltun Bay, and they were seen feeding south of Piltun Bay at coordinates 52°47'42"N and 143°20'26"E about 1.5 km from the coast at a water depth of 6-8 m. A female with a calf was seen at coordinates 52°59'25"N and 143°19'55"E (Table 2.4), with another whale nearby. The female behaved calmly, but during the survey, the group turned away from the coast.

Analyzing the results of the survey, it should be mentioned that in August, the whale distribution was similar to the July distribution. The whales mainly stayed in shallow depths along the coast. The number of whales counted south of Piltun Bay on August 30 was similar to the survey count on August 7 (31.0% and 32.1%). It may suggest that the whales prefer certain feeding areas in the feeding period.

September. In September, there were two surveys conducted using the extensive grid.

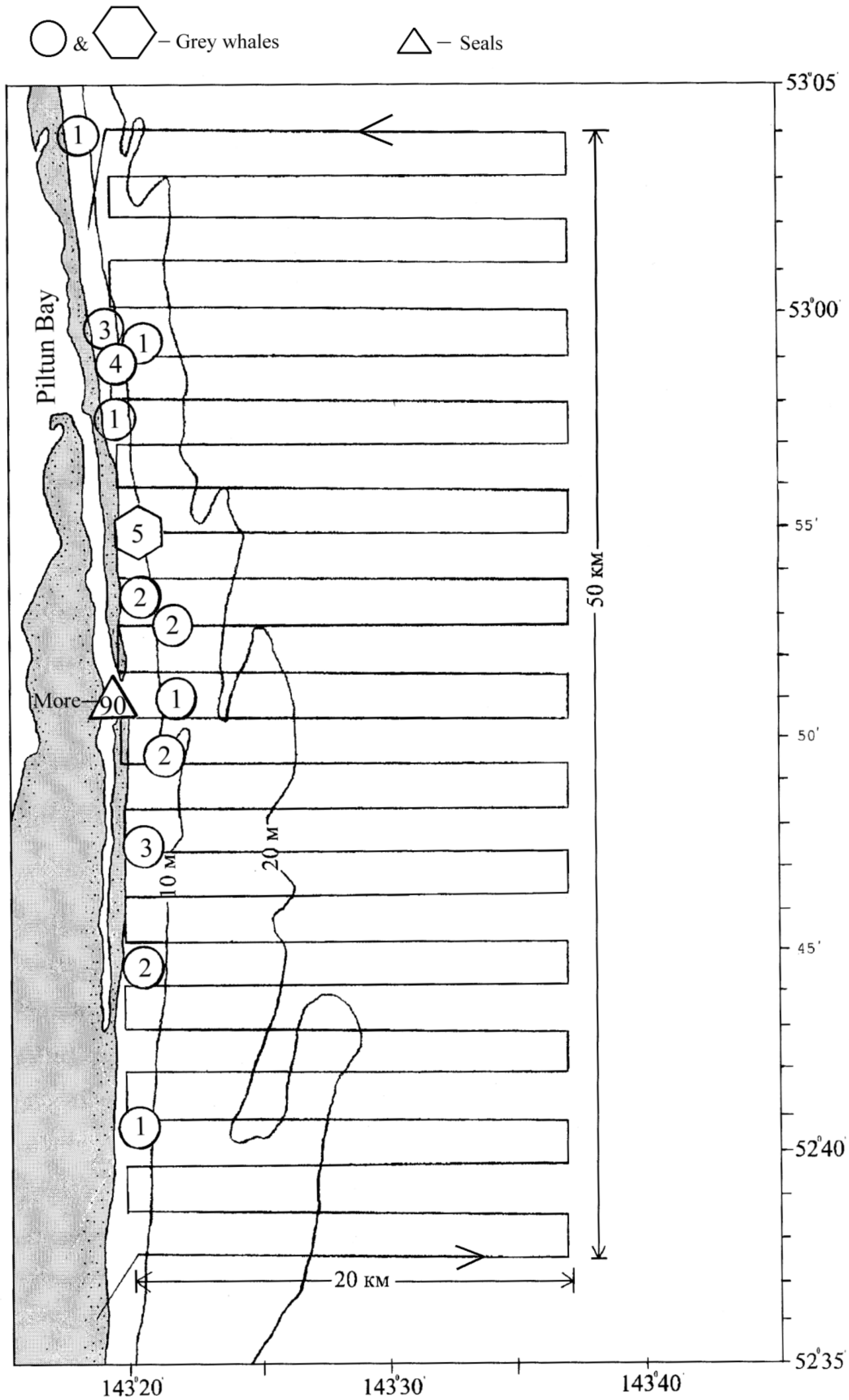


Fig. 2.7. Occurrence of mammals on shelf of Sakhalin by aerial survey at 30 August, 1999

On September 21, whales were observed on 16 transects from the Nyisky Bay toward the north. The weather was not favorable for the survey; a strong wind was blowing and the sea was slight (2-3 points). Due to bad weather, the survey was cancelled after covering 10 transects. After the weather improved, the survey resumed. It stopped raining by that time and the visibility improved, but the sea remained slight (2-3 points). A total of 33 whales were observed, though there were no whales on 10 southern transects (Fig. 2.8). Whales were not observed south of Piltun Bay either. The whales were located mainly north of 53°N, where the maximum number (78.8%) was observed. Most whales were observed at a water depth from 12 to 20 m, which may be explained by strong surf.

The whales were relatively active14 out of 33 encountered whales were moving toward the north. The other whales were feeding actively, as evidenced by mud spots and sometimes even whole mud “roads” in the locations where whales gathered. Only 4 single whales out of a total of 33 whales were observed; the other whales were observed in small groups (2-4 whales) (Table 2.5).

Table 2.5

Occurrence of mammals offshore Sakhalin based on aerial surveys in September 1999.

Date	Time	Location of sightings (longitude, latitude)	Mammals sighted, behavior
1	2	3	4
September 21	10:15 a.m.	52°18'-52°19' 143°10'-143°12'	Group of seals (25-30 individuals) on the water
	12:20 a.m.	52°48'52" 143°21'05"	1 (Gray whale) The whale is swimming along the bank to North
	From 12:20 a.m. to 4:15 p.m.		The helicopter was staying at Lighthouse
	4:20 p.m.	52°52'20" 143°21'02"	2 (Gray whale)
	4:55 p.m.	52°58'15" 143°20'32"	2+2 (Gray whale) The whales are moving to North
	5:30 p.m.	53°04'47" 143°17'50"	2 (Gray whale) The whales are feeding, muddy spots
	5:33 p.m.	53°06'41" 143°17'19"	2 (Gray whale) The whales are diving
	5:35 p.m.	53°08'11" 143°18'35"	2+1 (Gray whale)
	5:36 p.m.	53°08'27" 143°17'09"	4 (Gray whale) The whales are moving to North
	5:40 p.m.	53°09'40" 143°16'53"	1+2 (Gray whale)
	5:43 p.m.	53°10'43" 143°17'39"	2 (Gray whale) The whales are moving

			to North
	5:45 p.m.	53°11'06" 143°16'10"	4 (Gray whale) The whales are feeding
1	2	3	4
	5:48 p.m.	53°12'27" 143°15'50"	1+2 (Gray whale) The whales are feeding and diving
	6:32 p.m.	53°15'53" 143°14'36"	3 (Gray whale) The whales are feeding. There are many feeding plumes
September 22	11:30 a.m.	53°28'25" 143°07'59"	2 (Gray whale) The whales are feeding. There are feeding plumes.
	11:52 a.m.	53°21'37" 143°12'55"	1+1 (Gray whale) The whales are moving to North.
	11:53 a.m.	53°21'35" 143°12'55"	2+1 (Gray whale) The whales are moving along the bank to North
	12:03 a.m.	53°17'02" 143°14'46"	1 (Gray whale) The whale is diving and feeding
	12:07 a.m.	53°15'45" 143°15'10"	1 (Gray whale) The whale is feeding
	12:08 a.m.	53°15'04" 143°14'46"	1+1 (Gray whale) The whales are feeding
	12:11 a.m.	53°14'10" 143°17'04"	1+1 (Gray whale)
	12:13 a.m.	53°13'00" 143°16'50"	6 (Gray whale) Two males and female are playing breeding game
	12:19 a.m.	53°12'08"	5 (Gray whale) The

		143°15'47"	whales are feeding
	12:22 a.m.	53°11'41" 143°16'11"	1+1+1 (Gray whale) There many feeding plumes around the whales
	12:23 a.m.	53°11'12" 143°16'30"	1 (Gray whale)
	12:42 a.m.	53°08'07" 143°18'26"	1 (Gray whale)
1	2	3	4
	12:48 a.m.	53°06'10" 143°17'16"	1 (Gray whale) There is muddy trace on the water more than 20 m.
	1:11 p.m.	52°58'13" 143°20'10"	1 (Gray whale)
	1:15 p.m.	52°57'00" 143°20'45"	1 (Gray whale)
	1:22 p.m.	52°53'48" 143°22'21"	2+1 (Gray whale)
	1:28 p.m.	52°53'26" 143°22'26"	2 (Gray whale)
	1:33 p.m.	52°52'55" 143°21'40"	2 (Gray whale)
	2:12 p.m.	52°49'08" 143°21'51"	1 (Gray whale)
	3:48 p.m.	52°19'46" 143°10'16"	Herd of seals (more than 60 individuals)
	3:58 p.m.	52°19'09" 143°11'15"	Herd of seals (more than 100 individuals)
	4:08 p.m.	52°04'17" 143°09'15"	8 (Seals)

On September 22 we repeated the extensive grid. The weather was good; the sea was slight (about 2 points). We counted whales from the north, from Okha toward the Piltun Bay.

The first whales were encountered along the coast far from the survey area, so we decided to survey the coastal area between the 10-m and 30-m isobaths, especially because on September 21 we observed whales swimming to the north along the coast. We counted 30 whales north of 53°05′N (Fig. 2.9); most of them were feeding actively. We saw many mud spots and much evidence of their feeding. The whales were scattered mainly at a water depth of 10-20 m. Five out of 30 observed whales were moving north.

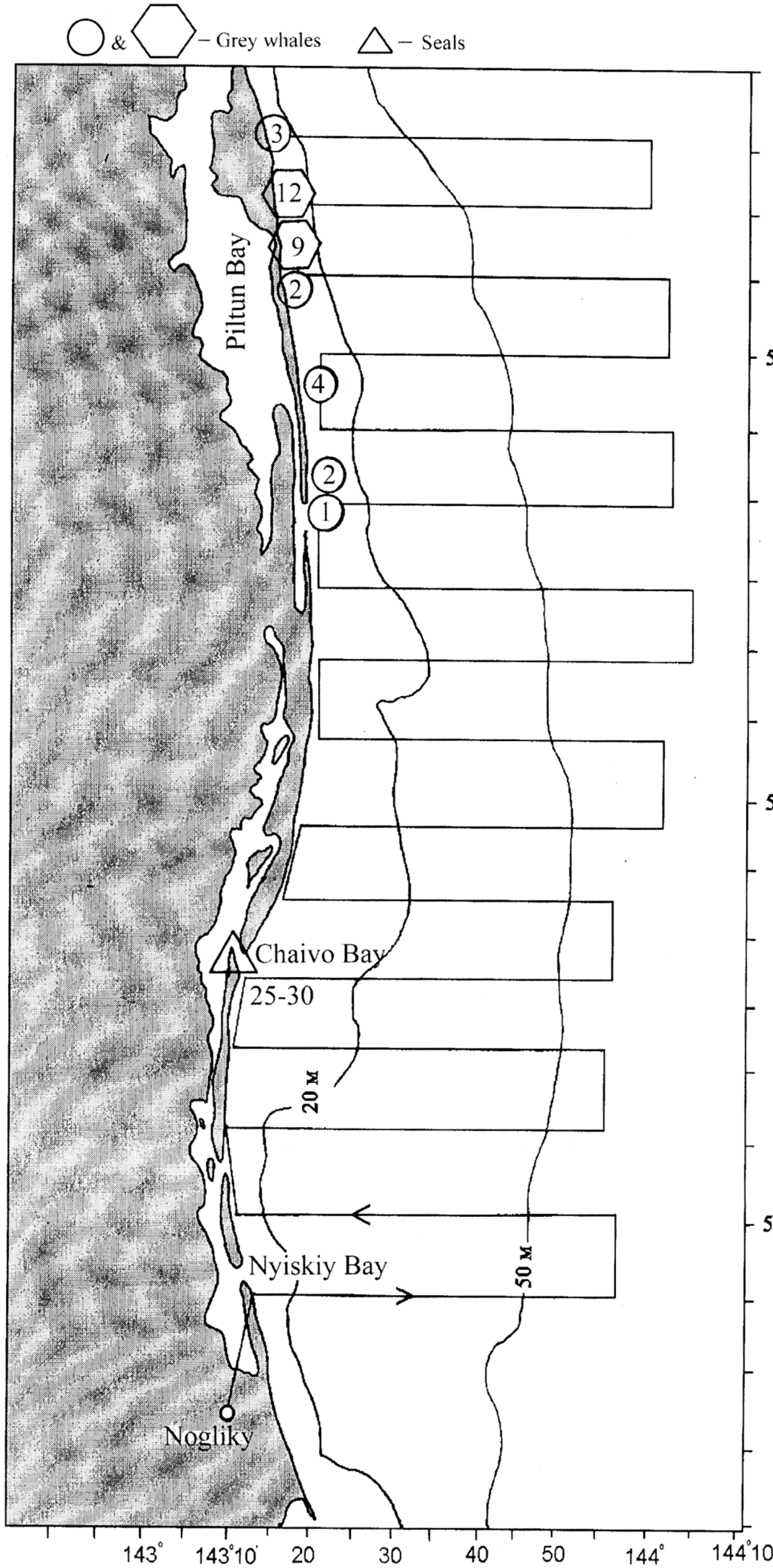


Fig. 2.8. Occurrence of mammals on shelf of Sakhalin by aerial survey at 21 September, 1999

We observed a group of 6 whales at coordinates 53°13'00"N and 143°16'50"E (Table 2.5). Slightly south, at coordinates 53°12'08"N and 143°15'47"E, we saw a group of 5 whales. We did not observe two whale groups simultaneously during the previous surveys. This group consisted of 6 units; we saw one whale (probably female) swim underwater on its back and sometimes its position was almost vertical. Another two whales were swimming next to it. Three more whales were circling nearby. All whales in the group were large. We did not observe mating, but we saw males court the female and noticed a playful behavior of the whales.

We encountered another 10 whales south of 53°N (Fig. 2.9). Like September 21, whales were not encountered south of Piltun Bay. We did not encounter a single whale on 10 southern transects of the survey area during two days.

Summarizing the results of the surveys, it was observed that at the end of September, most gray whales moved to the area lying north of Piltun Bay. During two days of the survey to the north of 53°N, we counted 56 whales, i. e., 76.8% of the total number of observed whales.

October. We conducted surveys of the intensive grid on October 8 and the extensive grid on October 9.

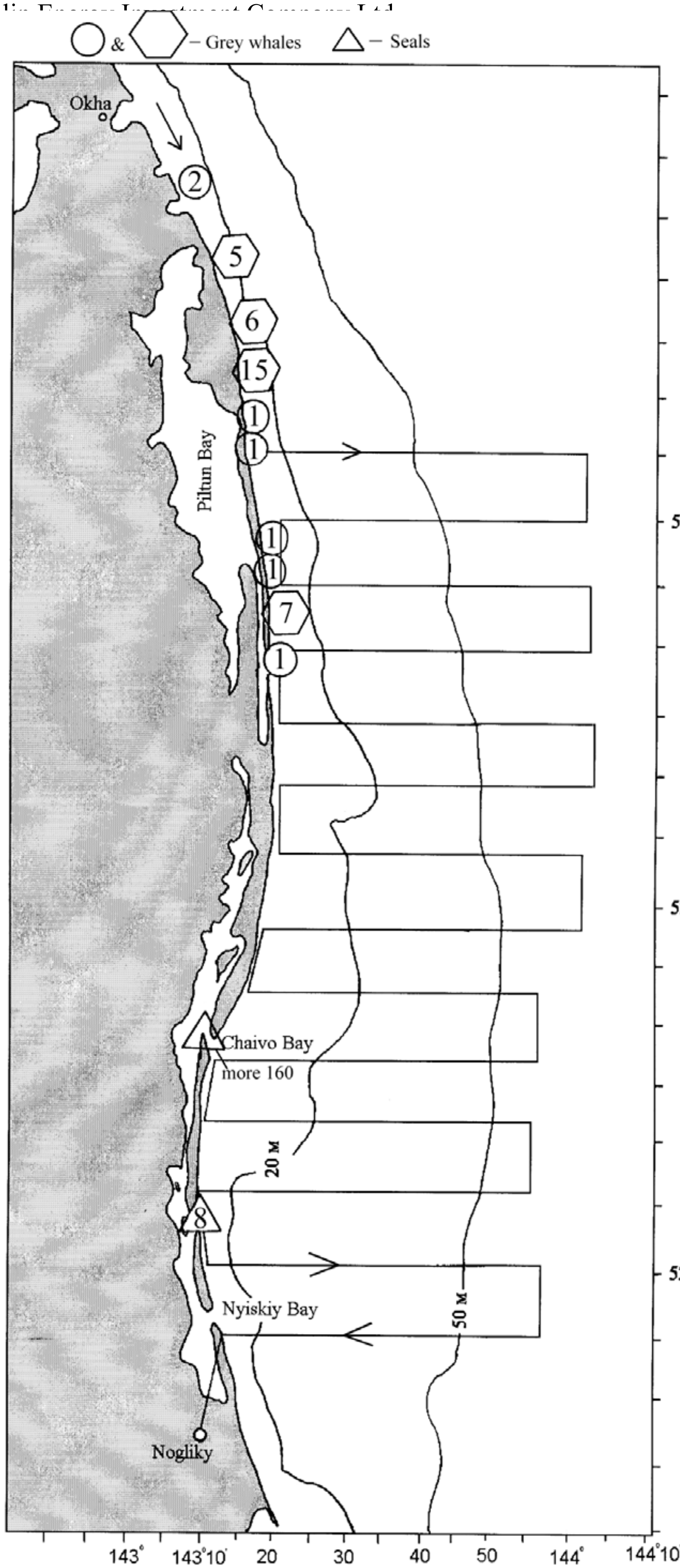


Fig. 2.9. Occurrence of mammals on shelf of Sakhalin by aerial survey at 22 September, 1999

On October 8 the sea was breaking (3 points), that is why whales' spouts could not be practically seen. We could only see a whale when the helicopter flew exactly above it or very close to it. We counted 4 whales (Fig. 2.10), one of them was going north along the coast.

On October 9, a survey of the extensive grid was completed in good weather. We observed whales from the Nyisky Bay south toward Piltun. We counted 32 gray whales (Fig. 2.11), but did not observe a single whale on 10 southern transects. No gray whales were observed swimming toward the south along the Sakhalin coast. We observed 3 whales north of 53°20′N feeding and swimming north along the Sakhalin coast. We observed 10 whales outside the survey area; one was observed as far north as on the traverse of Okha, about 47 miles north of the Piltun lighthouse.

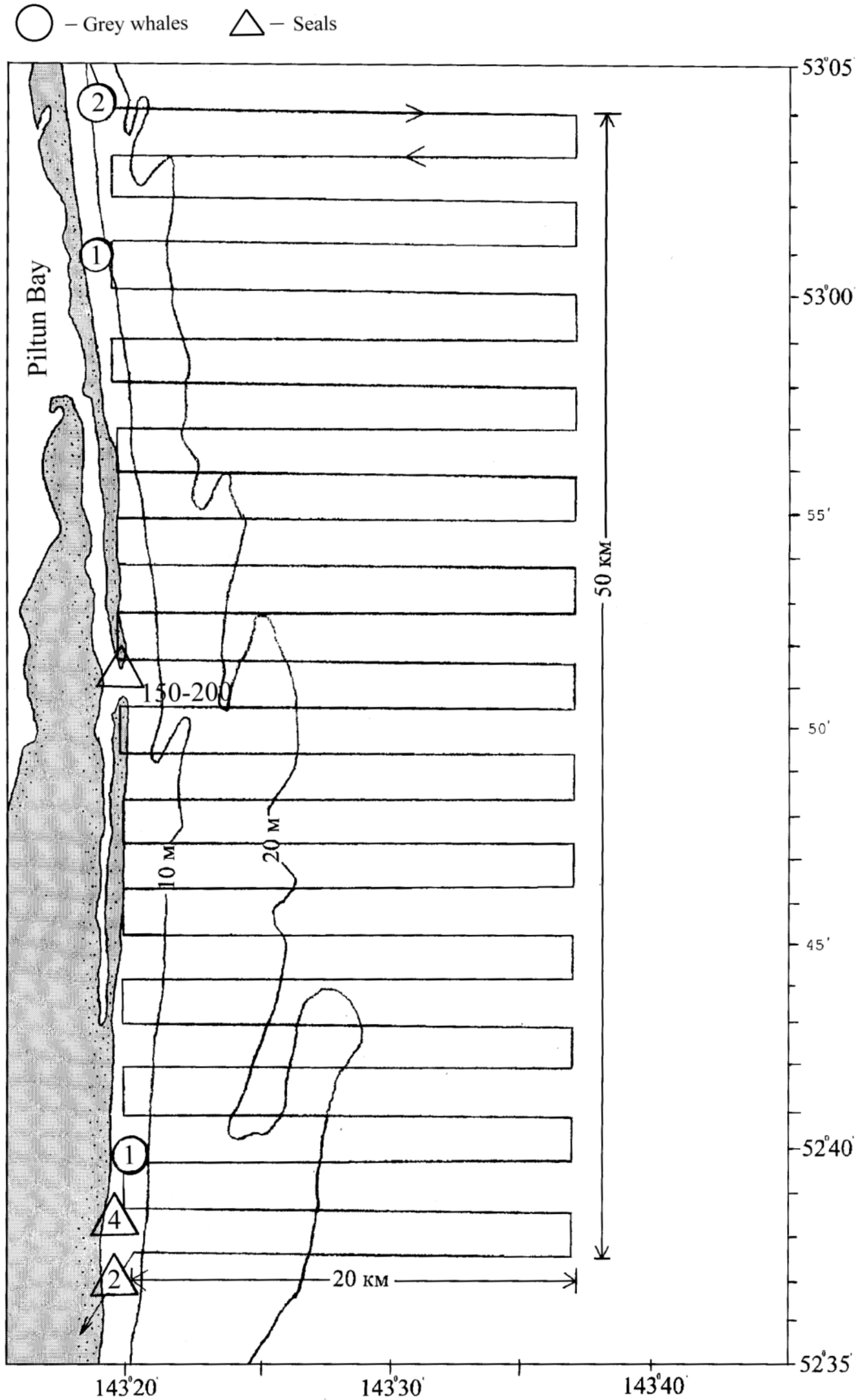


Fig. 2.10. Occurrence of mammals on shelf of Sakhalin by aerial survey at 8 October, 1999

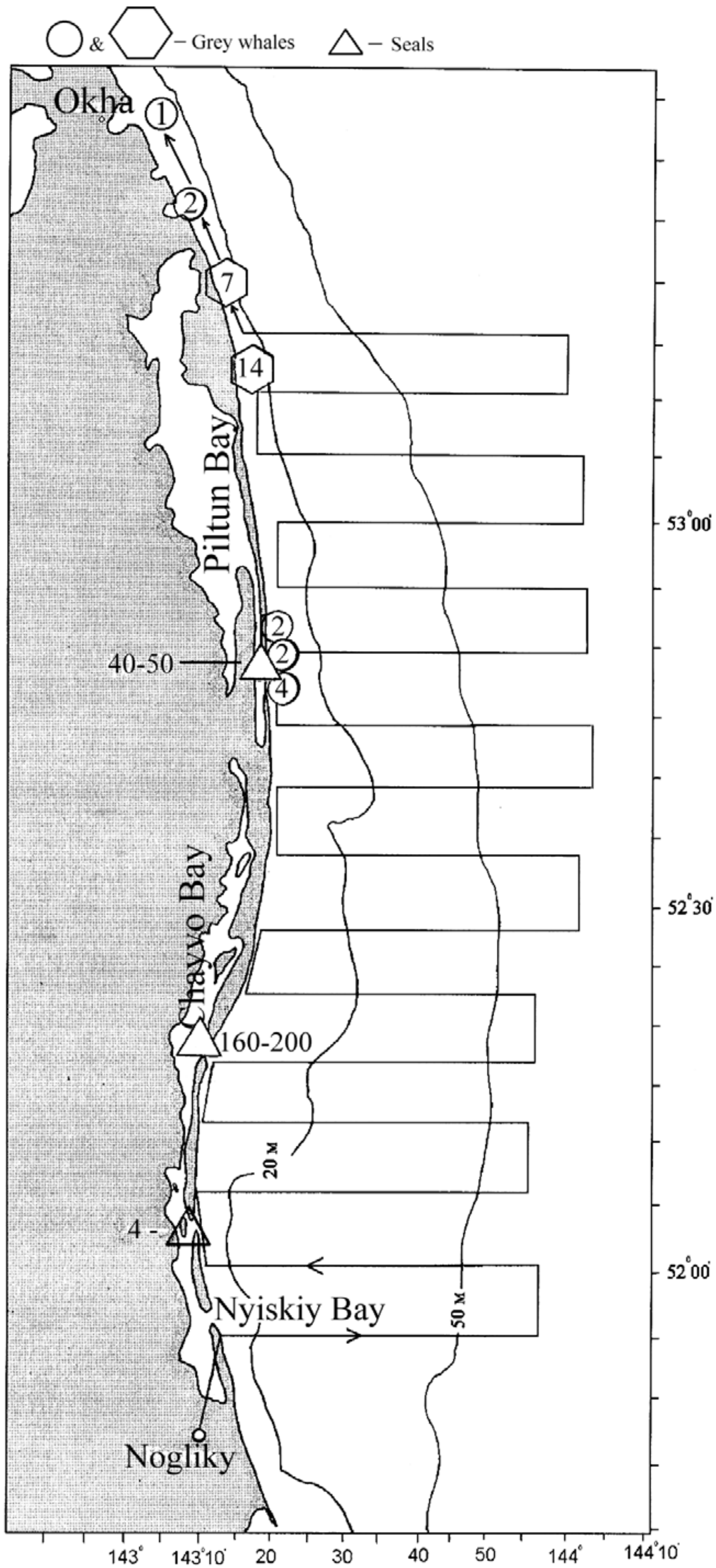


Fig. 2.11. Occurrence of mammals on shelf of Sakhalin by aerial survey at 9 October, 1999

Table 2.6

Occurrence of marine mammals offshore Sakhalin based on aerial surveys in October 1999.

Date	Time	Location of sightings (longitude, latitude)	Mammals sighted, behavior
October 8	2:28 p.m.	53°04'29" 143°19'16"	2 (Gray whale)
	3:10 p.m.	53°01'16" 143°18'53"	1 (Gray whale)
	4:23 p.m.	52°51'38" 143°19'44"	Herd of seals on the bank of Piltun Bay (about 150-200 individuals)
	5:49 p.m.	52°40'04" 143°19'58"	1 (Gray whale)
	6:05 p.m.	52°38'10" 143°19'35"	4 (Seals)
	6:22 p.m.	52°36'50" 143°19'39"	2 (Seals)
October 9	12:30 a.m.	52°05'19" 143°09'45"	4 (Seals)
	1:13 p.m.	52°19'15" 143°11'01"	160-200 (Seals)
	3:00 p.m.	52°47'54" 143°20'31"	2+2 (Gray whale)
	3:13 p.m.	52°49'20" 143°21'50"	2 (Gray whale) The whales are swimming calmly
	3:18 p.m.	52°48' 143°19'	40-50 (Seal) The seals are on the water near the cave of Piltun Bay
	3:23 p.m.	52°51'51" 143°20'06"	1 (Gray whale)
	3:26 p.m.	52°52'13"	1 (Gray whale)

		143°19'48"	
	4:58 p.m.	53°12'32" 143°15'28"	1 (Gray whale)
	5:00 p.m.	53°12'54" 143°16'12"	1+1 (Gray whale)
	5:02 p.m.	53°13'21" 143°16'16"	3+1(Gray whale) The whales are circling on the water in radius about 35-50 m
	5:06 p.m.	53°13'44" 143°15'12"	3+4 (Gray whale)
	5:12 p.m.	53°19'51" 143°12'48"	1+1 (Gray whale)
	5:13 p.m.	53°20'39" 143°12'28"	2 (Gray whale)
	5:16 p.m.	53°20'43" 143°12'18"	2+1 (Gray whale)
	5:16 p.m.	53°27'52" 143°08'15"	1 (Gray whale)
	5:20 p.m.	53°28'23" 143°07'30"	1 (Gray whale)
	5:22 p.m.	53°33'53" 143°04'43"	1 (Gray whale)

The whales observed on October 9 were in two areas. 8 whales were sighted opposite the Piltun lighthouse, swimming near the coast, in 8-12-m of water. No whales were encountered on three transects north of Piltun, but whales were observed north of 53°10′N. The most (14) whales were observed in the coastal zone between 53°12'32" – 53°13'44"N and 143°15'28" – 143°15'12"E (Table 2.6.).

On October 9, we observed circling in one of the groups consisting of 3 large whales. The whales were following each other in a circle with a radius of 40-50 m. The circling whales did not appear to be disturbed by the approach of the helicopter.

While we had presumed that gray whales would begin migrating south along the east coast of Sakhalin during October, our observations suggested that whales were still feeding actively and moving north, rather than south, during October. **November**. The original workplan concluded field observation efforts in October, but because we had observed substantial numbers of gray whales during the October surveys, we proposed that the aerial surveys be extended through November so that we could determine when gray whales left the Sakhalin feeding grounds. Project sponsors agreed to extend the survey funding through November.

On November 18 we surveyed the intensive grid. The helicopter with observers departed from Nikolayevsk-na-Amure, crossed the Amur Liman and flew along the northwestern coast of Sakhalin. The Amur Liman was covered by ice at that time, but there were iceleads everywhere. The ice was thin and mobile. We saw a group of 5 white whales (*Delphinapterus leucas*) at coordinates 53°24'23"N and 141°43'43"E. White whales were sighted along the coastal ice off northwest of Sakhalin as well.

At 11:45 we skirted Sakhalin on the north, flew over the Elizaveta Cape and began a casual survey of the coastal zone of northeast Sakhalin. Ice was being formed actively along the northeast coast of Sakhalin. The large stones projecting from the water were covered by ice. There was much sludge ice in the surf zone, sometimes 3-10 m^2 ice cakes could be seen. Ice formation was restricted to the surf zone, the rest of the water area was free of ice. There was no ice on the 10-20-m isobaths. The Sakhalin Island was covered by snow.

We observed a single whale at 53°07'16"N and 143°17'44"E (Table 2.7). It was swimming south along the coast on a 10-m isobath. The next whale, a large adult swimming south, was sighted on the 5th transect near the cost (Fig. 2.12). A female still pair-bonded with its calf were observed north of the Piltun lighthouse. The calf was characterized by a darker color and had a few light rings on the back. The female had a very light color and large light spots on the sides and the back. The behavior of whales in the Piltun area was unusual: they were secretive avoided the helicopter, barely broke the surface to respire, and dove for 5 to 7 minutes. It was practically impossible to take their picture.

On November 20 we surveyed the extensive grid from north to south (Fig. 2.13). On that day the weather was cold and sunny (air temperature 9-12°C), the sea was from calm to slight (1-2 points). There was a heavy surf resulting from a cyclone in the Sea of Okhotsk. The first singleton whales were observed near the coast in the area of 53°N on the 10-12-m isobaths (Table 2.7). The singleton whales stayed in the same General area, but blew infrequently. Some dives were timed at more than 8 minutes. Two feeding whales were sighted at coordinates 52°56'36"N and 143°19'48"E.

We observed two whales swimming north along the coast (at 52^{0}53’30”N and 143^{0}21’42”E). The whales were going at a usual speed, typical of the whales feeding in the Bering Sea and in the area of the St. Lawrence Island (Wursig et al., 1986). The speed of migrating whales increases to 3-4 km/h (Mate, Harvey, 1984).

On November 20 it was relatively difficult to observe the whales in spite of good weather. The whales were cautions and remained submerged for long periods of time.

We counted a total of 14 whales on November 20. All whales were observed opposite the mouth of Piltun Bay. No whales were observed from Piltun bay to Nyisky Bay.

If it were true that autumnal whale migrations go along the Sakhalin coast toward the La Perouse Strait, we would have encountered whales south of the Piltun Bay in October-November. But it was not so. Therefore, the existing opinion about autumnal migrations of gray whales along the Sakhalin coast to south requires accurate definition.

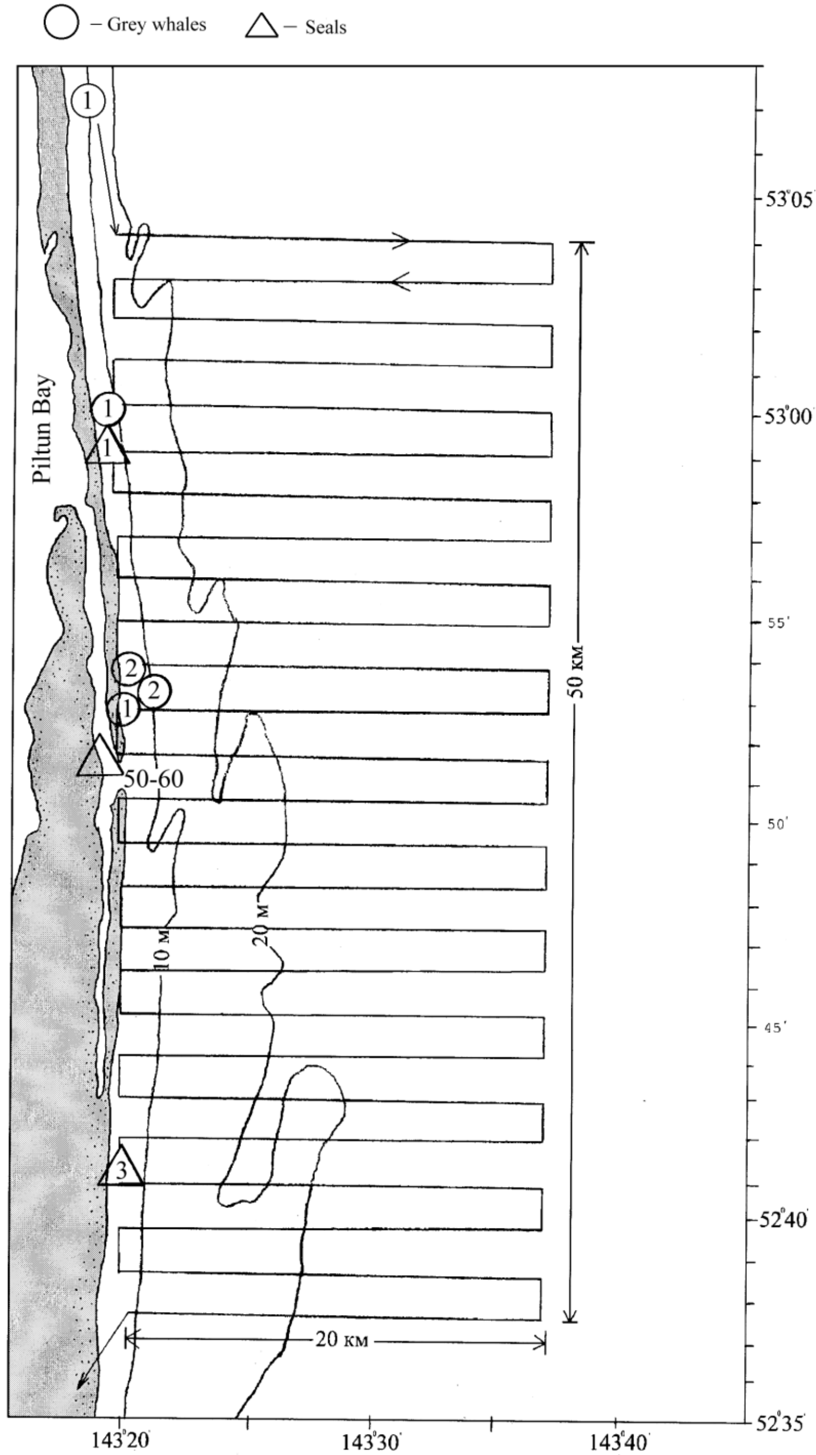


Fig. 2.12. Occurrence of mammals on shelf of Sakhalin by aerial survey at 18 November, 1999

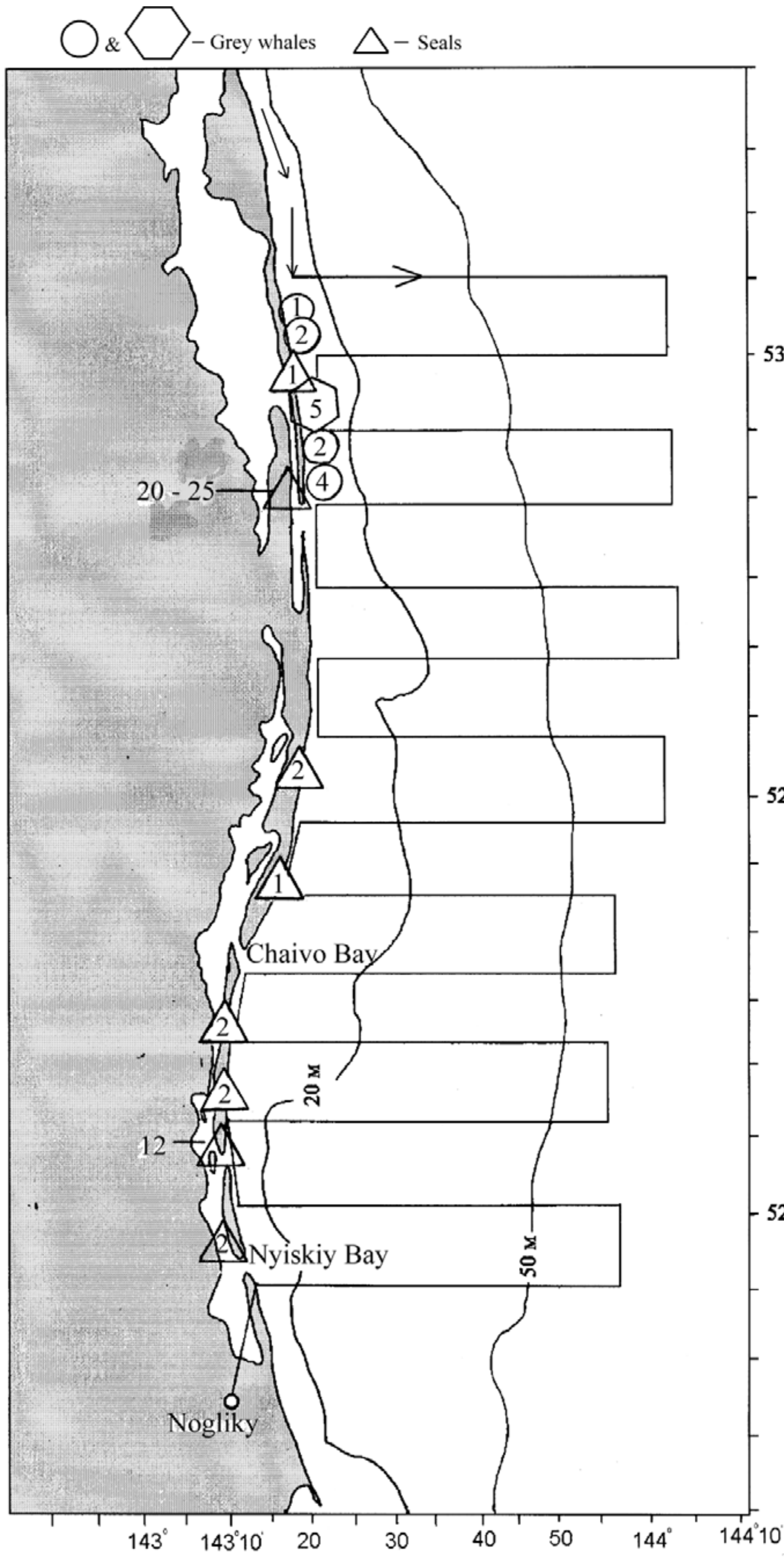


Fig. 2.13. Occurrence of mammals on shelf of Sakhalin by aerial survey at 20 November, 1999

Table 2.7

Occurrence of marine mammals offshore Sakhalin by aerial surveys in November 1999.

Date	Time	Location of sightings (longitude, latitude)	Mammals sighted, behavior
November 18	11:45 a.m.	54°01'53" 142°59'14"	1 (Spotted seal)
	12:35 a.m.	53°13'23" 143°15'16"	1+2 (Seals)
	12:45 a.m.	53°07'16" 143°17'44"	1 (Gray whale)
	1:20 p.m.	53°01'25" 143°19'46"	1 (Gray whale)
	1:41 p.m.	52°59'49" 143°19'31"	1 (Seals)
	2:26 p.m.	52°53'57" 143°19'35"	1+1 (Gray whale) Female with young one
	2:33 p.m.	52°53'20" 143°21'00"	2 (Gray whale)
	2:47 p.m.	52°53'08" 143°20'39"	1 (Gray whale) The whale is very careful. It is spending long time under water
	2:55 p.m.	52°51'01" 143°19'15"	50-60 (Seals) The seals are on the ice
	4:10 p.m.	52°41'05" 143°19'56"	3 (Seals)
November 20	11:20 a.m.	53°01'08" 143°19'12"	1 (Gray whale)
	11:26 a.m.	53°02'06" 143°18'18"	1 (Gray whale) The whale is very careful
	11:30 a.m.	53°01'24" 143°18'12"	1 (Gray whale)
	11:43 a.m.	52°59'42"	1 (Seals)

		143°18'12"	
	11:52 a.m.	52°57'12" 143°20'30"	1 (Gray whale)
	12:00 a.m.	52°56'36" 143°19'48"	2 (Gray whale) The whales are staying on one place
	12:05 a.m.	52°56'12" 143°20'42"	2 (Gray whale) The whales are very careful. They are spending 5-7 min. under water
	12:24 a.m.	52°53'30" 143°21'42"	2 (Gray whale) The whales are moving along the bank to the North
	1:05 p.m.	52°52'18" 143°20'36"	1 (Gray whale)
	1:07 p.m.	52°52'17" 143°20'18"	1 (Gray whale)
	1:16 p.m.	52°50'54" 143°22'18"	1+1 (Gray whale)
	1:22 p.m.	52°50' 143°18'	20-25 (Seals) The seals are on the ice
	2:10 p.m.	52°31'42" 143°18'53"	2 (Seals)
	2:56 p.m.	52°23'30" 143°15'48"	1 (Spotted seal)
	3:38 p.m.	52°12'42" 143°09'35"	1 (Seals)
	3:49 p.m.	52°10'48" 143°09'06"	1 (Seals)
	3:52 p.m.	52°07'30" 143°09'36"	2 (Seals)
	3:55 p.m.	52°05'18" 143°08'06"	12 (Seals)
	4:00 p.m.	51°57'54" 143°11'15"	2 (Seals)

2.2 Analysis of Spatial Distribution of Gray Whales in the Summer Feeding Areas

The analysis of spatial distribution of gray whales requires simultaneous count over their entire summer habitat. This problem can be solved only using a helicopter and small ships. Observations from some lighthouses and observational stations do not provide the overall picture of whale distribution. Such operations only show the whale occurrence in a given area and direction of summer migrations. Count of whales by photographs does not provide information on their distribution, main area of their aggregation and monthly and seasonal migration paths either, because such work was done in a limited area near the Piltun lighthouse and did not cover the greater part of the summer habitat off northeast Sakhalin.

According to the results of the whale count, their distribution is not uniform. Earlier we have already analyzed in detail the count results month by month. The aerial count enables us to make some generalization and analyze the spatial distribution of gray whales offshore Sakhalin. In the first place, we should point out a relatively nonuniform whale occurrence in the accounting area. Most whales were encountered in the coastal zone at a depth of 16-20 m, whales were practically absent beyond the 50-m isobath (Table 2.8).

The analysis of the results of count made in July-November 1999 (Table 2.8) indicated that in all months the whales preferred the coastal zone with depths to 20 m. More than 90% of all counted whales were encountered there. The offshore areas with depths from 21 to 50 m were visited by whales much more seldom (7.9%), in August-November whales were not practically encountered beyond the 50-m isobath.

Table 2.8.

The gray whales distribution pattern offshore North-East Sakhalin in July – November 1999.

Month	Isobaths where whales were encountered								Total number of whales encountered (ind.)
	up to 10 m		10 – 20m		21 – 50 m		over 50 m		
	no.	%	no.	%	no.	%	no.	%	
July	33	40.7	38	46.9	8	9.9	2	2.5	81
August	45	43.3	57	54.8	2	1.9	0	-	104
September	21	28.8	43	58.9	9	12.3	0	-	73
October	13	36.1	17	47.2	6	16.7	0	-	36
November	9	42.9	12	57.1	0	-	0	-	21
Total	121	38.4	167	53.0	25	7.9	2	0.6	315

Note: The table presents the results of 8 surveys using an extensive grid and 5 surveys using an intensive grid.

Gray whales feeding in the shallow waters offshore Sakhalin

Thus, the shallow-water offshore area is the main habitat of whales in the feeding period.

In summer 1999 gray whales were not encountered south of 52°30′N. But on July 21, 1995 we observed a group of 5 gray whales about 58 miles south of the Piltun Bay and 19 miles from the coast, opposite the southern part of the Nyisky Bay while aboard the Russian Academy of Sciences ship *Vulkanolog* (Sobolevsky, 1998). During the first ten days of July 1999 we observed 2 gray whales at a large distance from the coast north of 53°N (Fig. 2.1). Therefore, in the analysis of distribution of gray whales off northeast Sakhalin in the summer feeding period we should consider the possibility of their presence at a large distance from the Piltun Bay.

It is known that each whale species has its habitat depending on climatic factors and trophic specialization (Zemsky, 1974). The distribution pattern of gray whales offshore Sakhalin probably depends on the presence of adequate stocks of available prey species (Sobolevsky, 1998). During the initial stage of the recruitment of the Okhotsk-Korean population the feeding area of gray whales will likely be smaller than when the population has recovered fully. At present, the population of the Okhotsk-Korean stock is growing slowly; it is important to minimize the impact of factors that might hinder the recovery of the Okhotsk-Korean stock of gray whales, including negative impacts on the offshore area by industrial activity and harvest of marine resources in the region.

It is well-known that the whales are characterized by good cooperation and mutual assistance (Tomilin, 1935, 1957; Krushinskaya, 1974) which evidence themselves in the formation of small groups during the summer feeding period. The analysis of occurrence of individual groups showed that in spite of relatively small number of whales off northeast Sakhalin we often encountered groups consisting of 2-3 and more individuals. We dominantly encountered groups of 2 whales (26.6%); groups consisting of 3-6 animals were less common (Table 2.9). There is an opinion that small groups normally consisting of 2 whales are the most stable.

Table 2.9.

Analysis of Occurrence for Individual Groups of Gray Whales Offshore North-East Sakhalin in July – November 1999

Months	Number of encoun-ters	Percentage of occurrence of single whales and individual groups											
		single whales		two whale groups		three whale groups		four whale group		five whale group		six whale group	
		no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
July	58	42	72.4	11	19.0	3	5.2	2	3.4	0		0	
August	59	29	49.2	18	30.5	10	16.9	1	1.7	1	1.7	0	
September	42	23	54.7	14	33.3	1	2.4	2	4.8	1	2.4	1	2.4
October	23	14	60.9	6	26.1	2	8.7	1	4.3	0		0	
November	17	13	76.5	4	23.5	0		0		0		0	
Total	199	121	60.8	53	26.6	16	8.0	6	3.0	2	1.0	1	0,5

Groups consisting of 3 and more whales are considered less stable, they take apart easily (Sokolov, Arseniev, 1994).

During the July-November 1999 period, we observed no whales south of 52°30'N and a maximum concentration between 52°45' – 53°15'N at a distance of 1-5 km from the coast on the 8-15m isobaths. During the summer and fall of 1999, this area appeared to be the primary feeding grounds for gray whales (Table 2.10). As shown in Table 2.10, the seasonal distribution of feeding whales varied. During July and August, most feedling whales were observed off Piltun Bay. During September and October, feeding whales were most often observed north of Piltun Bay in the vicinity of 53°20'N. Generally poor weather during the November surveys prevented good behavioral observations, nevertheless we observed two feeding gray whales at 52°56'36"N and 143°19'48"E on November 20. In summary, it appears that during 1999, the feeding grounds of gray whales off northeast Sakhalin included a strip of coastal habitat about 80 km long (N_S) in waters 5-15 km deep.

In the future, it will be important to extend the aerial surveys in time and space to include the May-June period and ice free areas north of Piltun Bay. In this way, we will be able to determine the seasonal extent of gray whale use of the northeast Sakhalin area and also determine if gray whales are using areas away from Piltun Bay.

In September-October the feeding areas of gray whales shifted toward the north considerably up to $53^0$20'N. Most whales fed in the shallow water zones in these areas. Feeding of whales opposite the Piltun lighthouse and south of the mouth of Piltun Bay in these months was reported much more seldom (Fig. 2.14). In November the weather did not enable us to observe feeding of whales. Me can only mention that we saw two feeding whales at water depth of 9-10 m at coordinates $52^0$56'36"N and $143^0$19'48"E.

Thus, our aerial observations suggest the existing of feeding areas preffered by gray whales in various seasons. In July-August most whales preffered shallow water zones south of 53^0 N; only a few whales were noticed on 10-15 m depth slightly north of 53^0N. In September-October most whales fed north of 53^0N in four feeding areas (Fig. 2.14).

Table 2.10

Spatial Structure of Summering Whale Groups Offshore North-East Sakhalin

Month	Number of whales observed in the regions												Total	
	51º55' – 52º30'		52º30'1"- 52º45'		52º45'1"- 53º00'		53º00'01' '-53º15'		53º15'1"- 53º30'		53º31'- 53º45'			
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
July	0	-	5	6.2	48	59.2	23	28.4	5	6.2	0	-	81	100
August	0	-	5	4.8	56	53.8	40	38.5	3	2.9	0	-	104	100
September	0	-	0	-	17	23.3	42	57.5	14	19.2	0	-	73	100
October	0	-	1	2.8	8	22.2	17	47.2	9	25.0	1	2.8	36	100
November	0	-	0	-	16	76.2	5	23.8	0	-	0	-	21	100
Total	0	-	11	3.5	145	46.1	127	40.3	31	9.8	1	0.3	315	100

Note: The table presents the results of 8 surveys using an extensive grid and 5 surveys using an intensive grid. Coordinates of extensive photography 51º55'-53º15' N, distance of each transect from the shore 50 km.

Much less feeding whales were noticed in the area of the Piltun lighthouse. It is known that the spatial distribution of any population is closely associated with abundance of animals (Shilov, 1977). At present due to low number of whale population this factor does not matter. After recruitment of Okhotsk-Korean stock we shall better understanding of the actual distribution of gray whales.

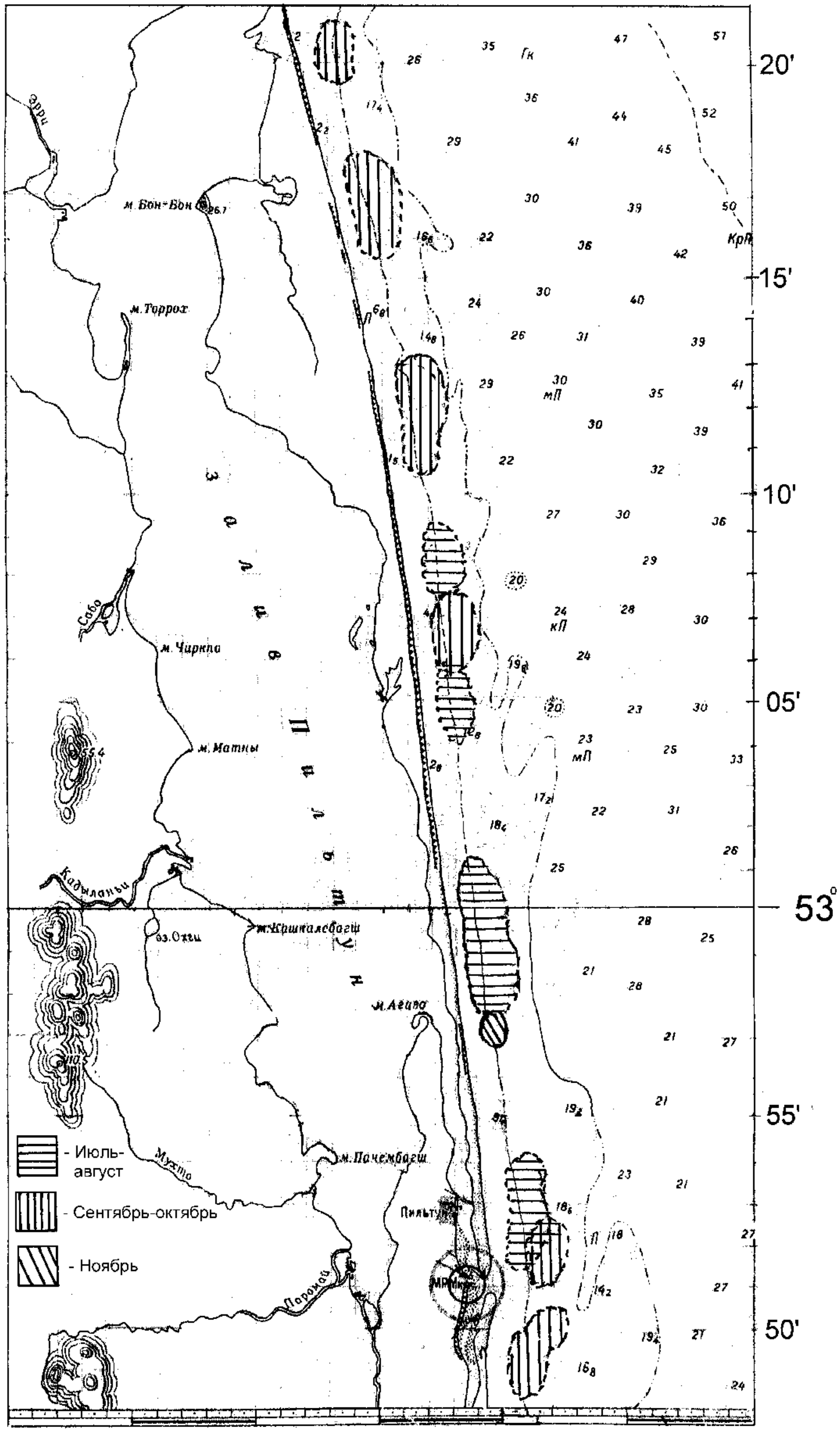


Fig. 2.14. Offshore areas where feeding whales were observed most often from the helicopter in June-November 1999.

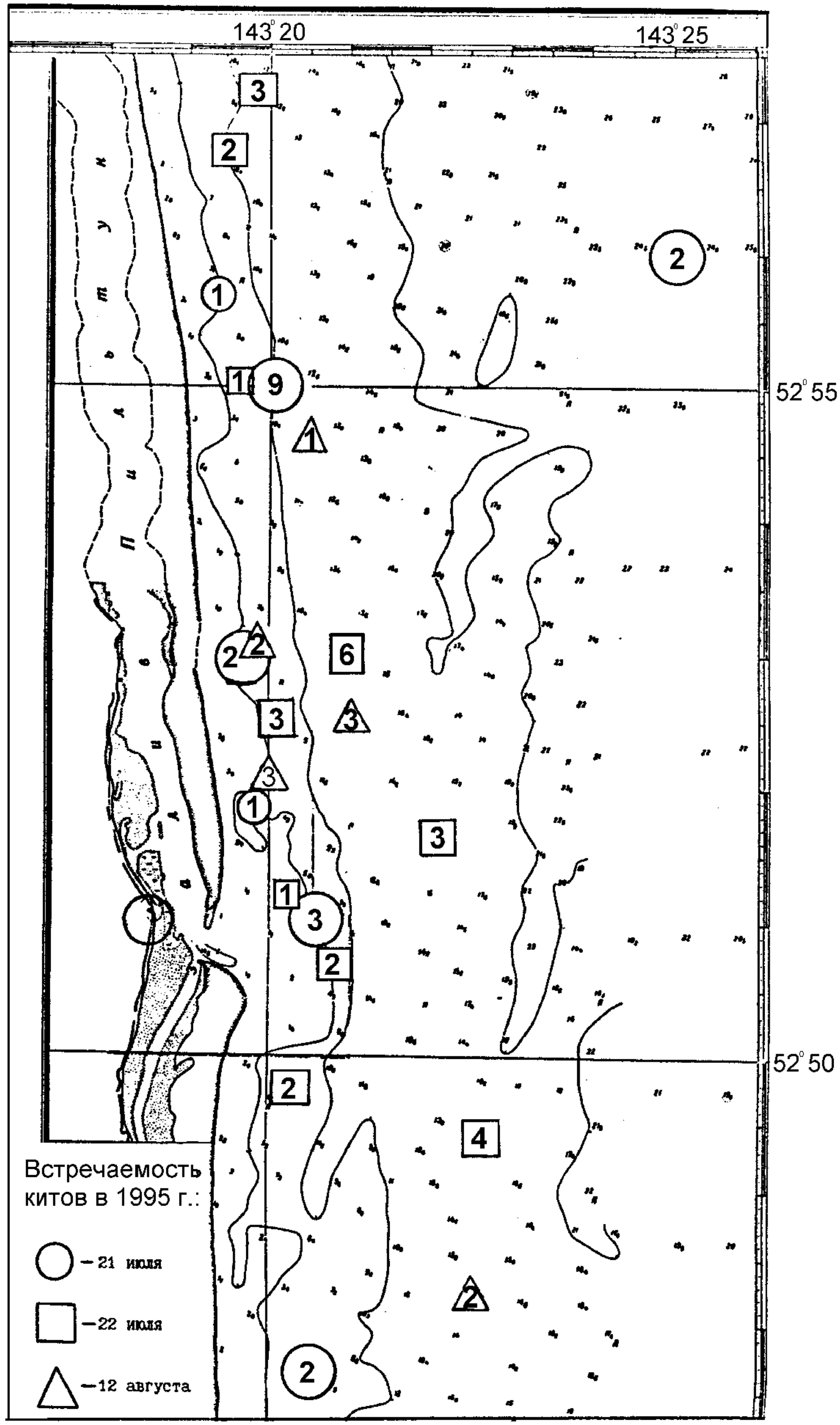


Fig. 2.15. Areas of the highest occurrence of gray whales offshore North-East Sakhalin in July-August 1995 (Sobolevsky, 1998)

3. Distribution and Number of Seals Offshore North-East Sakhalin

Systematic investigation of pinnipeds off eastern Sakhalin practically stopped in the early 90s because of the termination of hunting offshore Sakhalin in the spring period and reduction in funding of research. Previously, seal investigation off eastern Sakhalin was carried out in spring from hunting boats and during aerial censuses (Fedoseev, 1970; Fedoseev et al., 1970).

The investigation of summer distribution of seals was restricted to the identification of shore rookeries and approximate counts of seals (Kosygin et al., 1986).

The work completed under in the summer-autumn season 1999 off northeast Sakhalin covered a small area and could not reveal the actual distribution of marine mammals off eastern Sakhalin. Our research had a specific nature: identification of the largest seal rookeries and seal census. Seal aggregation were studied in greater detail in Piltun, Astokh, Chaivo and Nyisky Bays. Observation and surveys were made by helicopter along the shoreline mainly in the area of the Piltun Bay. We photographed and counted seals in the permanent and temporary rookeries.

According to the surveys, the distribution of seals off eastern Sakhalin is somewhat similar to that off the northwest coast of Sakhalin, in the area of the Shantar Islands (Sobolevsky, 1999). For most of the summer the seals disperse along the shore making aggregations of various size in the bays and places not fit for human economic activity.

Seal distribution at the beginning of summer (June-July) off northeast Sakhalin shows that most seals scattered along the shoreline (Sobolevsky,

1988) without large aggregations. The largha seal (*Phoca largha*) is the most abundant species at this time. The bearded seal (*Erignathus barbatus*) and ringed seal (*Phusa hispida*) are less common. The northern fur seal (*Callorhinus ursinus*) and the Stellar sea lion (*Eumetopias jubatus*) enter the Piltun Bay infrequently.

Until the arrival of spawning salmon, the seals are distributed along the coast almost uniformly. Their abundance varies from 1-3 to 6-10 animal units per kilometer of the shoreline. In the shore areas adjoining the bays the seal abundance increases to 15-20 units per km or more (Sobolevsky, in literature). In the bays seal density and their number can vary widely depending on the food availability and disturbance by people.

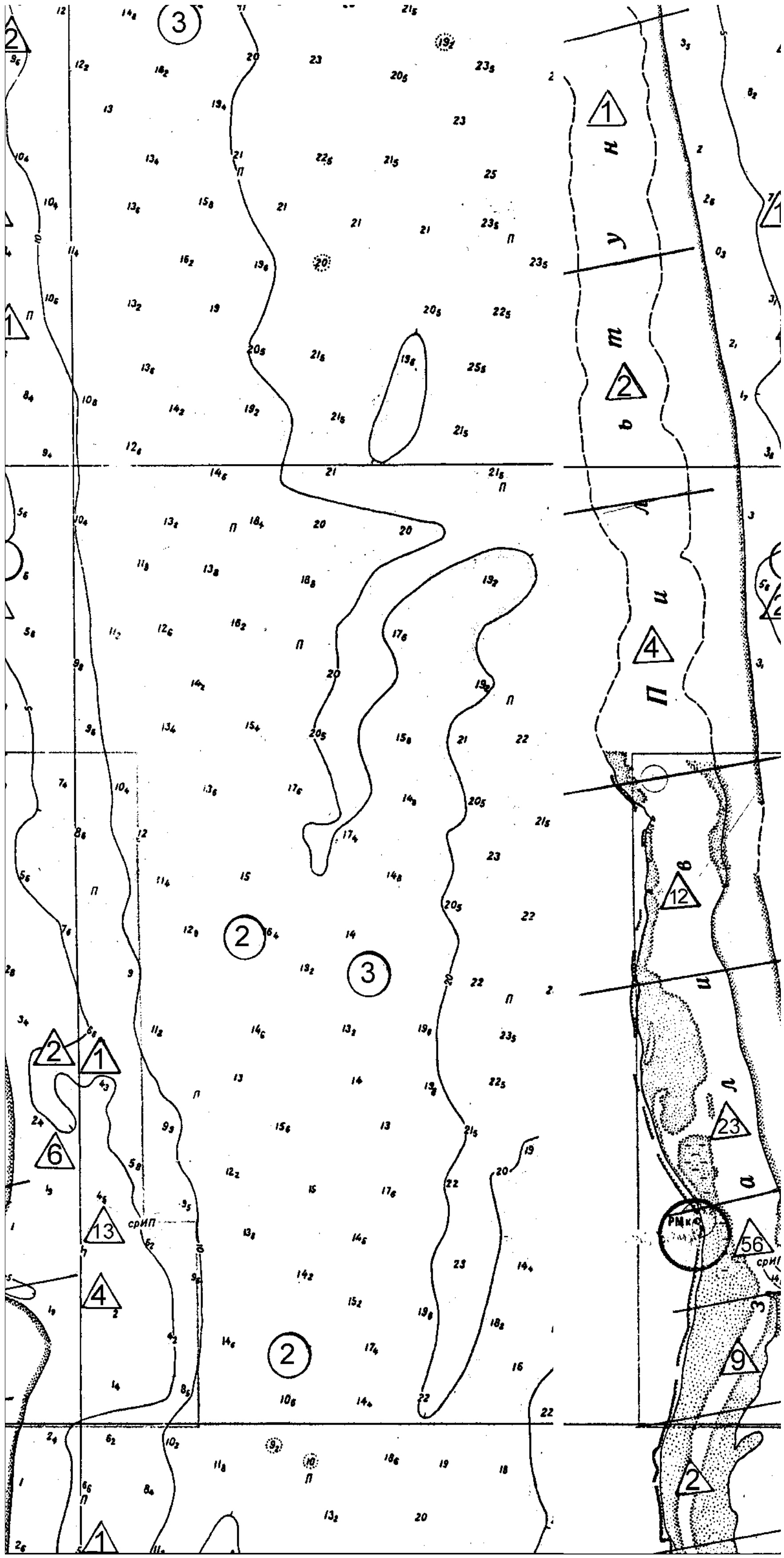
We began regular seal surveys in Piltun Bay using the *Zodiak* motorboat on July 13. The seals could be observed everywhere within the bay from its mouth to the Agiva Cape in the north. Seals made temporary rookeries on the shore opposite the lighthouse during daylight hours. The number of seals in the rookery varied continuously depending on the weather. During rainy or windy weather most animals stayed in the water, while on the warm and sunny days the seals preferred to lie on the beach. On such days they numbered more than 100.

In July-August seals often hauled out at different locations depending on the weather and disturbance by fishermen. In July, seals in the Piltun Bay were active in the morning and evening as they moved about the bay in the search for food. Seals were constantly observed from the Agiva Cape toward the lighthouse. Largha seals were most numerous in this area, bearded seals and ringed seals were rarely observed. The density of larghas increased toward the mouth of Piltun Bay.

In mid-July the lowest seal density was observed between the Agiva Cape and the fishery base: from 3-5 to 10 seals could be countered there in the morning. As a rule, these were juveniles or young-of-the-year pups. Between the fishery base and the lighthouse the seals could be seen floating at the surface; in the morning and evening they swam actively in the search for food. In mid-July the number of larghas in this area varied from 20 to 40 animals (Fig. 2.16). Throughout July the maximum number of seals could be observed near the mouth of the bay. On some days their number varied from 50-60 to 80-120. In shallow Astokh Bay (20 km in length) which is connected to Piltun Bay the number of larghas usually did not exceeded 11-27 heads.

Until the beginning of the pink salmon spawning season, seals could be always seen along the coast. Sometimes they could be seen in the vicinity of gray whales, but the whales mostly kept apart. The seal abundance at sea in the Piltun area varied from 1-2 to 5-6 units per kilometer of the shoreline. Before mid-July, small numbers of seals remained in the bays located south of Piltun. On July 17 we counted 60-65 seals on the sand spit in the mouth of the Chaivo Bay and 35-40 seals on the shoal near the shore.

Fig. 2.16. Marine mammals distribution over the water area of Piltun Bay in mid-July (data from the survey of 14.07.99).



The distribution of seals at the beginning of summer mainly depended on the availability of food. In the Piltun Bay fish serves as food for the largha, the most abundant species of seal. 32 species of fish were found in the bay in 1999 during fish fauna research. The dominant role in the nutrition of the largha in the summer-autumnal season belongs to the Pacific herring (*Clupea pallasi*), humpback salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), silver salmon (*O. kizutch*), Arctic char (*Salvelinus alpinus*), East Siberian char (*Salvelinus leucomaenis*), Asian smelt (*Osmerus mordax dentex*), pond smelt (*Hypomesus olidus*), big-scaled redfin (*Tribolodon hakonensis*), Far Eastern navaga (*Eleginus glacilis*), masked greenling (*Hexagrammos octogrammus*), and white-spotted greenling (*Hexagrammos stelleri*).

Many young herring were observed in the bay from July until September. Large herring entered the bay at the beginning of October. Many navaga (up to 70% of biomass) was observed in the mouth part of the bay. In July-August, 1999 many East Siberian chars were found in the catches, in September large individuals migrated from the bay. The number of larghas increased when salmons entered the bay.

The relatively large species diversity of fish in Piltun Bay and high biomass of fish species important for largha feeding (navaga, smelt, East Siberian char, redeye, rock trout etc.) enabled the seals to disperse over a large area from the mouth of the bay to the Agiva Cape in summer. The greatest seal density was observed toward the near-mouth part of the bay where the biomass of such species as navaga, East Siberian char, redeye, smelt and rock trout was much larger, compared to the center of the bay and north of the Agiva Cape.

During the salmon spawning migrations, the number of seals in the shore rookeries increased noticeably. Also during salmon spawning migrations, most seals stopped local movements along the shore and moved toward the bays and the mouths of spawning rivers. Such movements became especially noticeable during the second half of August when most seals gathered in the mouth of the spawning rivers. For instance, on August 7 the number of seals in the rookery in the Nyisky Bay increased to 150-180 animals. Another rookery appeared in the Piltun Bay at that time. The total number of seals in the bay in the first 10 days of August reached 220-250 animals. About the same number of seals was reported in July 1995 (Sobolevsky, 1998).

During daylight in August the seals in the Piltun Bay were very cautious and left the rookery when a boat or a small ship approached the shore. The seals often changed the location of the rookery and moved to the opposite part of the bay due to frequent disturbances by the fishermen. After humpback salmons entered the Astokh Bay the number of seals to about twice the total observed in mid-July.

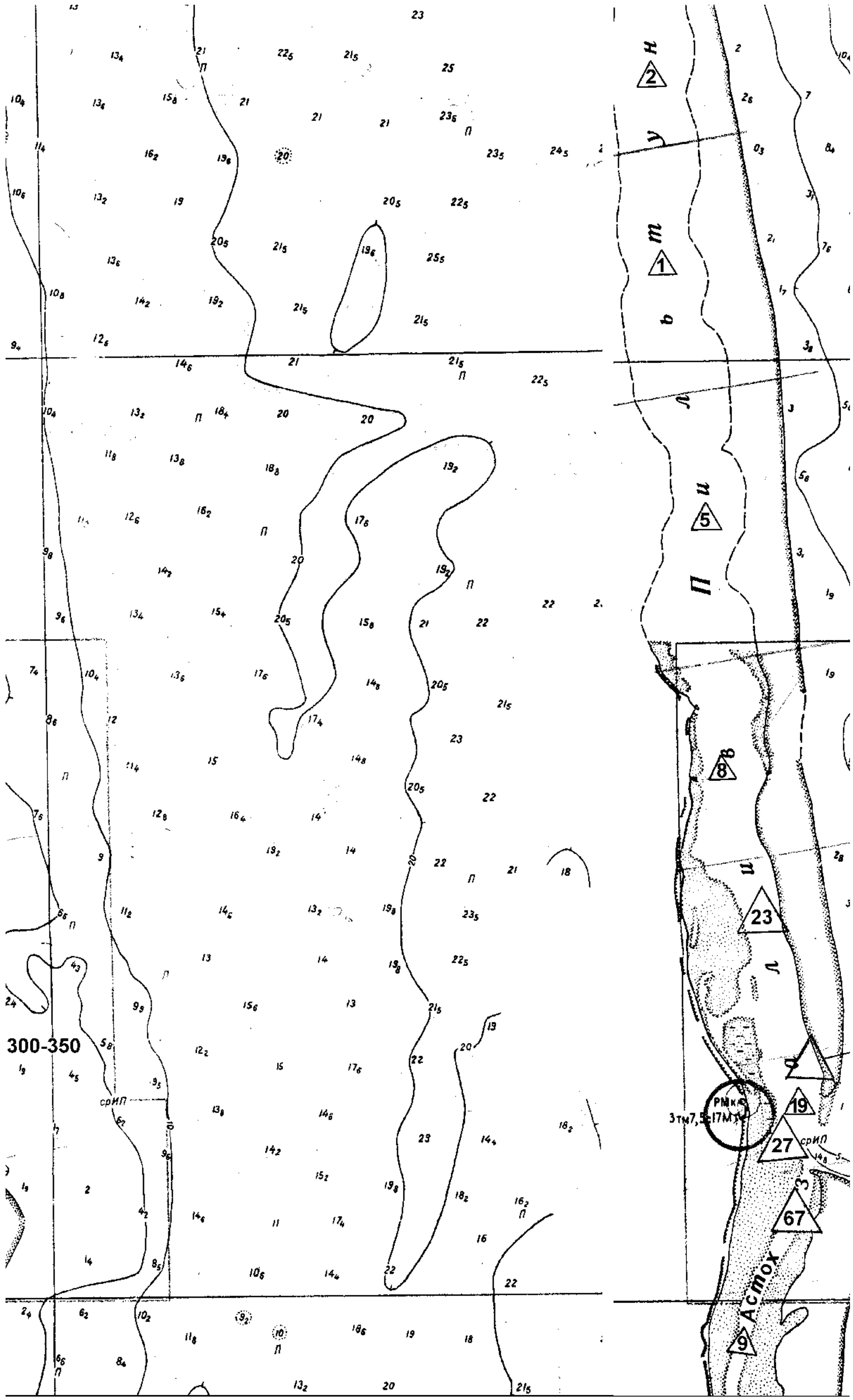
The maximum number of pinnipeds offshore northeast Sakhalin was observed during the aerial survey on **August 30** when a relatively large (more than 2000 heads) seal rookery appeared at the mouth of the Chaivo Bay. The rookery consisted of three herds. All herds were easily observed from the helicopter, which enabled us to photograph the animals. Two herds were located on the sand banks and one on a sand spit. The seals on the sandbars were lying close to each other. The first herd was 100-120 m in length and 10-20 m in width, the second herd 120-150 m in length and 10-30 m in width. The herds mainly consisted of larghas, but there were also bearded seals which could be recognized by their different color and larger size. The third herd was located on the sand spit dividing the bay into halves. The seals were not lying so close to each other there.

During the helicopter flight, the seals remained calm and did not go into the water. During the second flight and aerial photography about 10-15% of seals went into the sea from the central, largest rookery and about 25-30% from the sand spit. During the third flight at lower height (100 m) about 45% of the original number of seals remained in the rookery. The total number of seals in the rookery in the Chaivo Bay was 2,200 based on counts from photographs. In Nyisky Bay, about 150-200 seals stayed mainly in the mouth of the bay due to continuous disturbance by fishermen. A reliable count of seals in the large rookeries can be only done by good aerial photographs.

On **August 31** we counted 58 seals afloat and 27 seals lying on a shoal near the left shore of the bay from a motorboat Piltun Bay in cloudy weather (Fig. 2.17). Most seals were lying on a sand beach about 200 m from the mouth of the bay. The seals were lying relatively close to each other in 5-6 rows very close to the water line. The length of the rookery was 90-100 m. We estimated the number of seals at 300-350. About 60% of seals went into the sea when the helicopter approached the rookery. Seven beaded seals went into the sea together with the larghas.

On August 31, we counted 76 seals in Astokh Bay, all afloat at a distance of 1-2 km from Piltun bay. Eight larghas were countered in the back portion of the bay (Fig. 2.17). At 15 o’clock we repeated the count in the Piltun Bay.

Fig. 2.17. Seals distribution over the water area of Piltun Bay in late August (data from the survey of August 31)


300-350
срИП
Астох
2
1
5
8
23
19
27
67
9

At the connection with Astokh Bay we countered more than 200 seals afloat. About 220-250 seals were in the rookery on the opposite side of the bay; 37 seals were countered between the lighthouse and the fishery base and 17 seals between the fishery base and the Agiva Cape. Both counts showed about 480-540 seals in Piltun and Astokh Bays.

During **September-October** most seals left Piltun Bay and dispersed along the shoreline again. According to the census made in the third ten-day period of September, about 160-200 seals remained in the Chaivo Bay, i.e., their number decreased more than an order of magnitude in less than a month. A similar situation could be also observed in the Piltun Bay where the number of seals to at most 250 animals.

In **November** most seals left the bays and stayed in the shallow-water zones along the coast. By mid-November the greater part of the bays were covered by 20-25 cm of ice and the seals lay on the ice near the air holes.

On November 18 there were 50-60 seals in Piltun Bay. There were no seals on the ice in Chaivo Bay. We countered only two larghas on the ice of Nyisky Bay.

Surveys of seals during July through November showed that the animals moved from relatively scattered aggregations outside the bays into the mouths and bays proper during salmon spawning runs and then back to scattered aggregations on the outside beaches with some seals still in the bays as ice was forming in November.

4. Review of Known Physical Principles Concerning Offshore Acoustic Noise Sources

This section contains a brief review of the known works on acoustics to acquaint the non- acousticians with a number of problems associated with characteristics of acoustic noise fields generated in a shallow sea by natural (wind, surface waves etc.) and man-made (e.g., a ship) sources.

4.1 Ambient Noise Level

The ambient noise level is characterized by intensity of ambient noise in decibels measured with an omnidirectional hydrophone and related to the intensity of plane wave with a RMS pressure of 1 μPa. Though the ambient noise level is measured in various frequency bands, it is always converted to the 1 Hz band; it is called **the ambient noise spectrum level (**Urik, 1978). In order to measure the ambient noise one should exclude all possible sources of self noise, besides, strong noise sources such as individual ships must not participate in the generation of noise background.

4.2. Sources of Ambient Noise

Seismic events. Seismic events are an important source of low-frequency sea noise. **Microseisms** are one form of relatively strong and practically continuous form of seismic activity, they occur almost periodically, their frequency is 1/7 Hz, the amplitude of vertical ground motion is of the order of 10^{-4} cm. If microseisms with such amplitudes occur in the bottom at a large depth and if the disturbance is sinusoidal, the resulting pressure amplitude will be 120 dB relative to 1 μPa. The measurements of microseisms with submarine seismometers at frequencies above 1 Hz show that the influence of this source is noticeable at frequencies to 10-100 Hz.

Turbulence. Small-scale and large-scale nonstationary random currents can generate ambient noise in two ways: by flow and by pressure change; the most important acoustic effect of turbulence is generation of pressure variation within the turbulence zone. Let the turbulent component of flow velocity be υ, then the corresponding dynamic pressure is $\rho\upsilon^2$ where ρ is the fluid density. If we assume υ to amount to 5% of the steady-state flow velocity, the turbulent component of the steady-state flow with velocity 1 knot will be 0.05 knot, or 2.5 cm/s; then the dynamic pressure of turbulent flow (at ρ =1) will be 6.3 dyn/cm^2 or 116 dB relative to 1 μPa. Hence, turbulence is also an important source of acoustic noise in the 0.1-100 Hz range.

Navigation. In the areas located far from the measurement point navigation is the dominant source of noise in the 50-500 Hz range. ***Distant storms*** during which some energy is transmitted into the sea in the form of ultrasound can be regarded as “competitors” of navigation in respect of noise generation.

Surface waves. Surface waves generate ambient noise of even greater frequency. Numerous observations of ambient noise at deep sea at frequencies from 500 Hz to 25 kHz led to recognition of a direct relation between the sea state (or wind intensity) and the ambient noise level. The well-known Knudsen spectra, a family of curves whose parameter is the sea state or wind intensity, resulted from these observations. Though it seems apparent that the sea surface must generate the greater portion of ambient noise in the above frequency range, the mechanism of this process is not fully understood yet. For instance, the relation between noise and wind velocity is more obvious than the relation between noise and surface waves.

4.3. Specifics of Ambient Noise in Shallow Sea Waters

Unlike the levels of ambient noise in a deep sea whose properties are relatively constant, the noise ***levels*** in the nearshore waters, bays and harbors are characterized by large variability. Noise sources in these shallow-water areas are characterized by ***sharp*** temporal and spatial variations.

The noise background in a shallow-water area at a given frequency is a mixture of three types of noise: ***1) traffic and industrial noise***; ***2) wind noise; 3) biological noise***.

Besides the sources contributing to the total noise at large depths, in the offshore zone noise is also generated by industrial enterprises, sea organisms and animals, and also turbulence produced by tidal currents.

Near-shore waves. In the offshore zone the wind velocity is also the factor which determines noise level in a wide frequency range. For example, Piggott (1965) presents the results of measurements made offshore Scotland in a sea area with depths about 45 m. The relationship between the noise level in the 10-3,000 Hz range and the wind velocity was established. The noise level increases by 7.2 dB when the wind velocity increases twice, i.e., the noise intensity increases slightly faster than the wind velocity squared. Various events which presumably contribute to noise generation (hydrostatic phenomena associated with wind-induced waves, broken water and sound radiation from the sea surface) must influence the noise level in the coastal zone. The comparison with the Knudsen spectra for deep sea suggests that the noise levels at frequencies above 500 Hz are 5-10 dB higher in shallow water than in deep water. At low frequencies and low wind velocity the shallow sea is much more “ quiet” than the deep sea. This "relative quietness" is produced by the screening effect of the shallow sea where the conditions of sound propagation over a large distance are not so favorable. On the other hand, when noise is generated by ships or other anthropogenic factors or when biologic sources contribute to ambient noise, the shallow sea becomes noisy and variable medium for hydroacoustic measurements.

Ambient noise is characterized by a high variability associated with the variations in the dominant noise sources: wind velocity, traffic intensity and industrial activity.

Sources of intermittent ambient noise. The intermittent noise sources are those sources whose action does not continue for days or hours, but has a nature of a short transient process: living organisms, mainly sea mammals (whales, dolphins), rain and hail and industrial enterprises. For example, Teer (Teer, 1949) showed that during strong rain the noise level in the 5-10 kHz range increases almost by 30 dB. The noise spectrum of strong rain is close to that of white noise in the 1-10 kHz range.

4.4. Noise from Ships

Ships are a relatively strong source of underwater noise. Many machines and mechanisms with rotary and reciprocation motion are required to start and control a ship and also to create proper conditions for the crew. These machines and mechanisms produce vibration which after having gone through the ship's hull and the water column acts on a distant hydrophone as underwater noise. Propellers, which moves the ship, generate noise due to specific processes and play the key role in noise generation.

Noise generated by a ship can be classified into two types: ***broadband noise*** with a continuous spectrum and ***tone noise*** with a discontinuous spectrum. The latter type of noise consists of tone, or sinusoidal components, its spectrum contains linear components which appear at discrete frequencies. The noise generated by a moving object is a mixture of both types of noise over the greater part of the frequency band and can be regarded as noise with a continuous spectrum with superimposed discrete components.

Machinery noise. Machinery noise is generated by mechanical vibration of various parts of the moving ship transmitted to the water through ship's hull. There are the following sources of machine vibration:

1. Rotation of disbalanced parts, e.g., eccentric shafts or motor armatures.
2. Repeated bumps and collisions.
3. Reciprocating motion of some parts of mechanisms such as internal combustion engines.
4. Cavitation and turbulence of fluid flow in the pumps, pipes, valves and condensers.
5. Mechanical friction in bearings and journals.

The first three sources produce *line spectrum* where sinusoidal components at the main harmonics of the noise-generating process dominate; the two other sources generate noise with a *continuous spectrum* with superimposed discrete components when resonance vibration occurs in the structural elements. That is why the machinery noise spectrum of a moving object can be presented as a superposition of a low-level continuous spectrum and strong discrete components.

Propeller noise. In spite of the fact that the propeller is part of the propulsion plant, the noise generated by it differs form the machinery noise both in its nature and frequency spectrum. Whereas the machinery noise is generated *inside* the ship hull, the propeller noise is generated *outside* the hull as a result of propeller rotation and ship movement in the water. Propeller noise is dominantly generated by cavitation produced by propeller rotation. Regions of low, or negative pressure are produced at the surface and ends of the rotating propeller. When the negative pressures become relatively strong, water continuity breaks and cavities in the form of small bubbles start to be created. These bubbles produced by cavitation collapse after some time either in a turbulent flow or at the collision with propeller blades which generates strong noise pulses. As the cavitation noise consists of a great number of chaotic noise pulses due to bubble collapse, it has a continuous spectrum. At high frequencies the spectrum level of cavitation noise decreases with frequency at the rate of 6 dB per octave. The peak of the noise spectrum for ships is normally within the range from 100 to 1,000 Hz.

Besides, rotation of the propeller in the wake with peripheral heterogeneities produces oscillating thrust components with frequencies multiple of propeller rotation frequency. The presence of oscillating thrust generates noise with the same frequency as propeller rotation frequency and its harmonics. Though at small M numbers the propellers of sea ships do not generate much sinusoidal components with the same frequencies as the propeller rotation frequency, the oscillation is transmitted to the hull and serve as the main source of its vibration. If the oscillation frequency coincides with the low resonance frequency of the hull, it may result in strong vibration.

5. Effect of the Acoustic Properties of Sea Floor Rocks on Sound Propagation Offshore

From the acoustic viewpoint, the offshore zone is “a shallow sea”. The specifics of sound propagation in such environment are mainly associated with interaction with the sea bottom. The typical parameters of such acoustic waveguide as the shallow sea can vary in a large range. It depends not only on the dimensions of the waveguide, but also on the sound frequency. Such waveguide is characterized by the fact that acoustic energy per individual normal wave is much greater than per ray (Katsnelson and Petnikov, 1997), because for the waveguide with constant sound velocity and absolutely rigid bottom the maximum number of the energy-transmission modes can be found from the formula (Brekhovsky and Lysanov, 1982): $M \approx 2H / \lambda$ where H is the waveguide depth, λ is the length of a sound wave, a similar formula for maximum number of the energy-transmission rays is (Kravtsov, Kuzkin and Petnikov, 1988): $M' \approx 2r/H$ where r is the distance between the sound source and the receiver. The comparison of these two formulae shows that on condition $r >> H^2 / \lambda$ the number of rays exceeds the number of modes.

In the light of the ever increasing interest in the shallow sea on the part of acoustic engineers some empirical correlations for sound propagation and classifications have been suggested. Sometimes they were not quite correct in some respect due to poor understanding of the acoustic effects of the sea bottom which is the most important interface of the acoustic layer. It is often believed that at small incidence angles the reflection from a hard bottom or a bottom with a hard underlying layer is always close to total reflection, i.e., reflection without any loss of energy or with very small losses. Sometimes it is true, but sometimes not.

From the acoustic viewpoint, the offshore zone of the ocean behaves like a waveguide bounded by an absolutely soft boundary (water surface) and absorbing boundary (bottom). Many factors influence the sound propagation is such waveguide. The shape of the sound velocity profile and the geoacoustic properties of the bottom are the most important factors. The other factors influencing the sound field are the roughness of the bottom, surface waves, random heterogeneities in the water mass, tidal currents etc. Most of these factors experience large variations in the offshore zone depending on the season, weather etc. The shallow sea as a medium of sound waves propagation is characterized by a strong temporal-spatial variability. Generally, most offshore zones can be described with the following geoacoustic model: the water layer underlain by a multiple-layer bottom. The layers of which the bottom consists differ in their properties. The upper layer is composed of unconsolidated sediments, its thickness is from 1 to 100 m. Density of sediments in this layer is normally 1.5-2 g/cm^3. Sound velocity (P-wave velocity) varies from 1470 to 1900 m/s. This is an absorbing layer, at frequencies to 1 kHz the absorption coefficient for P-waves is roughly proportional to frequency: $\beta \approx \beta_f f$ where the magnitude of frequency-dependent absorption coefficient β_f lies within 0.01-0.3 dB/(km Hz). The dependence on frequency is greater at low frequencies. The second layer is composed of semiconsolidated sediments, its thickness is about 10-500 m. P-wave velocity in this layer is C_p = (2 - 3) x 10^3 m/s. The shear modulus in this layer is not zero, that is why shear waves can propagate in it, the S-wave velocity is $C_s \approx 0.2C_p$. This is also an absorbing layer. Its absorption coefficients for P and S waves are characterized by large variations and lie within 0.01-0.1 dB/(km Hz). The lower halfspace is the basis or basement. It is composed of bedrock (basalt, granite etc.) and is characterized by large P-wave velocity $C_p \approx (4 - 6) \times 10^3$ m/s and S-wave velocity $C_s \approx (1 - 3) \times 10^3$ m/s. The four-layer model can be simplified, but sometimes even a more complicated model is used when some details important for sound propagation can be incorporated into the model.

In addition to the complication of the model by adding layers, a more comprehensive treatment of acoustic and mechanical properties of bottom sediments is possible. At present there are a few theories of sound propagation in sediments (Acoustics of marine sediments, 1974) based on the Biot theory (Biot, 1956). In these models sediments are regarded as a two-component medium consisting of solid framework and liquid component.

Seismic waves are another important physical source of transmission of low-frequency energy in the offshore zone, in the first place into the coastal zone. It is known that a surface wave can exist on the interface between any two media if shear waves can propagate at least in one of them. Such surface wave is characterized by the absence of critical frequency, though at a given depth the waves with frequency below some frequency depending on the ambient conditions attenuate rapidly. Ensen and Kuperman (1985) presented the results of numerical modeling based on the wave approximation for a route with parameters of the medium constant in the horizontal direction. Modeling was done for a typical structure of the sea bottom in the offshore zone: a 5-m layer of sediments composed of relatively compact sand overlies hard sedimentary rocks. Therefore, two surface waves must exist: one at the water-sand interface, the second at the sand-bedrock interface. But due to large attenuation of shear waves in sand (1.5 dB par wavelength) it turns out that only the wave at the sand-hard rock interface makes a considerable contribution into the acoustic field at the water-bottom interface. The calculations of the dependence of attenuation on frequency for a distance of 10 km for a seismic signal and an underwater acoustic signal (thickness of water layer 100 m) showed that the underwater signal propagated well at frequencies above 50 Hz and the seismic signal at frequencies below 10 Hz; for instance, at the frequency of 5 Hz the attenuation of seismic signal was 70 dB.

In conclusion of our review we want to give the results of the theoretical work by Bespalov et al. (1998) where a method of numerical modeling of low-frequency vector wavefields in stratified heterogeneous media is described, this method is characterized by good stability in respect of subdividing the medium into a large number of layers of arbitrary thickness. The results of calculations for a 6-layer model are given, the second layer belonging to the sedimentary cover (loose deposits, sand) was 50 m in thickness and had geoacoustic parameters close to those of our route. According to the analysis of the modeling results, a specific outflow of energy takes place at low frequency: the upper layer passes the energy downward and prevents its reflecting back toward the water layer. At the same time, for source frequency from 1 Hz and higher the introduction of a sand layer and a sand-limestone boundary instead of the sand halfspace increases wave amplitudes in the near-bottom zone. This increment is up to 50 dB at a distance of 20 km and frequency 1 Hz and to 60 dB at a frequency of 10 Hz. At frequencies above 10 Hz at a distance to 20 km we can ignore the layers lying below the upper surface of granite.

6. Results of the Acoustic Experiment Run in the Vicinity of the Molikpaq in July-September 1999

Introduction. Figure 8 presents the map of the area where the survey was made, the map shows the locations of the sonobuoys and potential sources of acoustic noise. In points 1, 2 and 3 (at distances of 24.6, 22.2 and 6 km from "Molikpaq" respectively) sound was measured with fixed bottom hydrophones (Fig. 4c), in point 4 (at 1 km from "Molikpaq") the sonobuoy was located in the way shown in Figure 4b, it was supposed to be located at a depth of 15 m, but the elastic rubber line was broken by strong current, that is why the actual depth of measurement could vary considerably. In September an anchored sonobuoy was set there twice and measurements were made at the bottom in a fixed location. Table 1 presents data of acoustic experiments made in the summer-autumnal season in the survey area off Sakhalin in 1999. The radio signals from the buoys located in points 1, 2 and 2-1 were received on the shore. The radio signals from points 3 and 4 were received on board the rescue ship *Agat* anchored in the location shown on the map presented in Figure 8. In the summer experiment acoustic signals were recorded on board the ship on a tape drive made by Brule & Kier; on the shore the signals were recorded by the computer. During the experiment (3 days) when *Agat* was anchored, hydrological measurements were made from it, in particular, tones of various frequency were generated continuously by a broadband transmitter lowered into the sea from the ship to a depth of about 6 m, but its depth varied due to strong current. In the September experiment near the Molikpaq the radio signals were received on board the rescue ship *Agat.* The acoustic signals were entered in the computer and recorded on a video tape simultaneously.

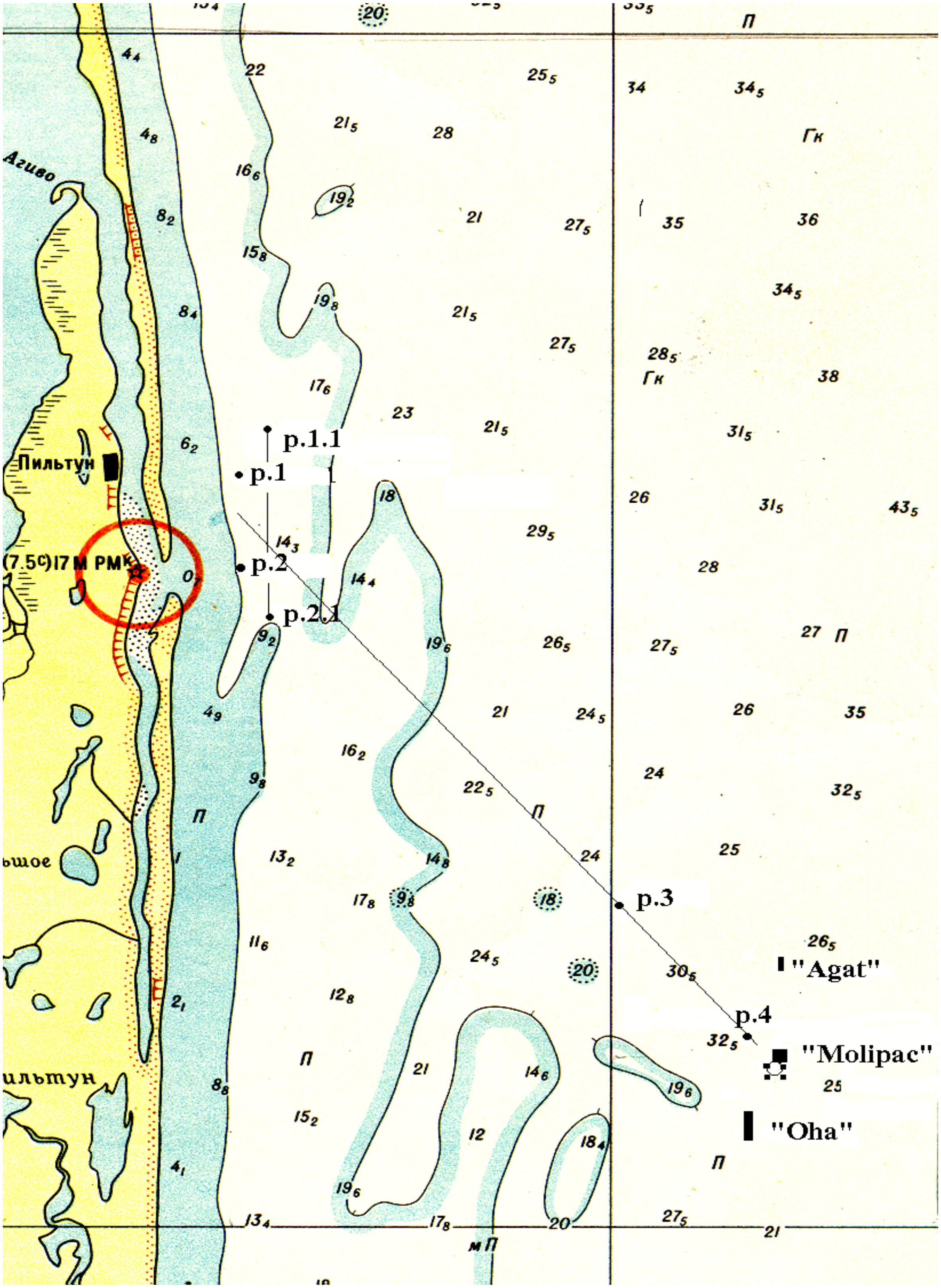


Fig. 8. The map of the area where the acoustic studies were made, the map shows the locations of the sonobuoys (p.1 …p.4).

Table 1.

Acoustical data

The beginning of measurements.	Finishing of measurements	Number coordinate of measuring point	Registering device	Additional measurements and observations of a whales	Comments notes
8h10min 16 July	13h15min 20 July	p.1 52^{0}52`57,1`` 143$^{0}$20`23.1``	Computer, tape recorder	The emission of the tone`s signals from the rescue ship “Agat” in point: 52$^{0}$44`30``, 143$^{0}$34`06``. Hydrological measurements. A visual observations. Map-time whales movements.	Whale’s pulse signals, rain with hail. Datas about ships movements at the “Molikpaq”
13h00min 18 July	9h00min 21 July	p.3 52^{0}45`34`` 143$^{0}$30`44``	tape recorder		
13h00min 18 July	9h00min 21 July	p.4 52^{0}43`26`` 143$^{0}$33`25``			
12h20min 25 July	15h00min 27 July	p.1 52^{0}52`57,1`` 143$^{0}$20`23.1``	Computer, tape recorder	A works with the towing sound source. An observation of the whales in a sea.	
12h20min 25 July	15h00min 27 July	p.2 52^{0}52`58,6`` 143$^{0}$21`21.4``			
7h55min 4 August	7h30min 5 August	p.1 52^{0}52`57,1`` 143^{0}20`23	Computer, tape recorder	Experiments with the towing sound source. An observation of the whales in a sea.	Whale’s pulse signals.
7h55min 4 August	7h30min 5 August	p.2 52^{0}51`48,3`` 143$^{0}$20`31``			
9h36min 23 September	15h20min 25 September	p.4 52^{0}43`27`` 143$^{0}$33`34``	Computer, Video tape recorder	Receiving on a board of the rescue ship “Agat”.	Dolphin’s acoustical signals.
19h20min 25 September	8h00min 27 September	p.4 52^{0}43`20`` 143$^{0}$33`35``			
19h20min 25 September	8h00min 27 September	p.3 52^{0}45`40`` 143$^{0}$30`46``			
10h18min 3 October	2h34min 5 October	p.2-1 52^{0}50`52`` 143$^{0}$21`45.6``	Computer, Video tape recorder	Receiving at the beacons. Whale’s observations on the beacon.	

6.1. ***Noise Background Around the Molikpaq***

In this section we discuss the results of spectral analysis of acoustic noise background recorded near the Molikpaq to determine its variation over 24 hours and obtain quantitative estimates of spectral levels of noise generated by service ships and mechanisms working on the Molikpaq. The results of special research of sound propagation in the area are presented.

6.1.1. Daily variation of noise background

Figure 9 shows the $\hat{G}(\omega, t)$ sonogram of estimates of power spectrum of the noise background measured on September 23-24 with a fixed hydrophone attached to the sonobuoy located in point 4 (Fig. 8). This figure illustrates daily variation of the noise background generated by the Molikpaq, its service ships and aggregations of sea animals (SA), presumably, killer whales (signals of sea animals could be heard from 0 till 2 o'clock on September 24, see Fig. 9). As can be seen in the picture, the strongest sound in the frequency band of interest was generated by moving ships, exactly as could be expected. The difference in noise level produced by the Molikpaq and the anchored ships in comparison with the moving ships can be seen best of all in Figure 9 in the time periods 10-11 and 22-23 o'clock. Figures 10-13 show the spectra which characterize daily variation of the noise background. In all figures the estimates of power spectra $\hat{G}(f)$ are given in decibels with respect to the intensity of plane wave where the RMS pressure is expressed μPa. The $\hat{G}(f)$ values are reduced to the 1 Hz band. We primarily used the sampling frequency of initial data f_s = 15 kHz, that is why we indicate the f_s value only when it is not 15 kHz. The length

Fig. 9. Sonogram of spectrum of acoustical background level measured at p. 4 on September 23-24, 1999.

of the series by which FFT was calculated is denoted by Fur-, for instance, the series consisting of 4096 numbers is denoted by Fur-4096; it is followed by the number of realizations by which $\hat{G}(f)$ spectra were averaged, for instance, "100 real" means that averaging was done by 100 realizations which do not overlap. Now let us discuss the results of spectral analysis shown in the above figures.

The plots shown in Figure 10 are obtained by the measurements made during movement of the ship *Sm. Sibu* near the Molikpaq. On that day diving operations were carried out from the ship *Anabar,* they were finished at 16 o'clock. At 20 o'clock the ship *Miss Sybil* came ($\varphi = 52^0 38'4, \lambda = 143^0 33.1, V = 14{,}5$ knots), at 20:27 it came to the Molikpaq to disembark people, then worked together with *Sm Sibu*, at 22:30 it weighed ($\varphi = 52^0 42'1, \lambda = 143^0 33'5$) and went to the port of Kaigan at a speed of 16 knots.

As can be seen in Figure 10, the noise background generated by moving ships is characterized by a continuous spectrum which decreases with increase of frequency at the rate of - 0.01 dB/Hz in the range to 2 kHz and at the rate of - 0.005 dB/Hz in the range 2-6 kHz. According to Figure 11, the spectral level of noise in the range to 500 Hz has a distinct interference nature which can be easily seen also on the $\hat{G}(\omega, t)$ sonogram (Fig. 9). At higher frequencies due to a greater number of modes the interference peaks and minimums are less distinct, and because the noise sources are moving, at such temporal averaging their variations and frequency shifts are not resolved either on the sonogram, or the spectrum. In the range to 1 kHz the $\hat{G}(f)$ spectra have narrow power peaks corresponding to the periodic noise sources. The peak at the frequency about 38 Hz has the

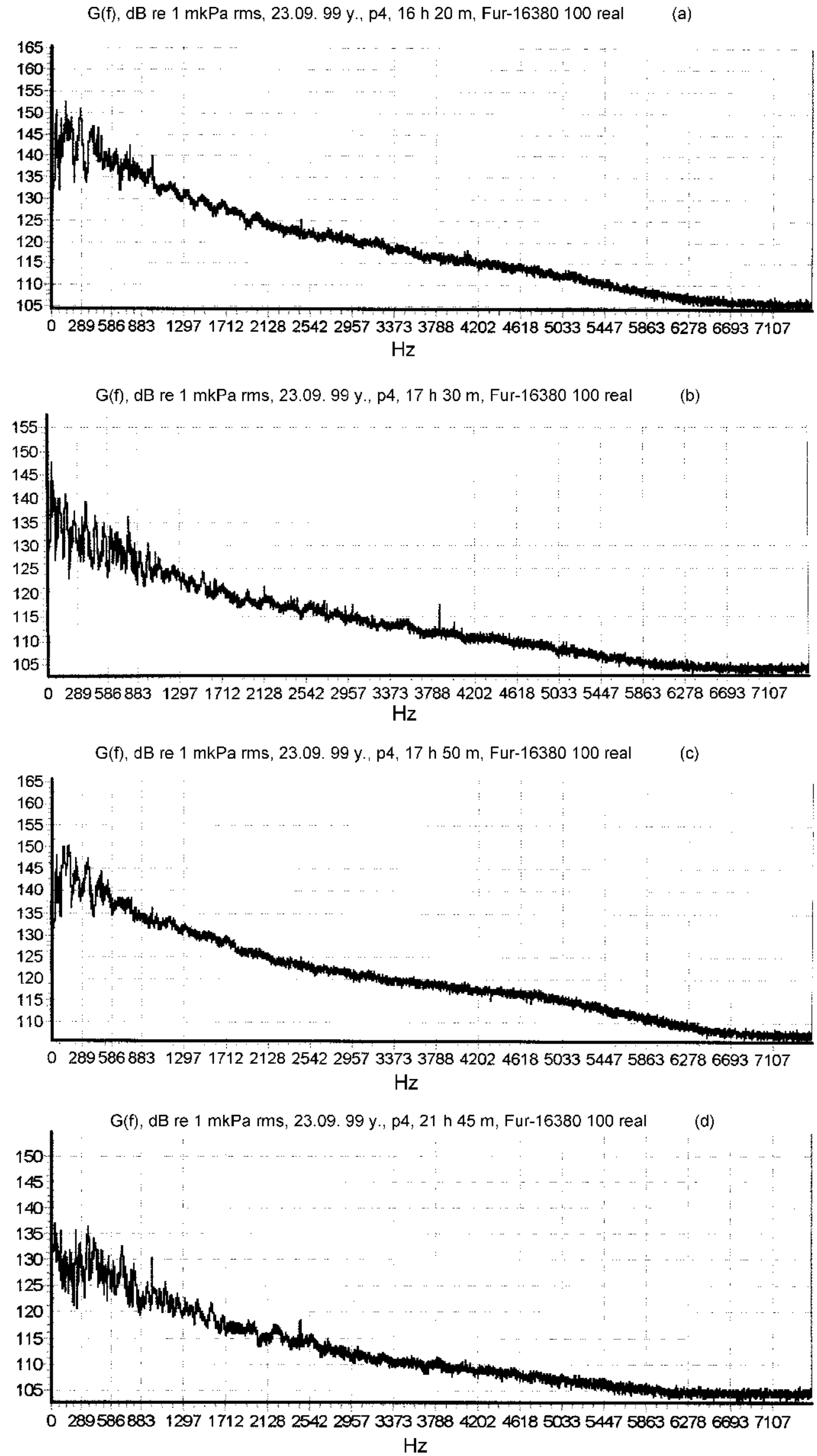

G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 16 h 20 m, Fur-16380 100 real (a)
165 160 155 150 145 140 135 130 125 120 115 110 105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz
G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 17 h 30 m, Fur-16380 100 real (b)
155 150 145 140 135 130 125 120 115 110 105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz
G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 17 h 50 m, Fur-16380 100 real (c)
165 160 155 150 145 140 135 130 125 120 115 110
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz
G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 21 h 45 m, Fur-16380 100 real (d)
150 145 140 135 130 125 120 115 110 105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz

Fig. 10

maximum level, 159 Hz (Fig. 11). According to Figure 10, the spectral level of traffic noise in point 4 in the range to 600 Hz varied from 145 dB (Fig. 10a) to 128 dB (Fig. 10d).

Figure 12 shows the $\hat{G}(f)$ spectra corresponding to the measurements made during ship movement (Fig. 12a), distant movement of the ship *Miss Sybil* which was going away (Fig. 12b), relatively quiet background (Fig. 12c) and when acoustic signals of sea animals (probably whale killers) were heard (Fig. 12d). The $\hat{G}(f)$ spectra shown in Figures 13-15 illustrate temporal variation of the noise background around the Molikpaq at night. As can be seen in Figure 12, the spectral level of the noise background in the range above 200 Hz decreased considerably after traffic near the Molikpaq stopped, for instance, according to Figures 12a and 12b, the sound spectral power in the 300-1,000 Hz range decreased by 15 dB, but narrow power peaks corresponding to the sources of tones appeared. Note the stable power peak near 1 kHz which can be seen on all spectra and according to Figure 13c reached the level of 125 dB at 3:25. Intermittent acoustic signals of sea animals made a considerable contribution into the averaged background spectrum in the 600-2,000 Hz, 4-4.5 kHz and 6-7 kHz range (Fig. 12c, 13a, 14a and 15a). The spectral power level of acoustic signals of sea animals in the background spectrum reached 118 dB at the frequency about 1.5 kHz.

The $\hat{G}(f)$ spectra shown in Figure 15 are obtained by averaging by 1,000 consecutive realizations which is approximately equivalent to 17 minutes and characterize the stationary portion of the noise background around the Molikpaq at this time of the day. Figure 16 shows the $\hat{G}(f)$ spectra corresponding to averaging by 100 realizations consisting of 65,536 values each and characterizing the continuous portion of the spectrum and

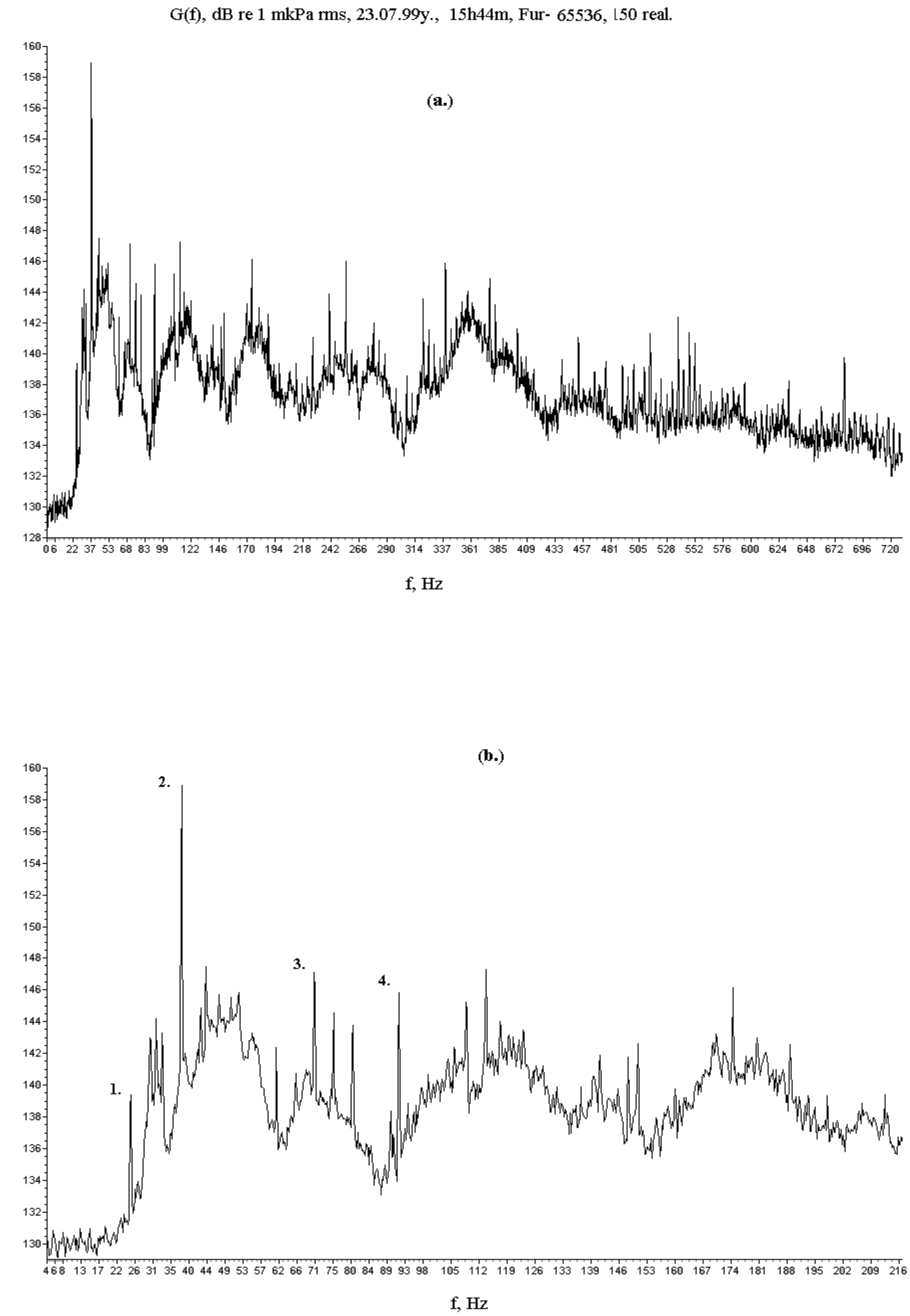


Fig. 11. Estimations of power spectrum of background level measured at p. 4 on September 23, 1999

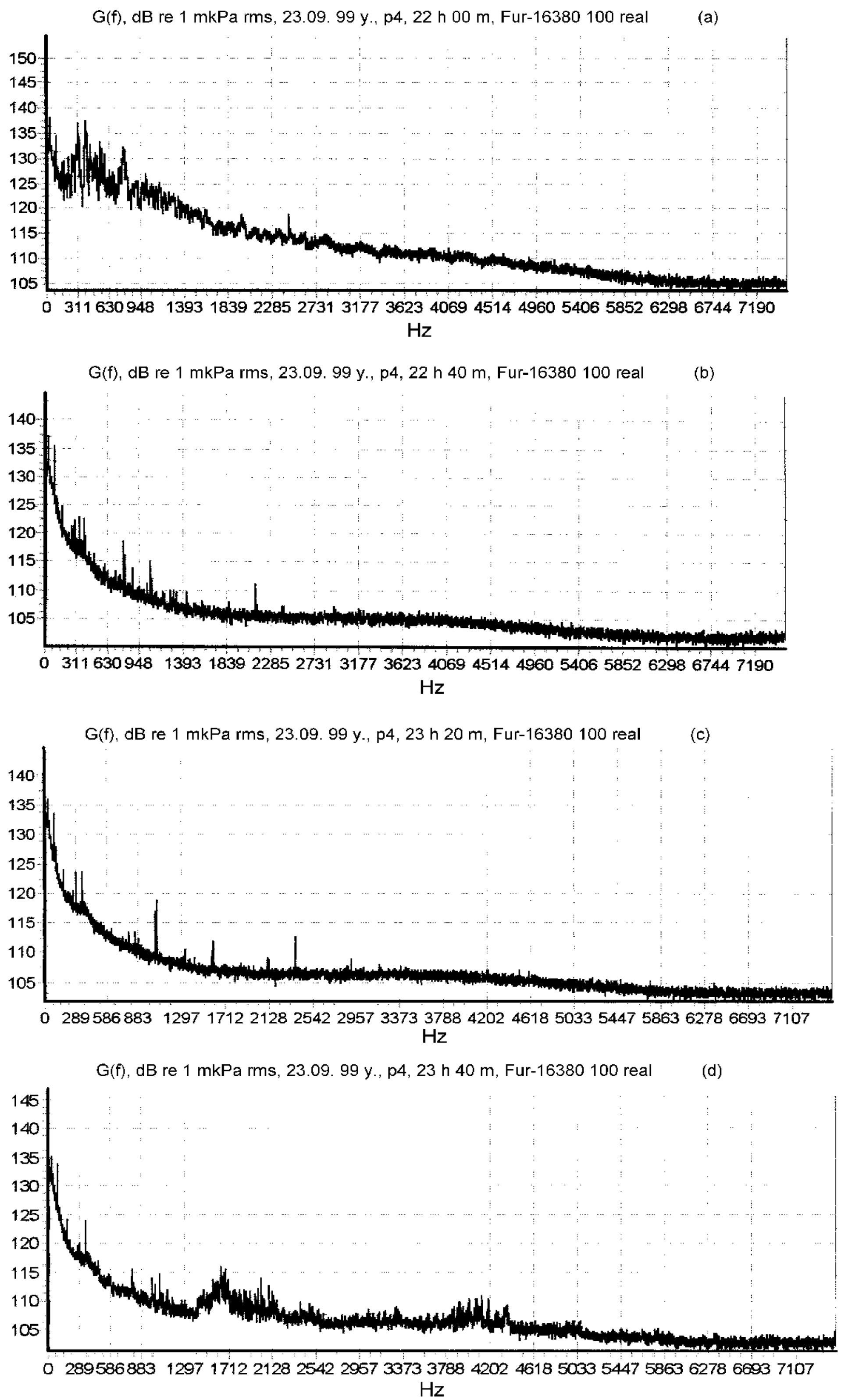

G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 22 h 00 m, Fur-16380 100 real (a)
150
145
140
135
130
125
120
115
110
105
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz
G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 22 h 40 m, Fur-16380 100 real (b)
140
135
130
125
120
115
110
105
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz
G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 23 h 20 m, Fur-16380 100 real (c)
140
135
130
125
120
115
110
105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz
G(f), dB re 1 mkPa rms, 23.09. 99 y., p4, 23 h 40 m, Fur-16380 100 real (d)
145
140
135
130
125
120
115
110
105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz

Fig. 12

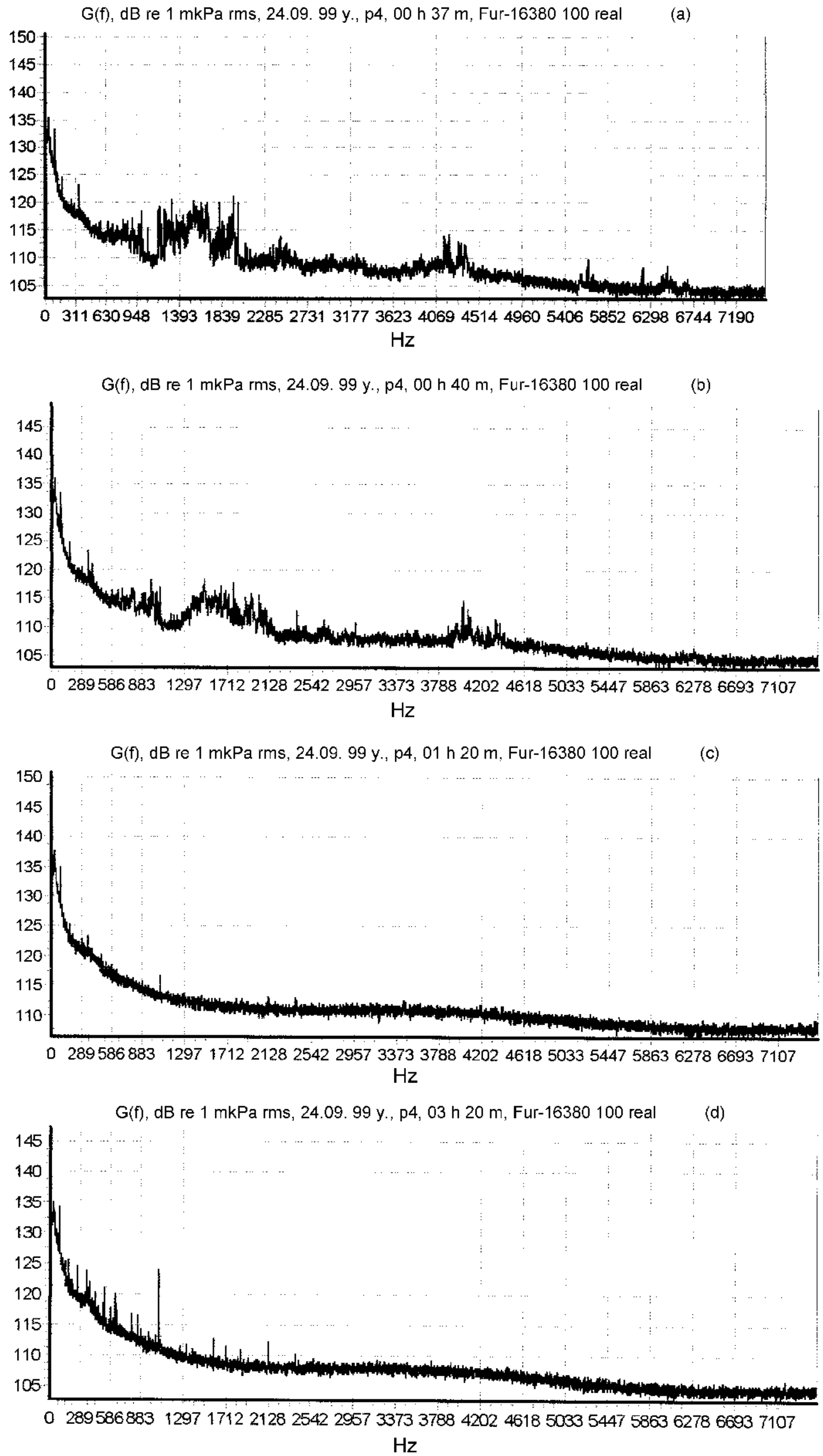

G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 00 h 37 m, Fur-16380 100 real (a)
150 145 140 135 130 125 120 115 110 105
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz
G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 00 h 40 m, Fur-16380 100 real (b)
145 140 135 130 125 120 115 110 105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz
G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 01 h 20 m, Fur-16380 100 real (c)
150 145 140 135 130 125 120 115 110
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz
G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 03 h 20 m, Fur-16380 100 real (d)
145 140 135 130 125 120 115 110 105
0 289 586 883 1297 1712 2128 2542 2957 3373 3788 4202 4618 5033 5447 5863 6278 6693 7107
Hz

Fig. 13

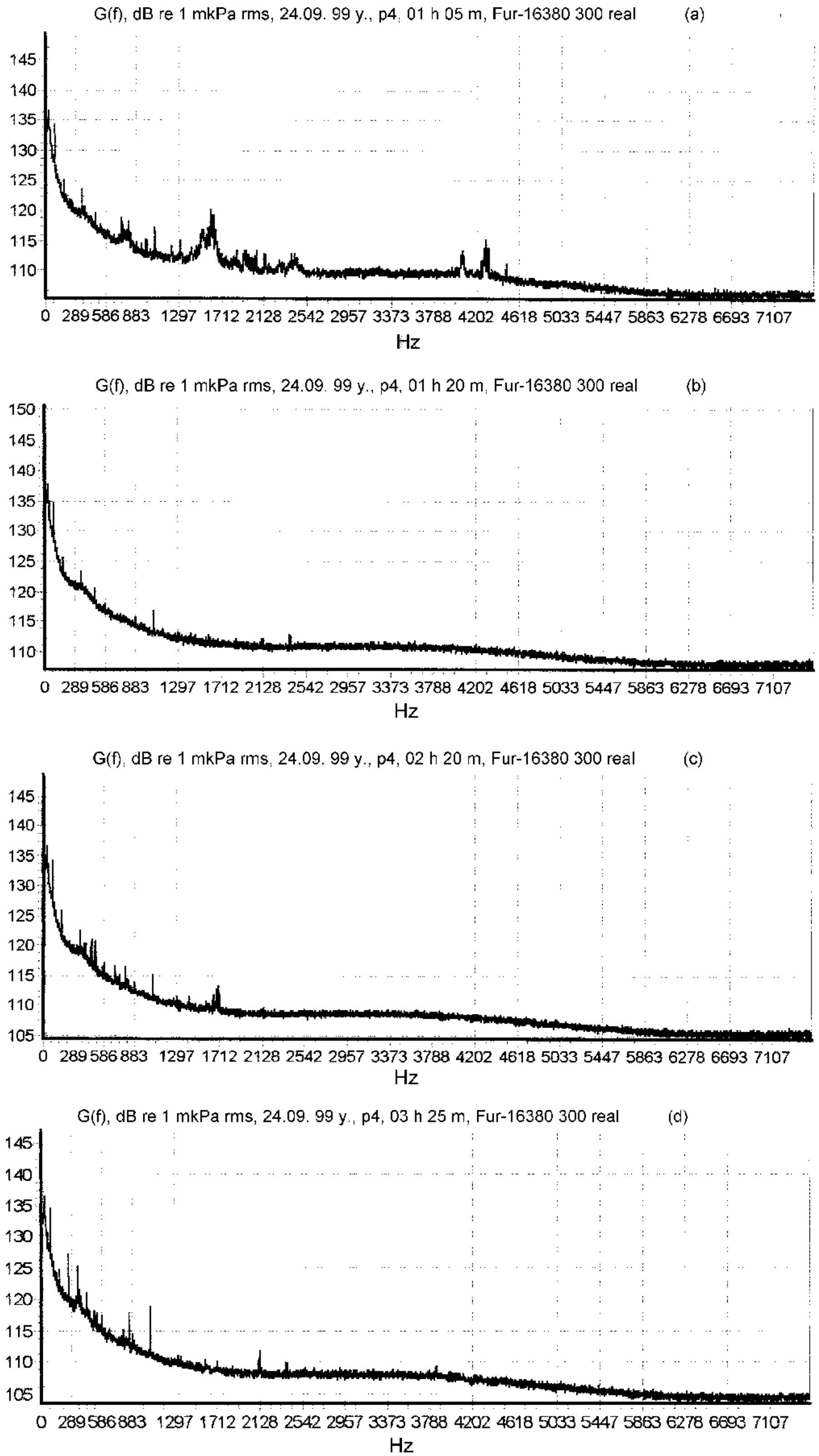
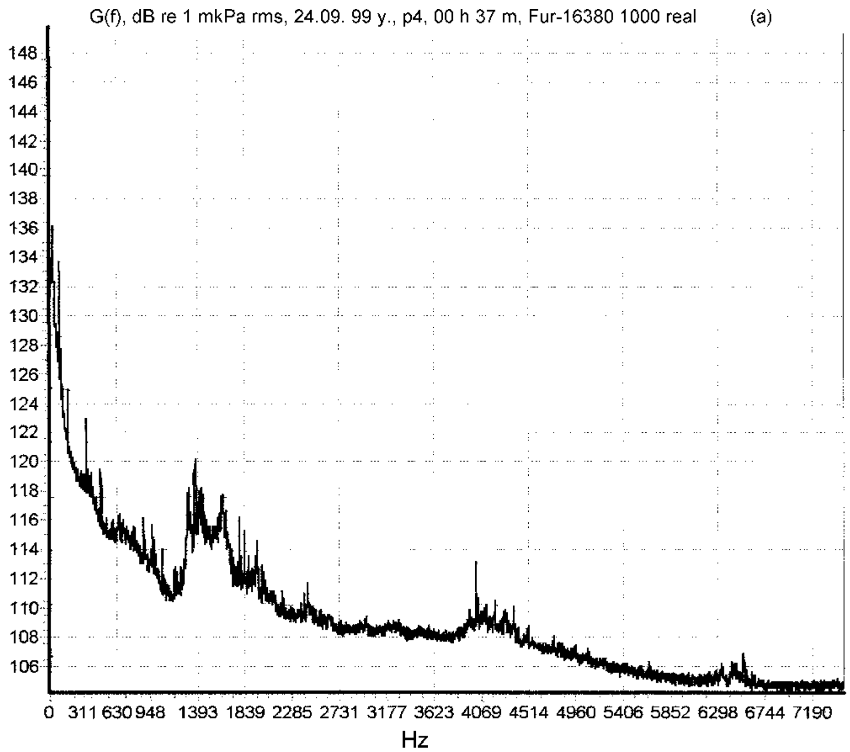

G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 01 h 05 m, Fur-16380 300 real (a)
Hz
G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 01 h 20 m, Fur-16380 300 real (b)
Hz
G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 02 h 20 m, Fur-16380 300 real (c)
Hz
G(f), dB re 1 mkPa rms, 24.09. 99 y., p4, 03 h 25 m, Fur-16380 300 real (d)
Hz

Fig 14



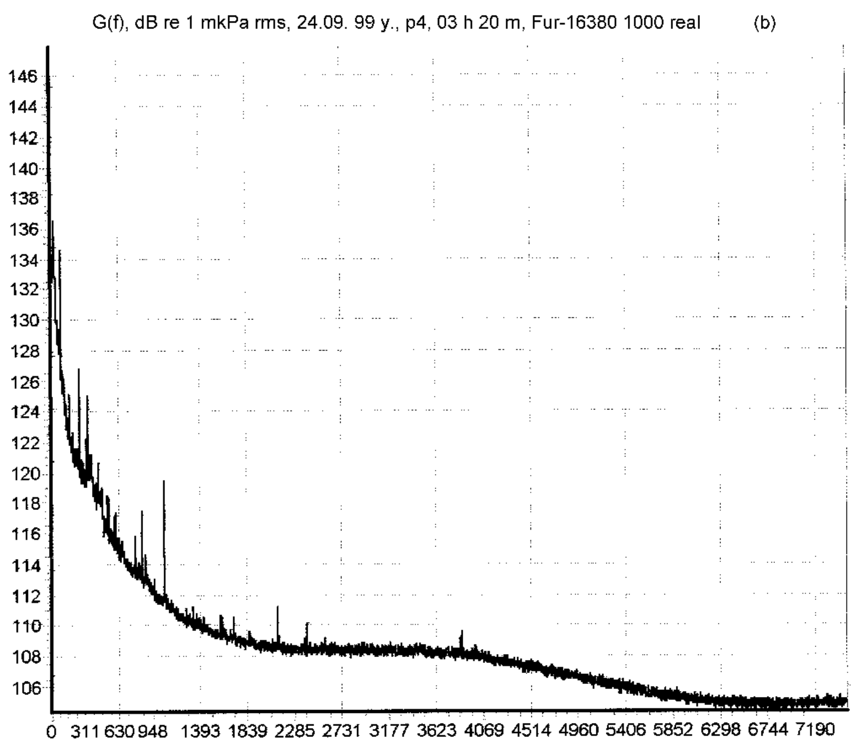


Fig. 15. Estimations of power spectrum of background level measured at p. 4

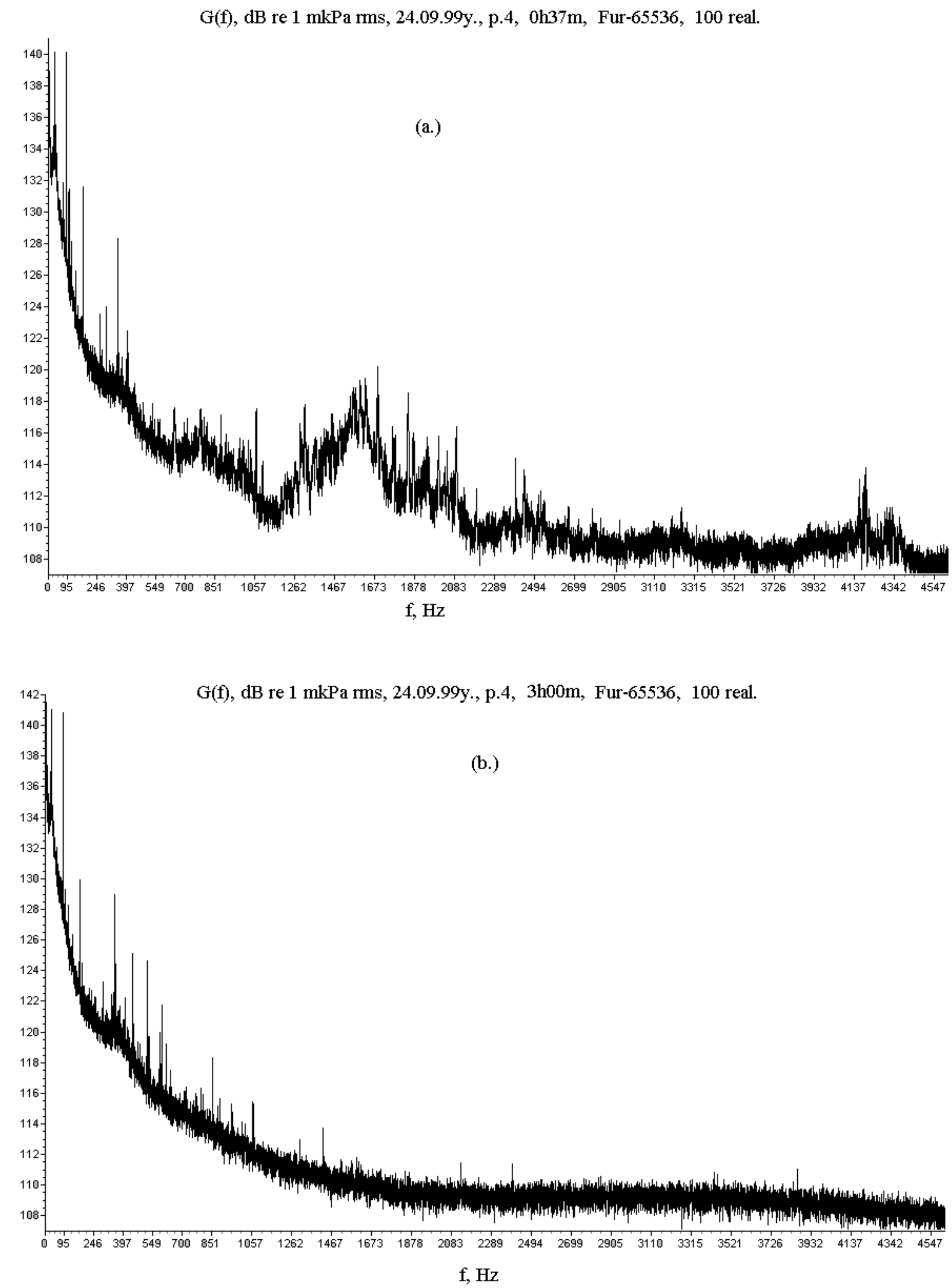


Fig. 16. Estimations of power spectrum of background level measured at p. 4 on night September 24, 1999

discrete components of the noise background in the range to 4.5 kHz in greater detail.

The $\hat{G}(f)$ plots in Figures 11b and 17 show the sinusoidal components in the low-frequency portion of the background spectrum around the Molikpaq recorded during traffic (Fig. 11b) and in a relatively quiet period (Fig. 17). The narrow power peaks at the frequencies about 26, 92 and 178 Hz can be seen in the figures illustrating night measurements, the peak at 26 Hz is distinct in all three figures corresponding to the measurement made at 15:44 on June 23, 0:36 and 3:00 on June 24 respectively. On all three plots this power peak has spectral level of 140 dB. At night (Fig. 17) the spectral levels of the two other power peaks were also stable and reached 140 and 131 dB. As follows from the comparison of the $\hat{G}(f)$ plots shown in Figures 11 and 17, during traffic the spectral power of the noise background measured in point 4 has three peaks in the range to 200 Hz in the interference region, at night (Fig. 17) there is one peak in the 22-45 Hz range, after that the spectral power decreases inversely proportional to frequency at the rate of 0.08 dB/Hz. Note the stationary power peak at 26 Hz; as it is also observed in the coastal zone at a distance of 23 km from the Molikpaq, and probably it is connected with work of pumps and compressors on “Molikpaq”.

The $\hat{G}(\omega, t)$ sonogram in Figure 18 shows that the moving ship generates acoustic noise in the range to 10 kHz which considerably exceeds the average noise background in this area. In this experiment acoustic data was input in the computer with sampling frequency of f_s = 20 kHz.

On the sonograms shown in Figures 9 and 18 the acoustic field generated by the moving ship can be easily recognized by the typical pattern

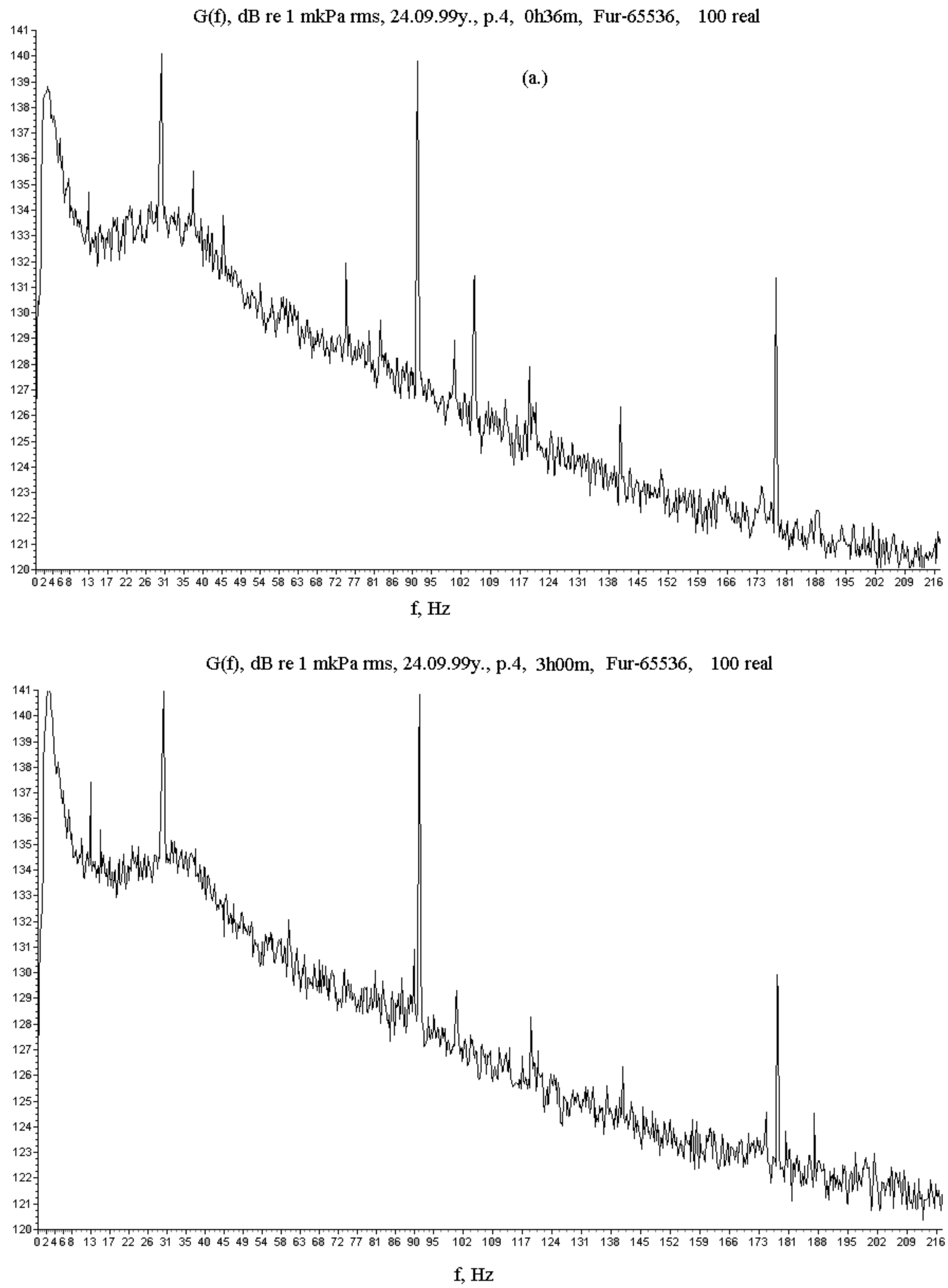


Fig. 17. Estimations of power spectrum of background level measured at p. 4 on night September 24, 1999

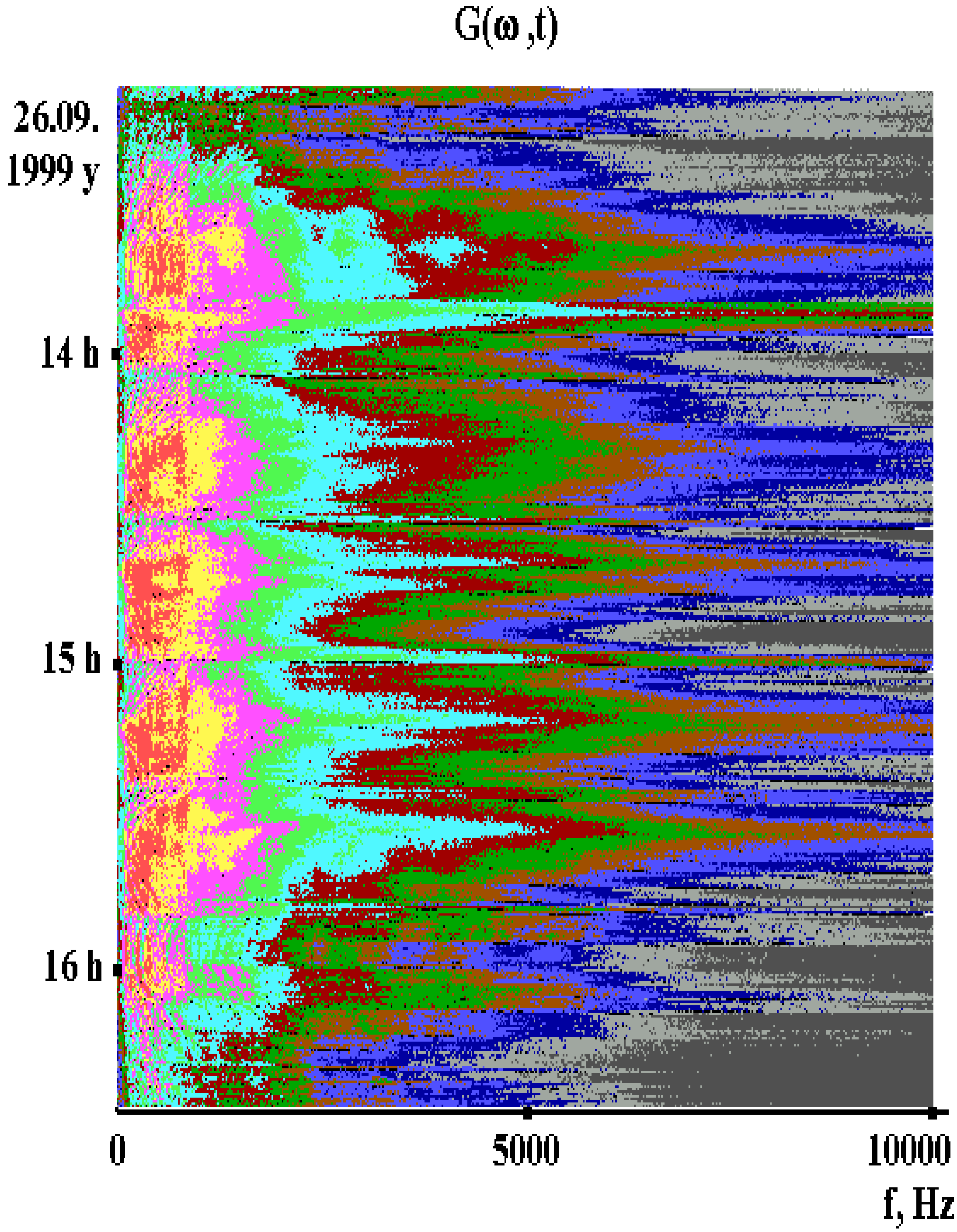


Fig. 18. Sonogram of acoustical background measured by sonobuoy at p. 4 on September 26, 1999.

of spatial-frequency interference of the ship-generated broadband noise with practically continuous spectrum. In the $\hat{G}(\omega,t)$ sonograms, especially at low frequencies, there are distinct interference peaks of noise generated by the moving ship. When the ship approaches the reception point, these peaks shift to the low-frequency region, and the other way round; that is why when the ship is going past the reception system the trajectory of the interference peak of sound intensity in the frequency-time domain looks like a hyperbola. The traverse, or minimum distance to the receiver, corresponds to the bend point. Another important criterion to recognize that a given sinusoidal component is produced by a moving ship is the Doppler shift $\Delta f = \frac{2V}{C} f_0$ where V is the rate with which the distance between the source of tone with frequency f_0 and the reception point varies; C is the average sound velocity in the water. If sound velocity is 1500 m/s, then $f = \pm 0.69$ Hz/(knot)(kHz) where the rate of distance variation is expressed in knots and the frequency of the ship-generated noise in kHz. If a ship generating a tone with the frequency of f_0 = 1 kHz is approaching the receiver at the speed of 10 knots, the frequency of the acoustic signal being measured at a fixed point increases with respect to f_0 by 6.9 Hz. The ± sign in the formula means that the approaching ship produces “positive Doppler” and the ship moving away produces “negative Doppler”.

Figure 19 shows the $\hat{G}(\omega,t)$ sonograms corresponding to the night noise background around the Molikpaq in greater detail. It should be noted that in spite of the considerable level of industrial noise in the day-time (Fig. 9) isolated typical signals of sea animals (presumably whale killers) started to be heard at 22:50 which after 0 o’clock turned into a “bird rookery” which ended at 2 o’clock. It did not repeat itself in July and subsequent nights, but

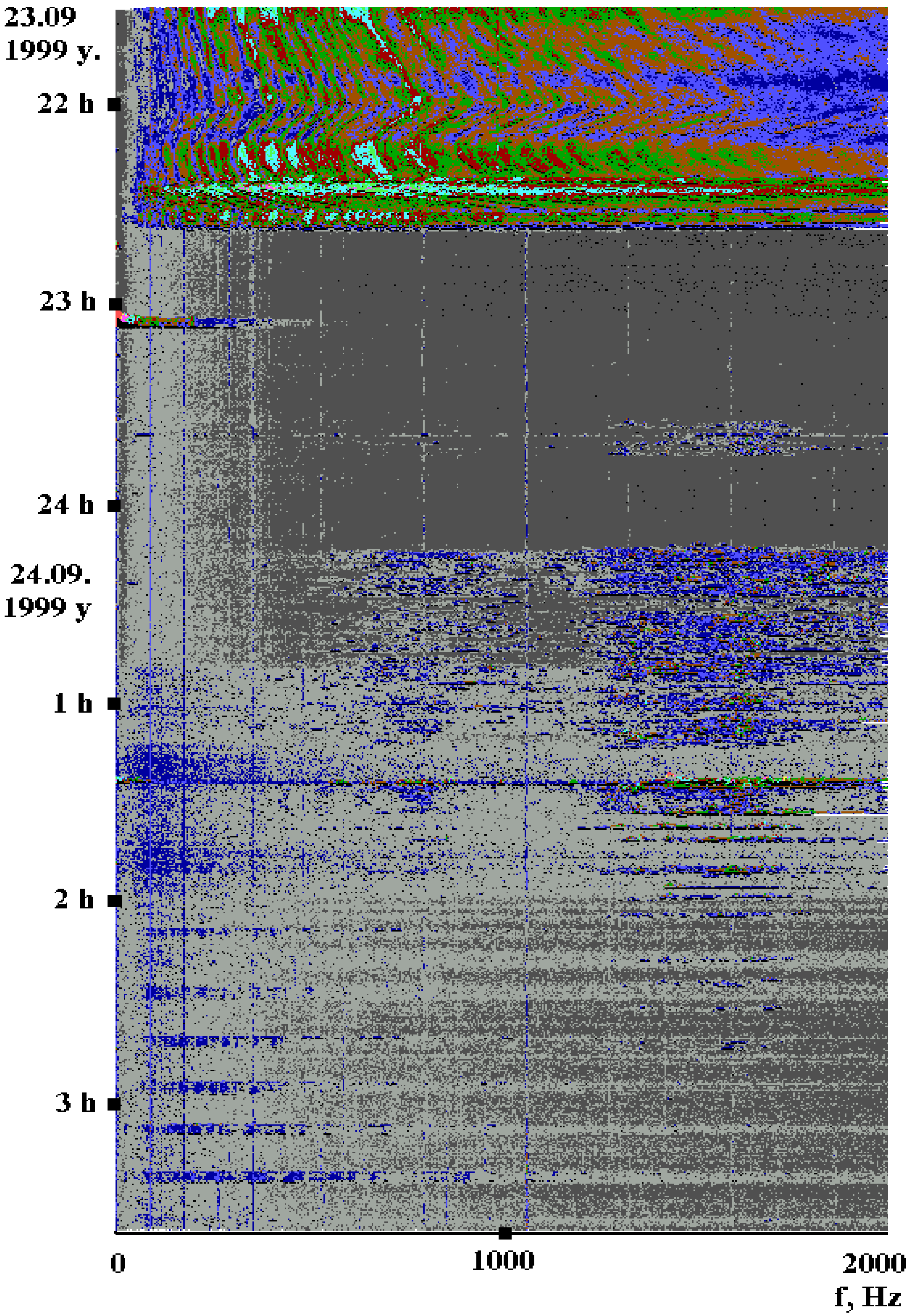


Fig. 19. Sonogram of acoustical background measured at p. 4 on night September 23-24, 1999.

distant signals of sea animals could be heard from time to time. With account of the above $\hat{G}(f)$ spectra it should be noted that when there is no traffic, the level of recorded signals of sea animals considerably exceeds the noise background typical of this area.

A relatively broadband noise can be observed on the $\hat{G}(\omega, t)$ sonograms obtained after 2 o'clock (Fig. 9 and 19), it might be generated by some mechanism started periodically (five times per hour) for 5-7 minutes.

6.1.2. Analysis of the Specifics of Noise Signals and Tones Propagation

Let us consider the results of measurements made at the Molikpaq in July. The acoustic signals were recorded by type 7005 tape drive made by Brule & Kier, unfortunately, some data was lost due to low quality of magnetic tape. We used high-quality magnetic tape made by AMPEX, unfortunately, it was of old vintage, 1984. In 1999 we could not purchase in Vladivostok the tape for such drive of later vintage. Besides, the tape speed during recording was 3.81 cm/s, and amplitude modulation was used which ensured the upper limit of frequency range of 7 kHz, but the lower limit of the frequency range was 20 Hz. That is why in the September experiment we recorded acoustic signals simultaneously on the computer and JVC hi-fi video tape recorder on its two audiochannels which ensured high quality records of acoustic signals in the 20 Hz-20 kHz range with dynamic range of 80 dB. Thus, the amplitude-frequency characteristics of the through recording channels shown in Figure 1 could be ensured only by direct, without distortions, input of data to the computer. Having all this in mind, let us consider the results of summer experiments made with two sonobuoys located in points 3 (fixed) and 4 where the buoy was attached to the anchored float, at the beginning the hydrophone was supposed to be at a depth of 15 m, but due to strong currents the rubber line was broken, the hydrophone with the anchor went down (by about 20 m) and lay down on the bottom; that is why measurements in point 4 can be considered made with a fixed hydrophone.

Figure 20 shows the $\hat{G}(\omega,t)$ sonograms of noise background simultaneously measured in points 4 (Fig. 20a and 20c) and 3 (Fig. 20b and 20d). The power peaks at 4 kHz corresponding to tone continuously transmitted by a broadband transmitter lowered into the water from the rescue ship *Agat* which was anchored in the point with coordinates $\varphi = 52^0 44'30'', \lambda = 143^0 34'06''$ (Fig. 8) can be easily seen. In Figures 20c and 20d the $\hat{G}(\omega,t)$ sonograms are shown in the 0-1,200 Hz range, they illustrate variations of the interference pattern of the noise field generated by a moving ship. Figure 21 shows quantitative estimates of $\hat{G}(f)$ power spectra of the recorded acoustic field corresponding to the time when there was no ship in the area (Fig. 21a) and when there was a ship (Fig. 21b). As follows from Figure 21a, the spectral level of the tone with the frequency of 4 kHz generated in the point where the ship *Agat* was anchored exceeds the noise background measured in both points, their levels differ by about 5 dB. The spectral levels of the sinusoidal components of the noise background measured in points 4 and 3 (Fig. 21a) with frequencies about 630 and 1,300 Hz differ in level by 17 and 14 dB respectively. As follows from Figure 21b, the continuous background spectrum and the discrete sinusoidal components of the acoustic wavefield generated by a moving ship can be easily seen on both $\hat{G}(f)$ plots in the frequency range to 3 kHz, but note large transmission

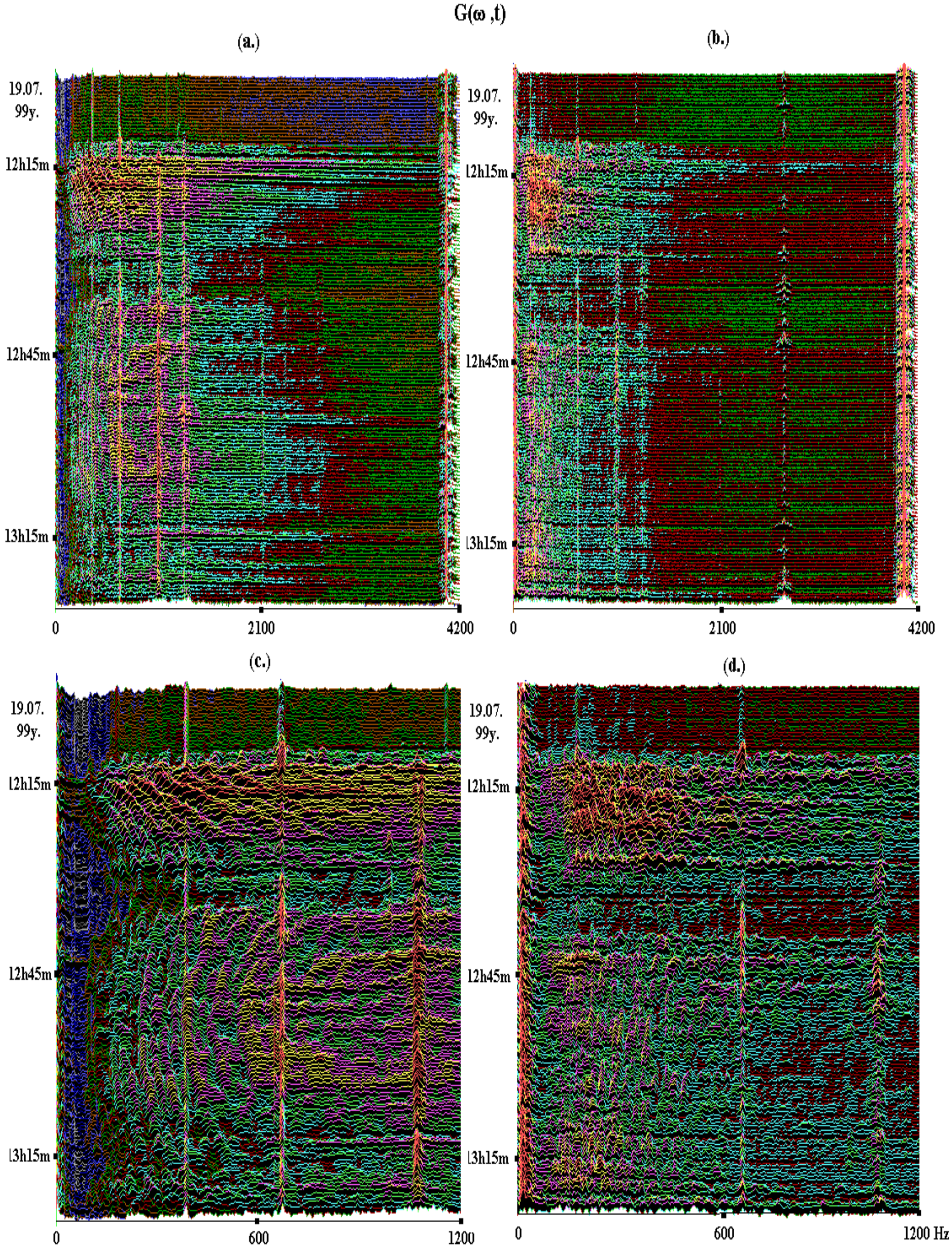


Fig. 20. Sonograms of acoustical background synchronously measured at p. 4 (a, c) and p. 3 (b, d) on July 19, 1999. Tonal acoustical signal was radiated from Agat's anchorage with frequency 4 kHz.

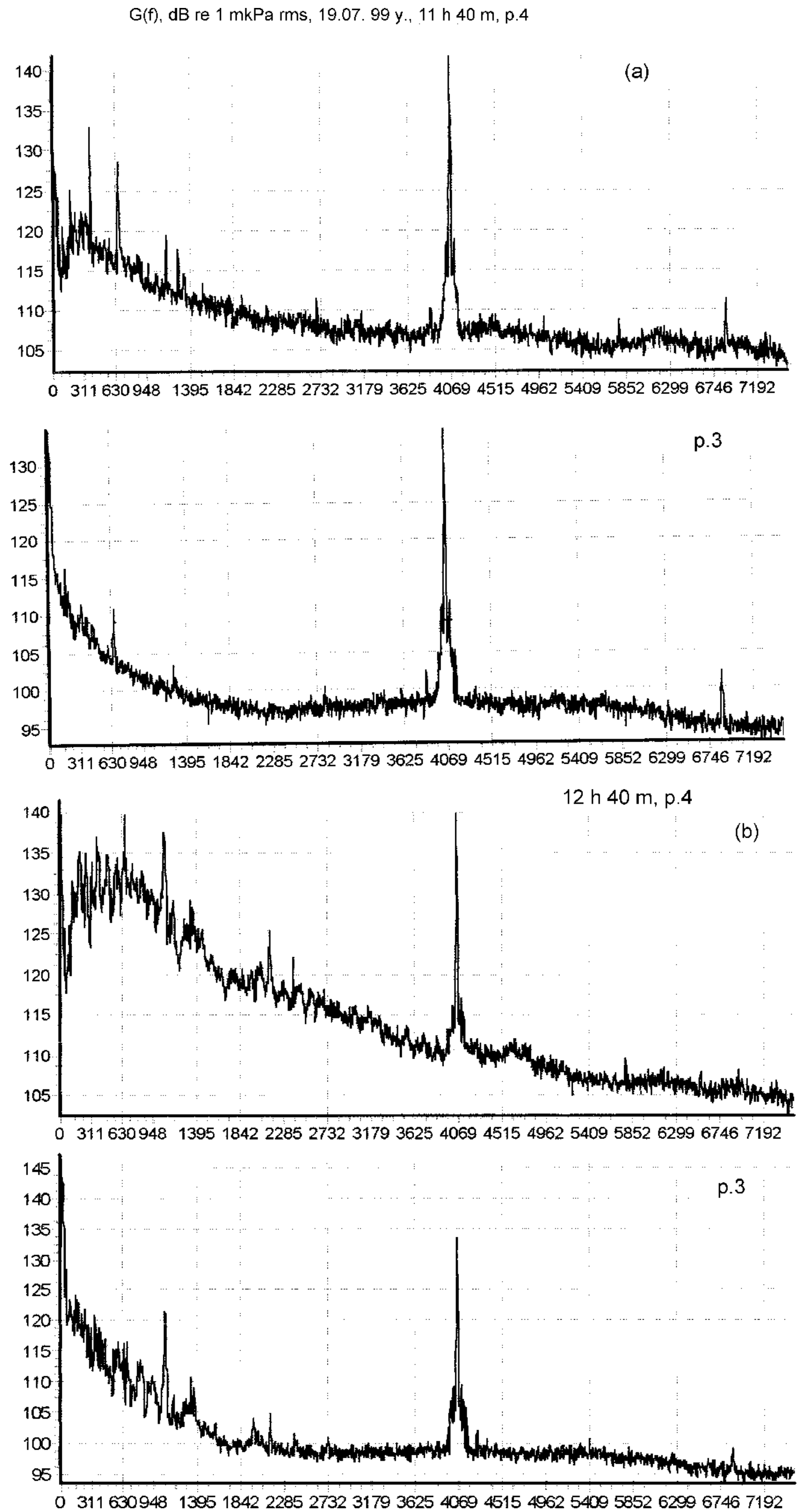

G(f), dB re 1 mkPa rms, 19.07. 99 y., 11 h 40 m, p.4
(a)
p.3
12 h 40 m, p.4
(b)
p.3
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192

Fig. 21

losses in the shallow-water zone. On the average, the spectral level of noise at frequencies from 200 to 1,000 Hz in point 3 is less than the background level in point 4 approximately by 22 dB. The level of the sinusoidal component with the frequency about 1 kHz (Fig. 21b) in point 3 is lower than that in point 4 by 17 dB.

Figure 22 shows the sonograms of acoustic wavefields simultaneously measured in points 3 and 4 during maneuvering of the ship *Neftegaz* near the Molikpaq. Acoustic tones with frequencies 2.2, 4.4 and 6.6 kHz were generated from the anchored rescue ship *Agat* by a transmitter lowered into the water from the ship during this experiment. *Neftegaz* started moving toward the Molikpaq at 18:10 to moor at stand No. 3 for unloading. At 18:15 the ship coordinates were $\varphi = 52^0 43{,}5'; \lambda = 143^0 34{,}4'$, it made good the course *192.8⁰* and was moving at a speed of 4.6 knots. At 18:20 the ship coordinates were $\varphi = 52^0 43.2', \lambda = 143^0 34.2'$, it made good the course 194^0 and was moving at a speed of 5.4 knots. At 18:23 the ship coordinates were $\varphi = 52^0 43', \lambda = 143^0 34{,}1'$, it moved at a speed of 6 knots. At 18:26 the ship came behind the Molikpaq. This data was obtained with the radar of the rescue ship *Agat.*

Figure 22 shows the $\hat{G}(f)$ plots pertaining to the measurements made in points 4 and 3 when the location of *Neftegaz* was known. Figure 22a corresponds to 18:15, 22b to 18:20. The $\hat{G}(f)$ plots in Figure 23a pertain to the measurements made at 18:23, 23b to the measurements made at 18:43. In all figures corresponding to the measurements made during ship's movement the continuous noise spectrum and discrete sinusoidal components measured with some propagation losses in both points are quite distinct. A more comprehensive analysis of this data will be made later. The average levels of

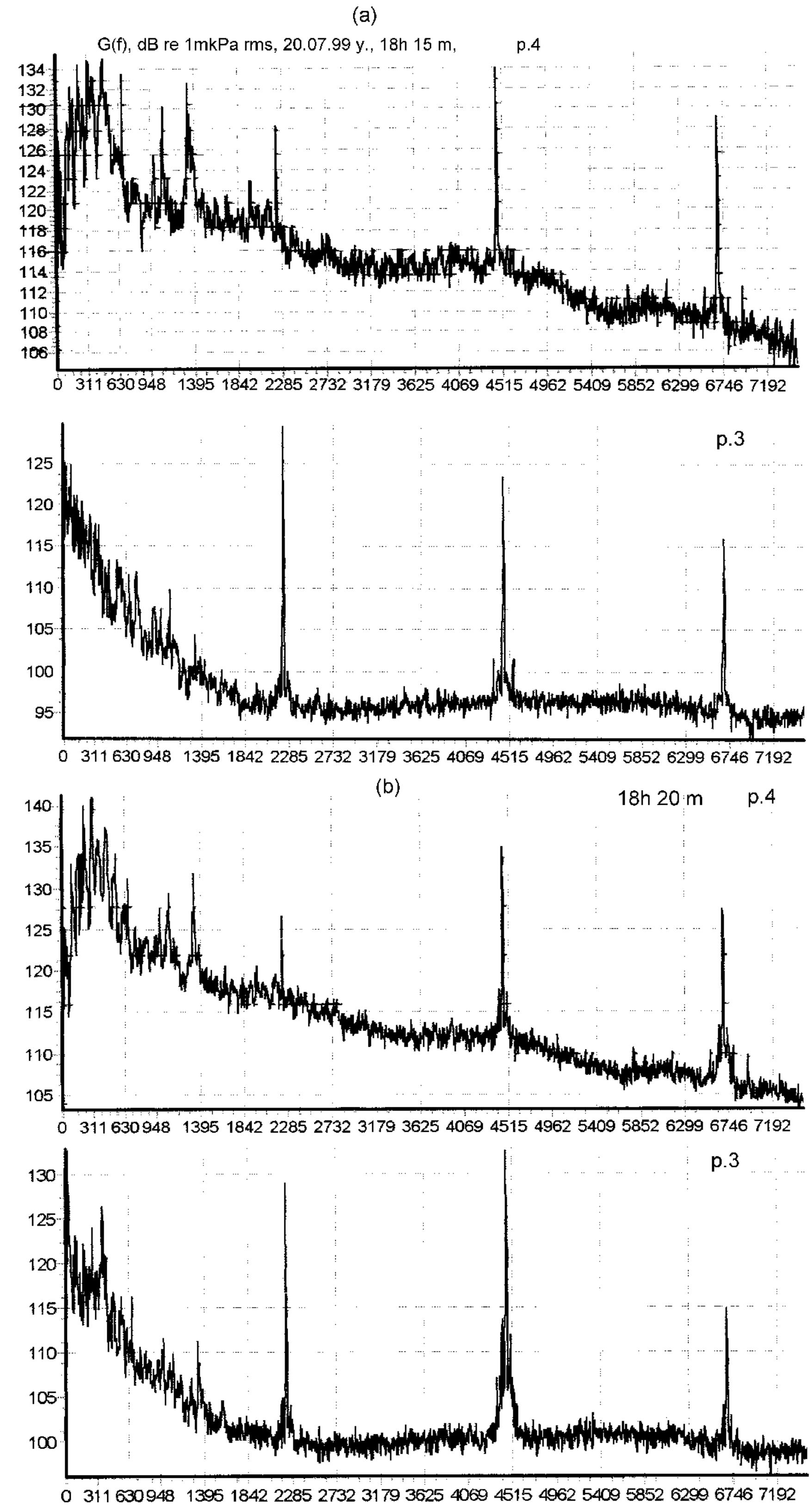

(a)
G(f), dB re 1mkPa rms, 20.07.99 y., 18h 15 m,
p.4
134
132
130
128
126
124
122
120
118
116
114
112
110
108
106
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192
p.3
125
120
115
110
105
100
95
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192
(b)
18h 20 m
p.4
140
135
130
125
120
115
110
105
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192
p.3
130
125
120
115
110
105
100
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192

Fig. 22

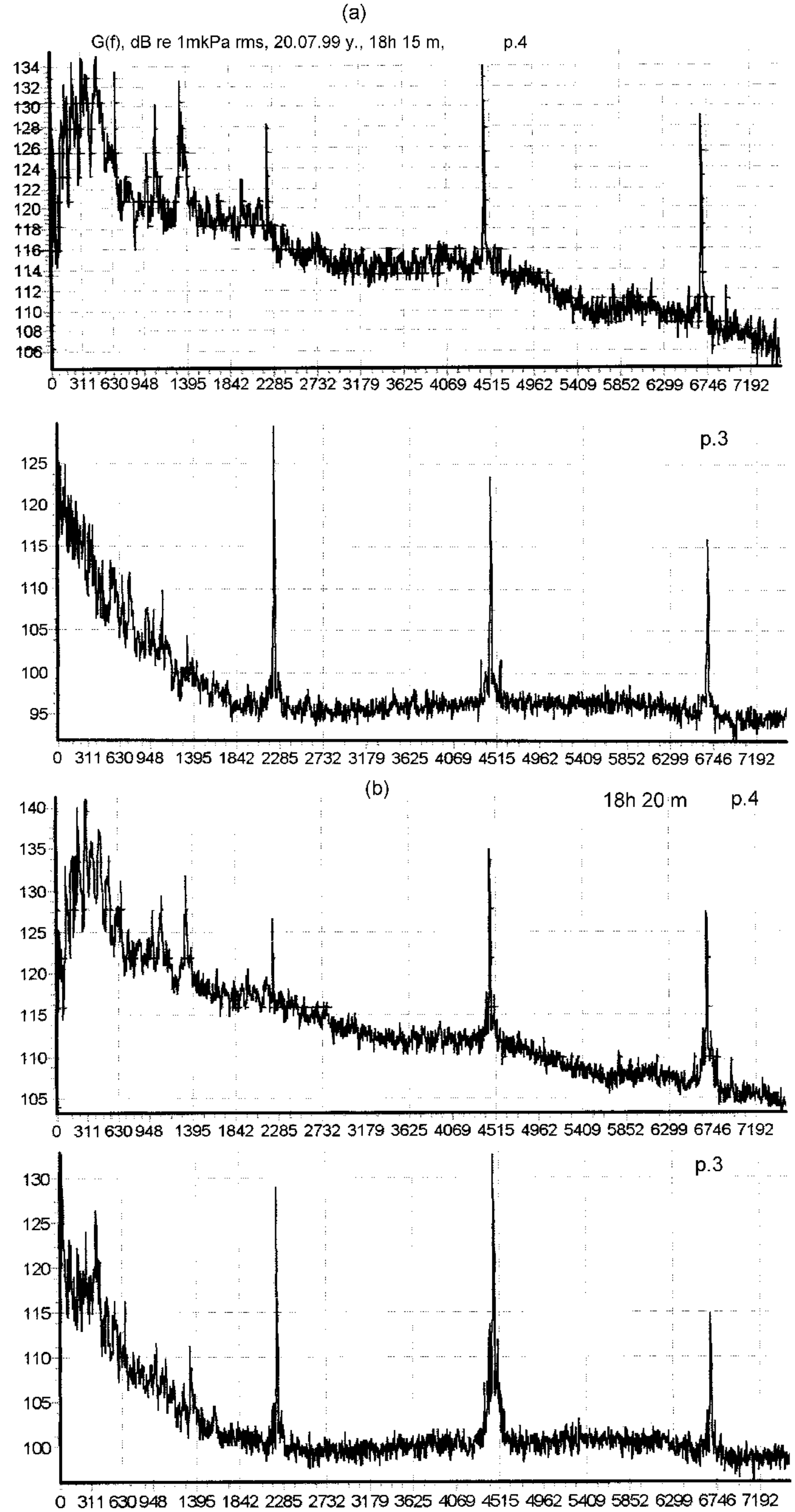


Fig. 23. Estimations of power spectrum of background level synchronously measured at p. 4 and p. 3 on July 20, 1999

the acoustic tones are by 20-30 dB higher than that of the noise background measured in point 3. The signal levels with frequencies 4.4 and 6.6 kHz in point 4 exceed the background by 30 and 20 dB respectively, the signal level with the frequency of 2.3 kHz exceeds the background level only by 8 dB due to relatively strong noise generated by *Neftegaz*, but at 18:46 (Fig. 23b) the difference reached 20 dB. According to the data shown in Figures 20-23, the level of acoustic tones generated at the anchorage of *Agat* exceeded the level of the noise background near the Molikpaq more than by 20 dB even during ship movement in the vicinity of the Molikpaq. According to the simultaneous measurement in point 1 at a distance of 24.6 km from the Molikpaq, the energy of the signals is below the noise background in that point due to transmission losses in the shallow-water zone.

6.2 Results of Theoretical and Experimental Sound Propagation Studies along the Molikpaq-Piltun Route

The assumption of possible anthropogenic impact on gray whales of acoustic noise generated by the Molikpaq oil production complex and its service ships required special theoretical and experimental investigations of the characteristics of sound propagation along the route shown in Figure 8.

The propagation of acoustic waves was modeled by normal waves in the adiabatic approximation using the MOATL program (Miller and Wolf, 1980). This program makes it possible to calculate energy losses during sound propagation in a waveguide with varying hydrologic characteristics and account of actual bottom topography. At each change of hydrological parameters and bottom topography the program recalculates the parameters of normal waves; the attenuation coefficient of each mode is integrated over the distance. The depth in the waveguide varied from 28 m in the location were sound was generated to 10 m in the reception point. The sound source was located at a depth of 5 m, the hydrophone at a depth of 10 m. The sound velocity in the waveguide varied from 1494 m/s on the water surface to a depth of 6 m and also linearly to 1460 from a depth of 6 m to 10 m, below 10 m the sound velocity remained constant, 1460 m/s. The bottom was assumed to be “liquid” overlying the basis with velocity of 5,500 m/s, density 5.5 g/cm^3 and absorption factor of 0.11 dB/km. The sound velocity in the bottom varied linearly with depth from 1,700 to 1,900 m/s, the absorption factor was 0.7 dB/km, density was 1.8 g/cm^3 which agrees with experimental data. Calculations were made for sound frequency of 500 Hz, 1 kHz and 3 kHz. In the numerical modeling 16, 32 and 89 normal modes were accounted for in conformity with the frequency of the acoustic field in the calculation of transmission losses for the assumed frequencies.

Figure 24 shows the configuration of the route and plots of losses (in decibels) for propagation in a wedge of acoustic waves with frequencies 500, 1,000 and 3,000 Hz. According to the calculations, under summer hydrological conditions a sound wave generated at a depth of 5 m near the Molikpaq attenuates by 60 dB and more during propagation toward the coast along the Molikpaq-Piltun route. The spatial interference pattern in the shallow portion of the route is well-defined for acoustic field with the frequency of 1 kHz and is characterized by intensity variation more than 40 dB.

Numerical modeling confirmed the experimental data. In point 1 (Fig. 8) we failed to record tones generated at the anchorage of the rescue ship *Agat,* because the levels of generated signals with frequencies 2.2, 4.4 and

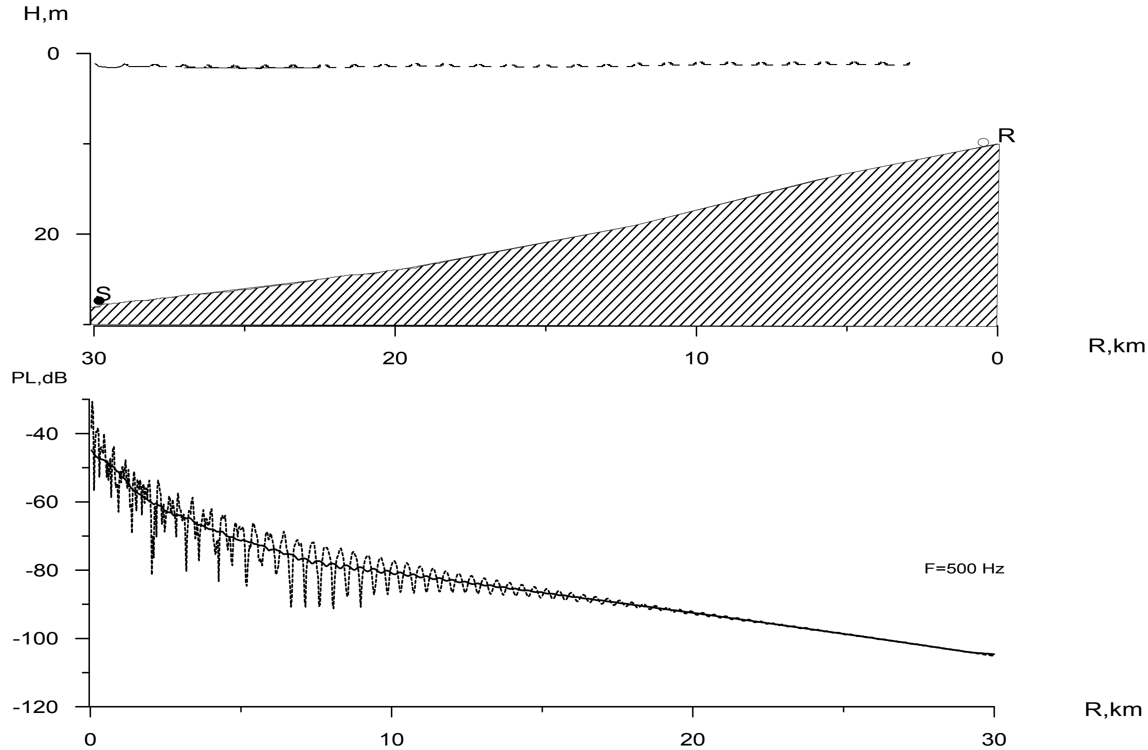


Fig. 24. Geometry of acoustical line and results of calculations of losses at sound propagation with frequencies 500 Hz, 1 kHz and 3 kHz

6.6 kHz (Fig. 21 and 22) were only 30-35 dB above the background level in points 3 and 4.

Unfortunately, we do not have a program accounting for elastic properties of the bottom rocks which could calculate transmission losses of acoustic waves with lower frequencies. As mentioned earlier, a considerable portion of energy of the low-energy acoustic field can be transmitted into the coastal zone by surface seismic waves propagating along the interface between any two media if shear waves can exist at least in one of them. We want to remind that in the theoretical work by Bespalov et al. (1998) it was shown that for sound with the frequency of 1 Hz and higher generated in a water layer the introduction of a sand layer and a sand-limestone interface instead of the sand halfspace increases the amplitudes in the near-bottom zone. This increment for a distance of 20 km amounts to 50 dB for frequency 1 Hz and 60 dB for frequency 10 Hz.

Taking into consideration the results of numerical modeling described by Bespalov et al. (1998) let us examine the plots of estimates of power spectrum $\hat{G}(f)$ of the noise background (Fig. 25) measured in point 2 (Fig. 8) on 3.10 99. The power peaks at frequencies about 2.7, 4.3 and 4.4 kHz (Fig. 25a) may be produced by electromagnetic pickup from the computer. Note small power peaks at frequencies 50 and 100 Hz (Fig. 25b). Electric power was supplied to the measuring equipment installed in the upper part of the Piltun lighthouse by a petrol engine-driven electric plant located at a distance of 70 m from the lighthouse. During these measurements the sea was relatively calm, because the westerly wind had been blowing for a few days and there were practically no swell typical of the summer season. In Figure 26 the narrow power peak at the frequency of 26 Hz which exceeds the background by more than 10 dB can be seen best of all. There is also a

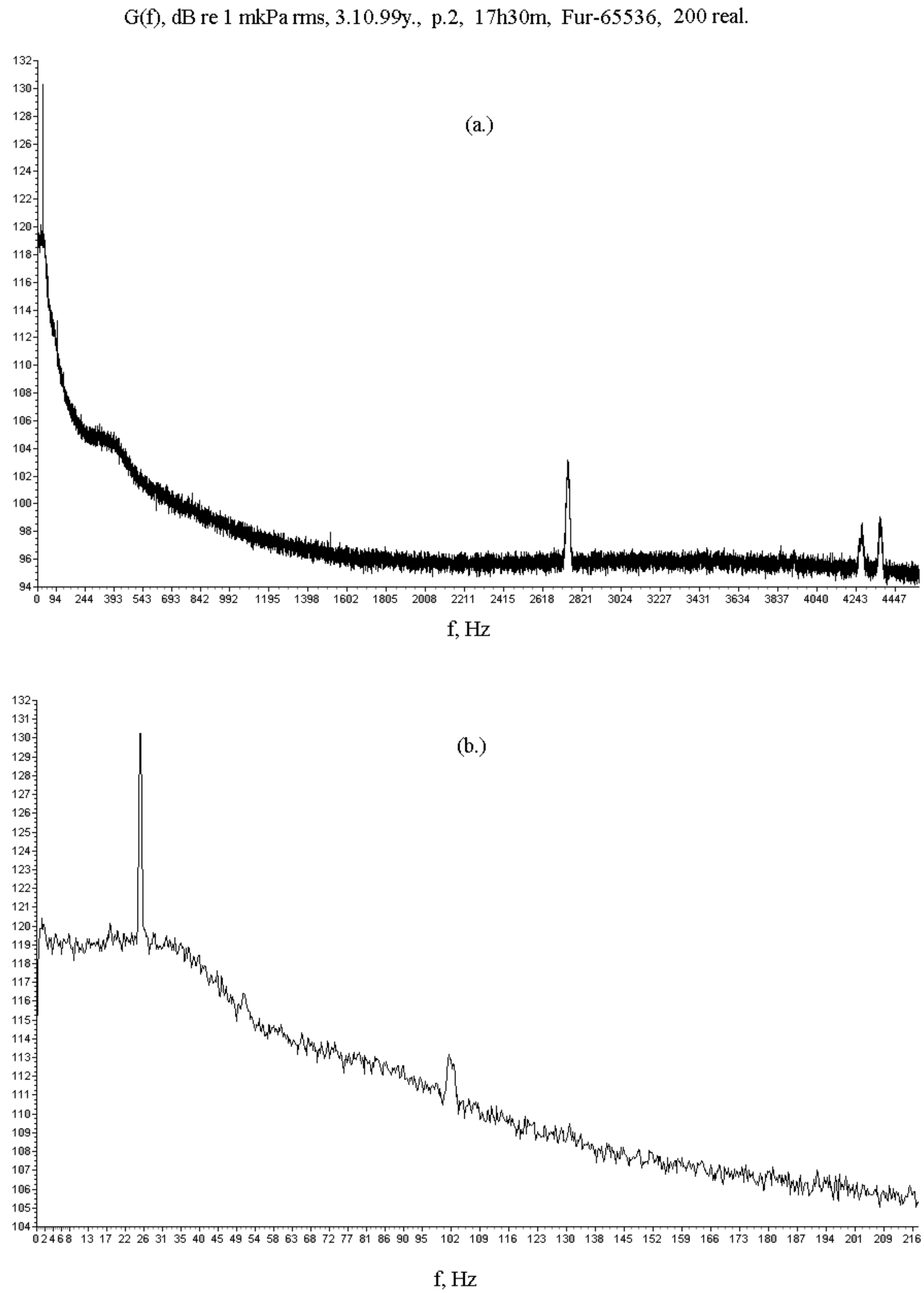


Fig. 25. Estimations of power spectrum of background level measured at p. 2 on October 1999

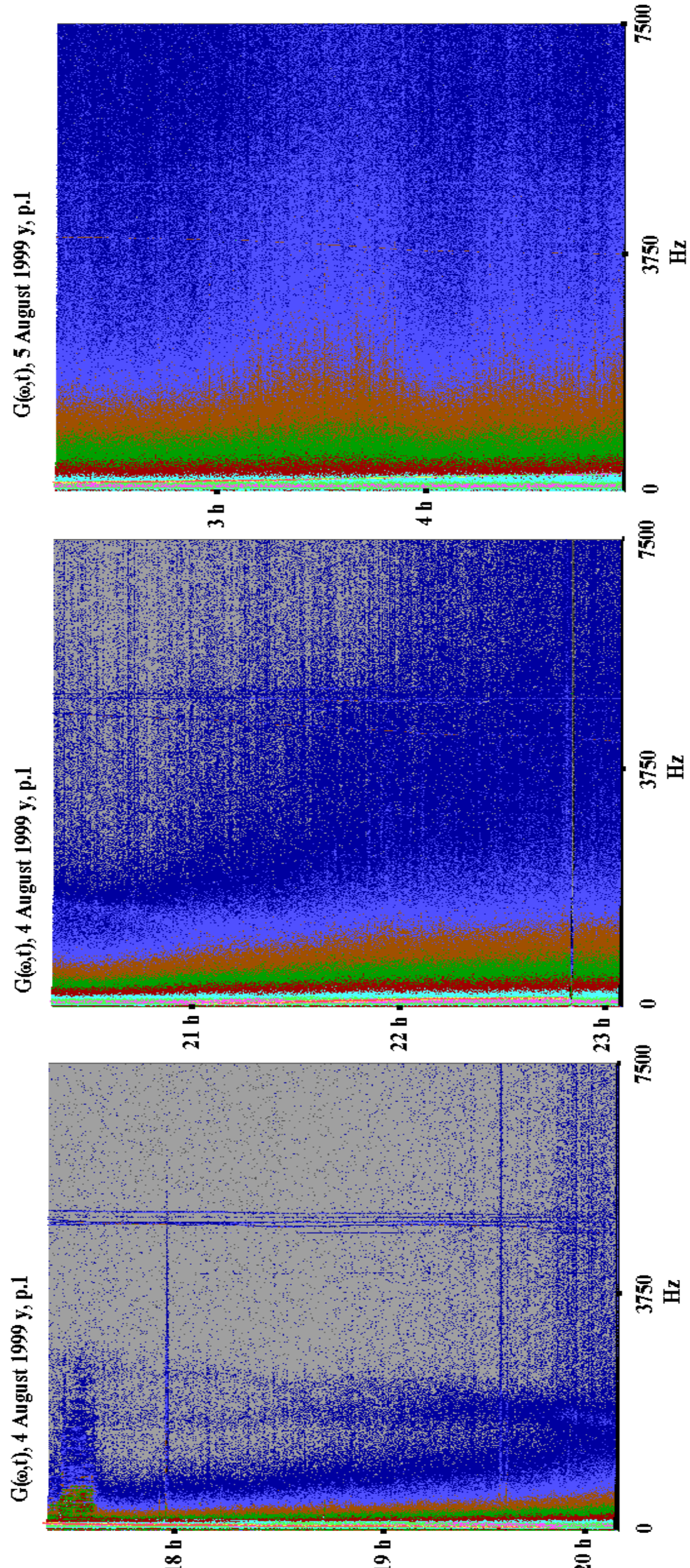


Рис. 26. Сонограмма акустичесого фона в точке p.1

Fig. 26. Sonogram of acoustic background at p.1

persistent power peak at the same frequency on the spectra obtained in point 4 near the Molikpaq (Fig. 17). We can presume that it was generated by a mechanism which always worked on the Molikpaq. The signal measured in point 2 is only 10 dB weaker than in point 4. So small transmission losses can be explained by the location of the source of this signal and by the fact that its energy was transmitted into the coastal zone by seismic waves.

6.3. Investigation of Noise Background and Sound Propagation in the Area of Summer-Autumn Feeding of Gray Whales

Systematic measurements of acoustic background in the area of maximum aggregation of gray whales in the summer-autumnal season were made with fixed sonobuoys located in points 1 and 2 (Fig. 8). Measurements were made continuously during several days until the electric batteries discharged completely. The sonobuoy installed in point 1 on July 16 remained in the sea until August 5. The buoy started working after the change of batteries from a boat without blasting its bottom anchor. Unfortunately, in August after we lifted the buoy onto the boat we saw that in spite of a considerable separation from the bottom (at least 25 cm) its hydrophone protected from flow by a special screen was blocked by silt and sand which must have influenced sound measurement at high frequencies. Besides, the first experiments showed that the measuring hydrophone must be separated by at least 60-100 m from the sonobuoy so that flow noise made by surface waves do not interfere. In the analysis of the sonograms of the spectra of measured noise background we identified a serious technical defect of the radio receiver-scanners AX-400 made by Standard and specially purchased by us for sonobuoys in 1999: a narrow-band noise was present in the electric signal on the output from the frequency discriminator, the frequency of this noise varied with time and could be correlated with the discharge of the batteries. We informed the manufacturer of this defect of AX-400; as a result it was transferred from the professional class to the of radio amateur class. Nevertheless, we hope to use this radio successfully in the future using a stabilized power supply.

Now let us discuss the results of measurements. Figure 26 shows the sonogram of the spectrum of noise background measured in point 1; it illustrates background variations due to variations of intensity of surface waves and wind.

The sonograms presented in Figure 27 show the frequency-spatial interference pattern of the noise field generated by a motor boat passing the sonobuoy (at a distance of at least 500 m) (Fig. 27b) and a short rain with hail (Fig. 27a) from 8:30 till 8:40. The corresponding estimates of power spectra $\hat{G}(f)$ are shown in Figures 28a and 28c. In figure 29 the $\hat{G}(f)$ plots corresponding to the noise generated by rain and hail (29a) and relatively quiet background (Fig. 29b) are shown enlarged for comparison. As follows from the figures, the motor boat generates in a given area a practically continuous, with a few steps, noise spectrum in the range to 7 kHz; its level exceeds the background (Fig. 28d) on the average by 15 dB in the range to 2 kHz and almost 20 dB in the 2.5-4.0 kHz range. The $\hat{G}(f)$ plot corresponding to the noise measured near the bottom in point 1 during a short rain and hail (Fig. 28c and 29a) is similar to the spectrum of red noise with a slope of about -0.003 dB/Hz. Note periodic variations of spectral power in the 1.8-3.6 kHz range. These variations (dependence of noise intensity on noise frequency) can be easily seen on all plots shown in Figures 28 and 29;

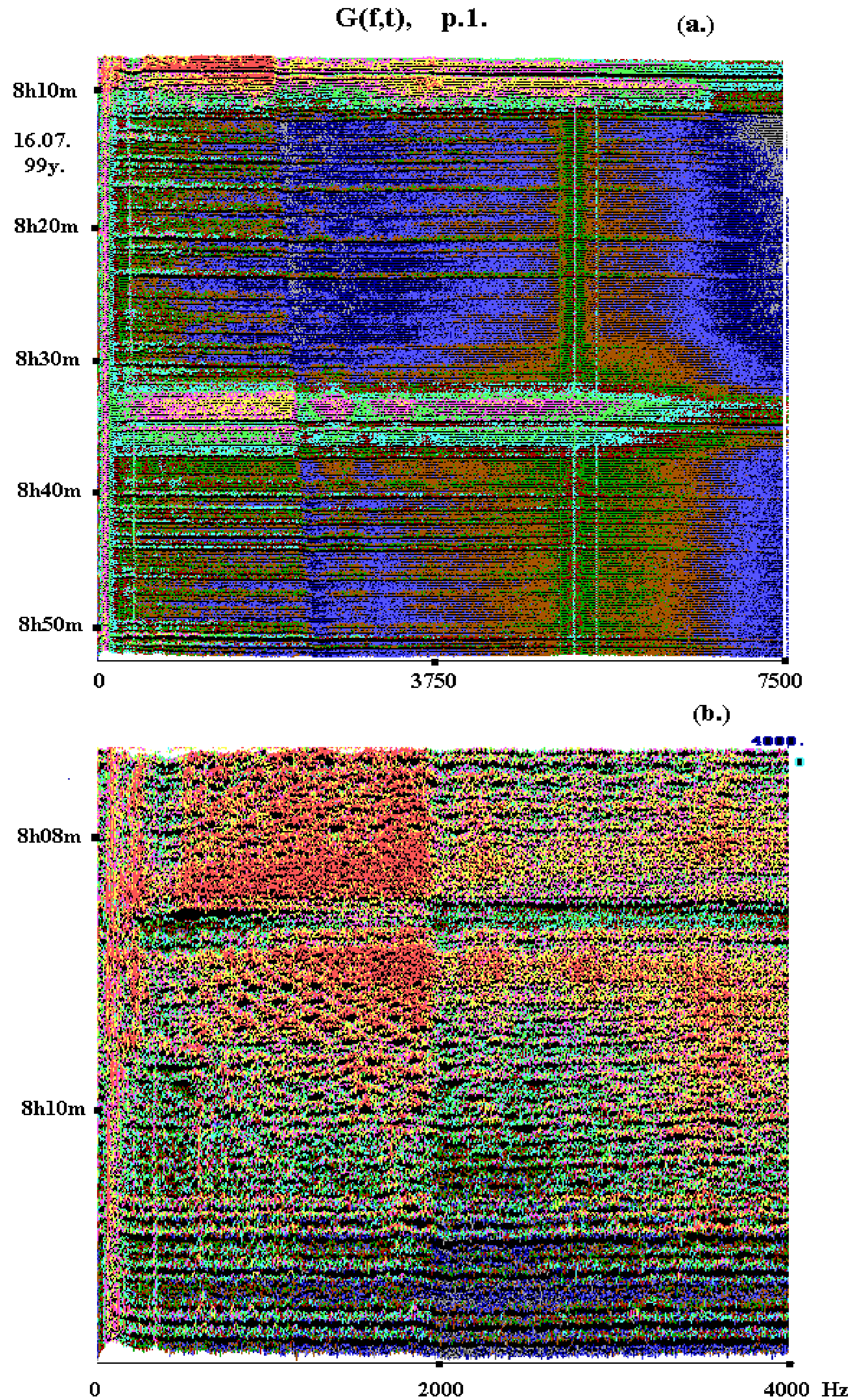


Fig. 27. Sonograms of acoustic background measured at p. 1 during moving of motorboat

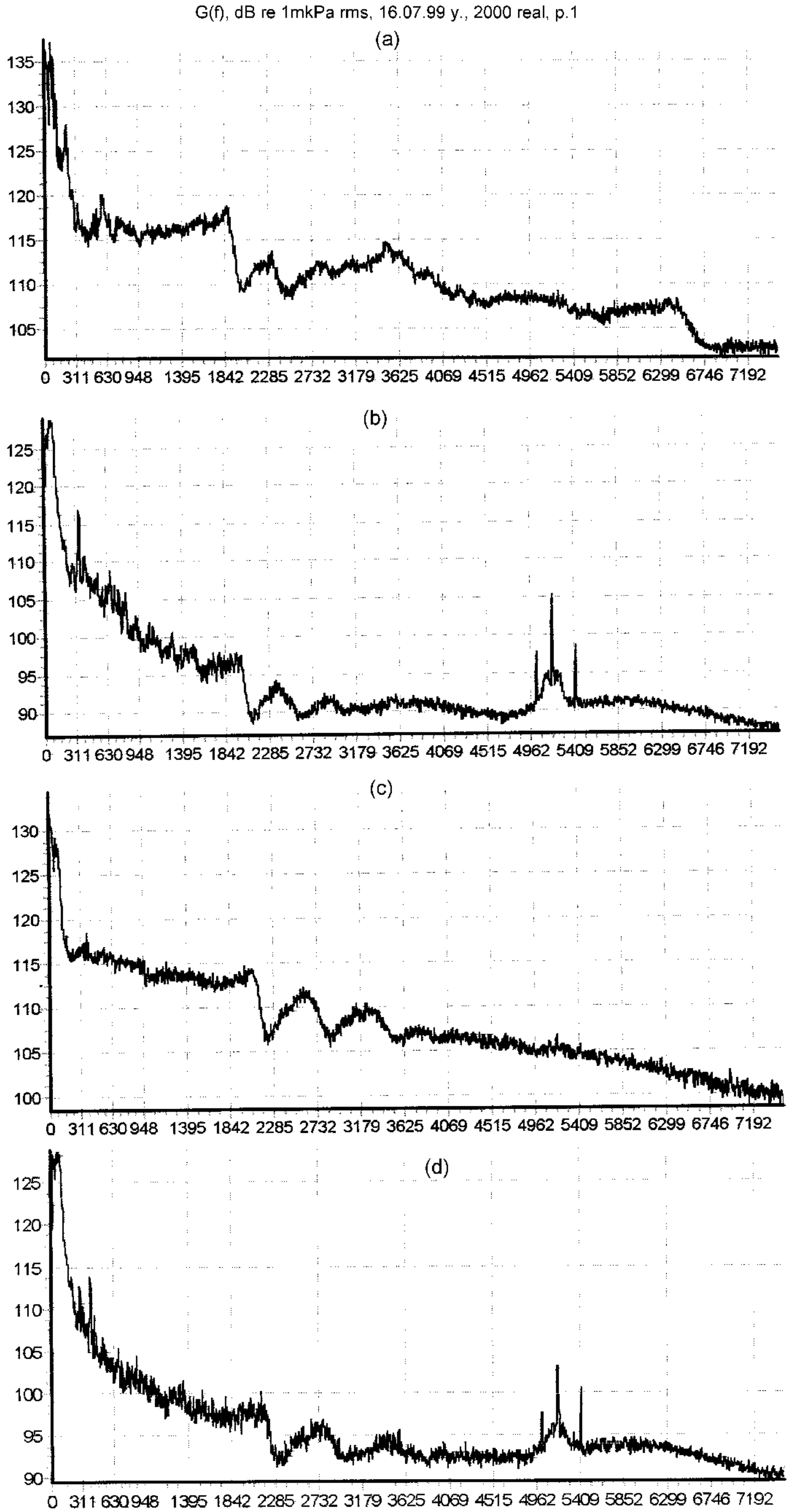
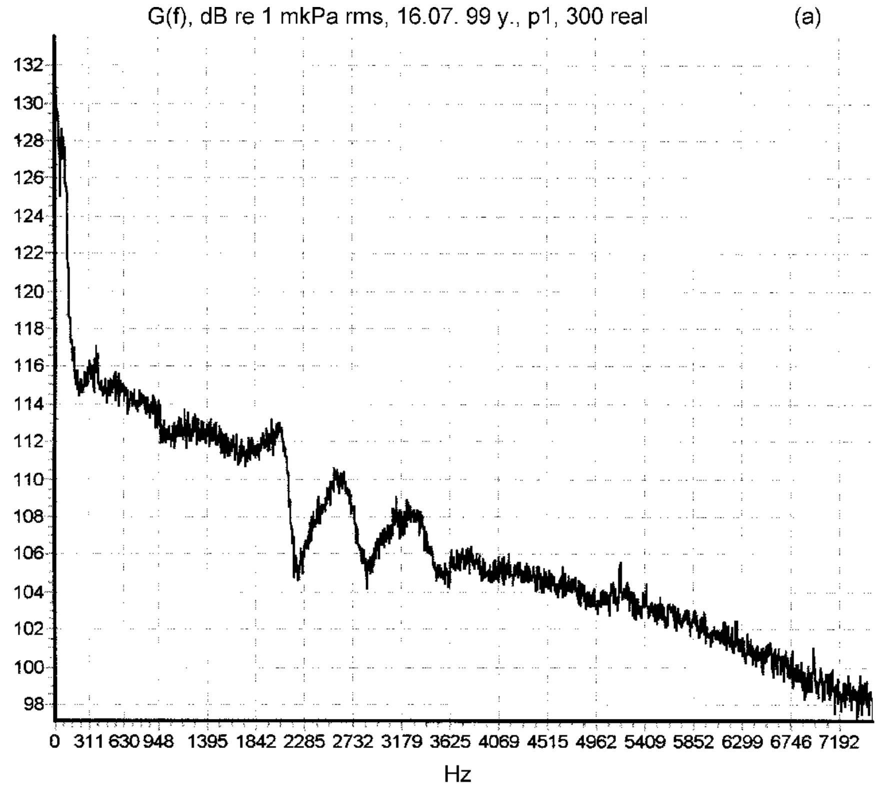

G(f), dB re 1mkPa rms, 16.07.99 y., 2000 real, p.1
(a)
(b)
(c)
(d)
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192

Fig. 28


G(f), dB re 1 mkPa rms, 16.07. 99 y., p1, 300 real
(a)
132
130
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192
Hz

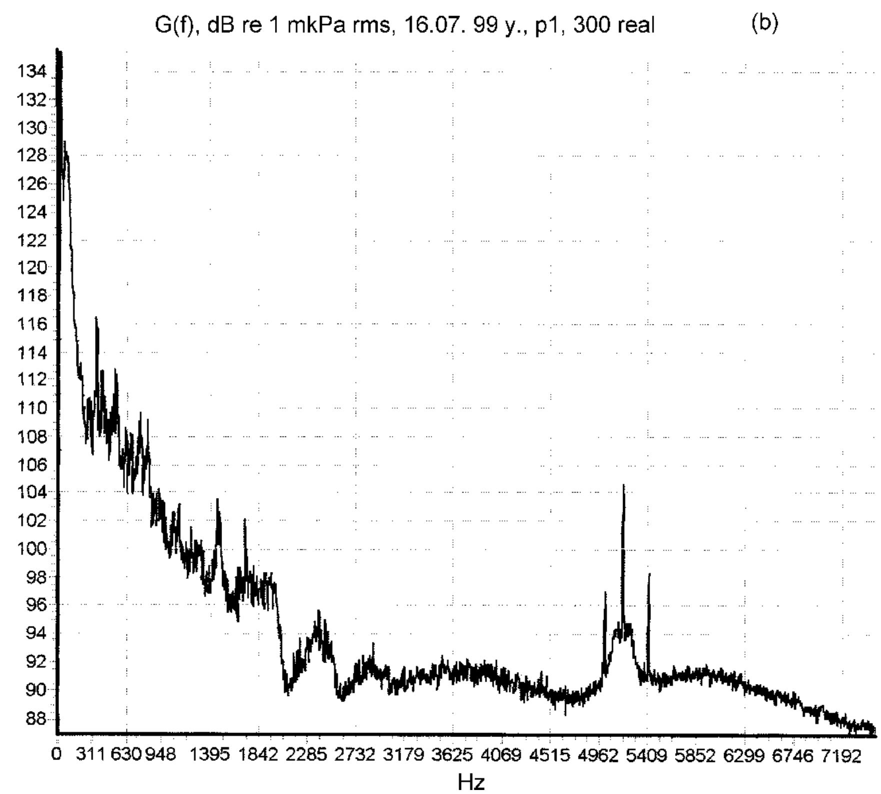

G(f), dB re 1 mkPa rms, 16.07. 99 y., p1, 300 real
(b)
134
132
130
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
88
0 311 630 948 1395 1842 2285 2732 3179 3625 4069 4515 4962 5409 5852 6299 6746 7192
Hz

Fig. 29

probably they are associated with specifics of generation and propagation of sound waves in this particular area. Modulation of intensity of received acoustic signals and the entire noise background by swell is another characteristic feature of sound reception at sea at a depth of 7-8 m. Reflection and scattering of acoustic waves by the sea surface when the crest of surface wave passes above the hydrophone provides a focusing effect which causes the audible and visible modulation.

The characteristics of sound propagation in a given water area were studied with a transmitter towed by a motor boat, the transmitter generated a number of tones. Figure 8 shows the route p.1.1-p.2.1 along which the transmitter was towed. The acoustic field was measured simultaneously in points 1 and 2. Figure 30 shows the sonogram of the spectrum of noise background measured during the experiment. The power peaks corresponding to generated tones are easily seen. It is seen well that the acoustic field having the frequencies of interest attenuates rapidly. The intensification of the signals received in point 1 immediately after 9 o'clock is produced by a special mode of sound generation undertaken when the ship heaved to near point 2.1 (Fig. 8): at 9:04 the transmitter was put on the bottom, at 9:07 it started to be lifted slowly and reached the surface at 9:08; after 30 seconds it started to be lowered, at 9:11 it was lifted to the surface again, from 9:16 till 9:18 it was kept at a depth of 3 m after which it was turned off and lifted on board the motor boat.

Figures 31 and 32 show the estimates of power spectra $\hat{G}(f)$ of noise background measured in point 1, they correspond to the periods of the experiment with the transmitter when the location of the motor boat was known due to GPS measurements. The experiment was carried out in the following way. We started towing at 8:20, at 8:23 we saw three whale

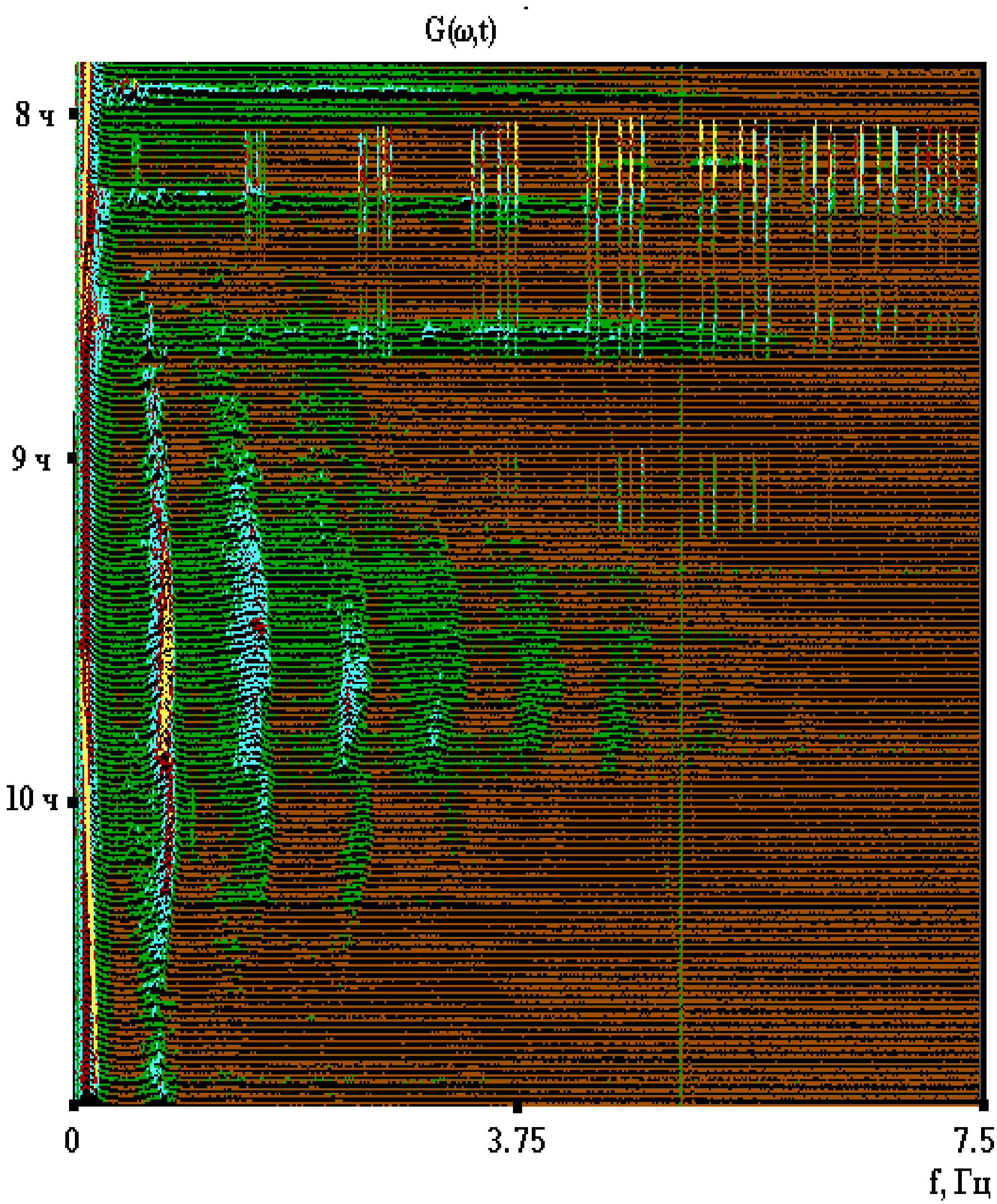


Fig. 30. Sonogram of spectrum of acoustic background measured at p. 1 during experiment with towing transmitter

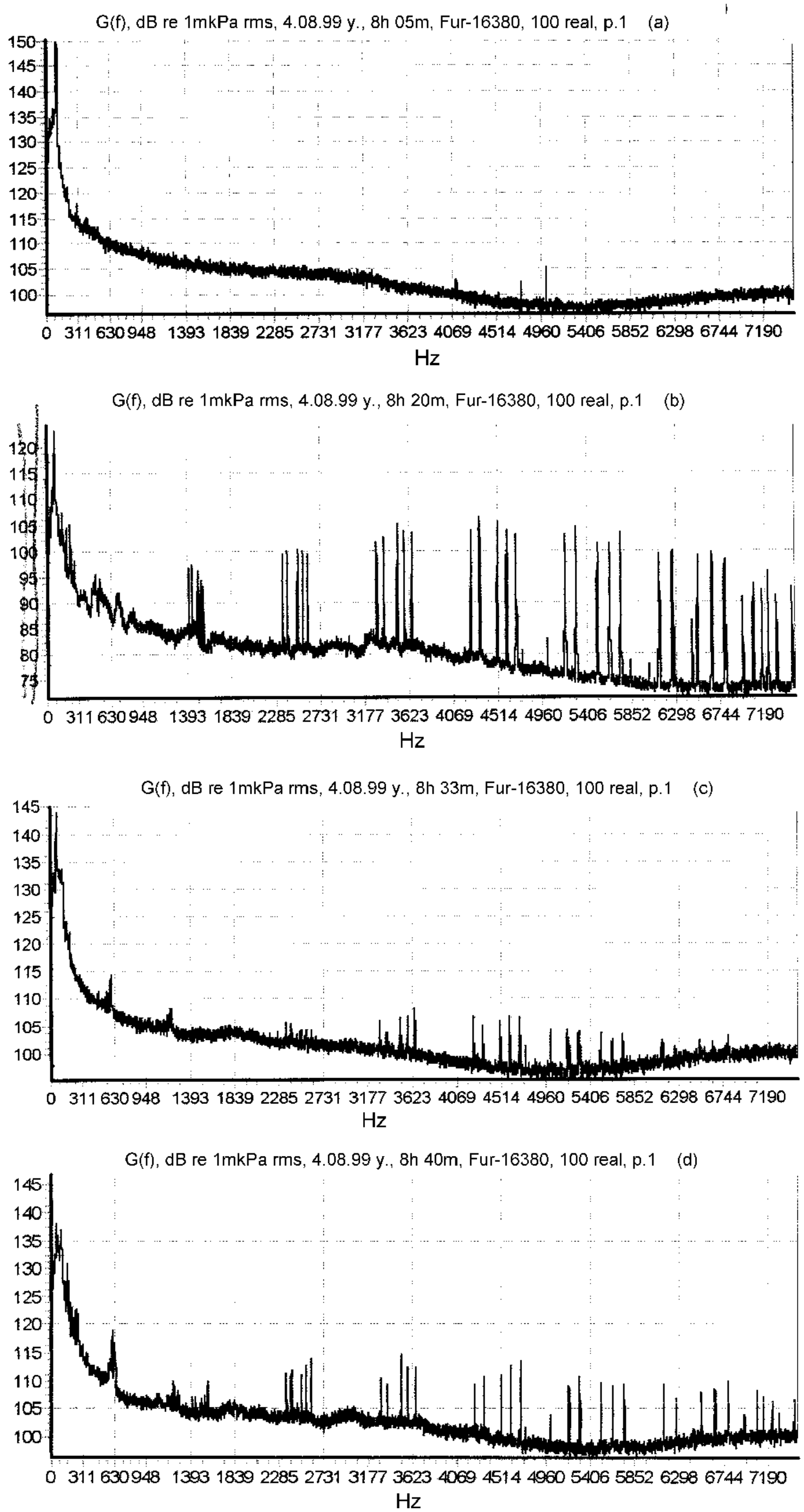

G(f), dB re 1mkPa rms, 4.08.99 y., 8h 05m, Fur-16380, 100 real, p.1 (a)
150
145
140
135
130
125
120
115
110
105
100
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz
G(f), dB re 1mkPa rms, 4.08.99 y., 8h 20m, Fur-16380, 100 real, p.1 (b)
120
115
110
105
100
95
90
85
80
75
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz
G(f), dB re 1mkPa rms, 4.08.99 y., 8h 33m, Fur-16380, 100 real, p.1 (c)
145
140
135
130
125
120
115
110
105
100
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz
G(f), dB re 1mkPa rms, 4.08.99 y., 8h 40m, Fur-16380, 100 real, p.1 (d)
145
140
135
130
125
120
115
110
105
100
0 311 630 948 1393 1839 2285 2731 3177 3623 4069 4514 4960 5406 5852 6298 6744 7190
Hz

Fig. 31

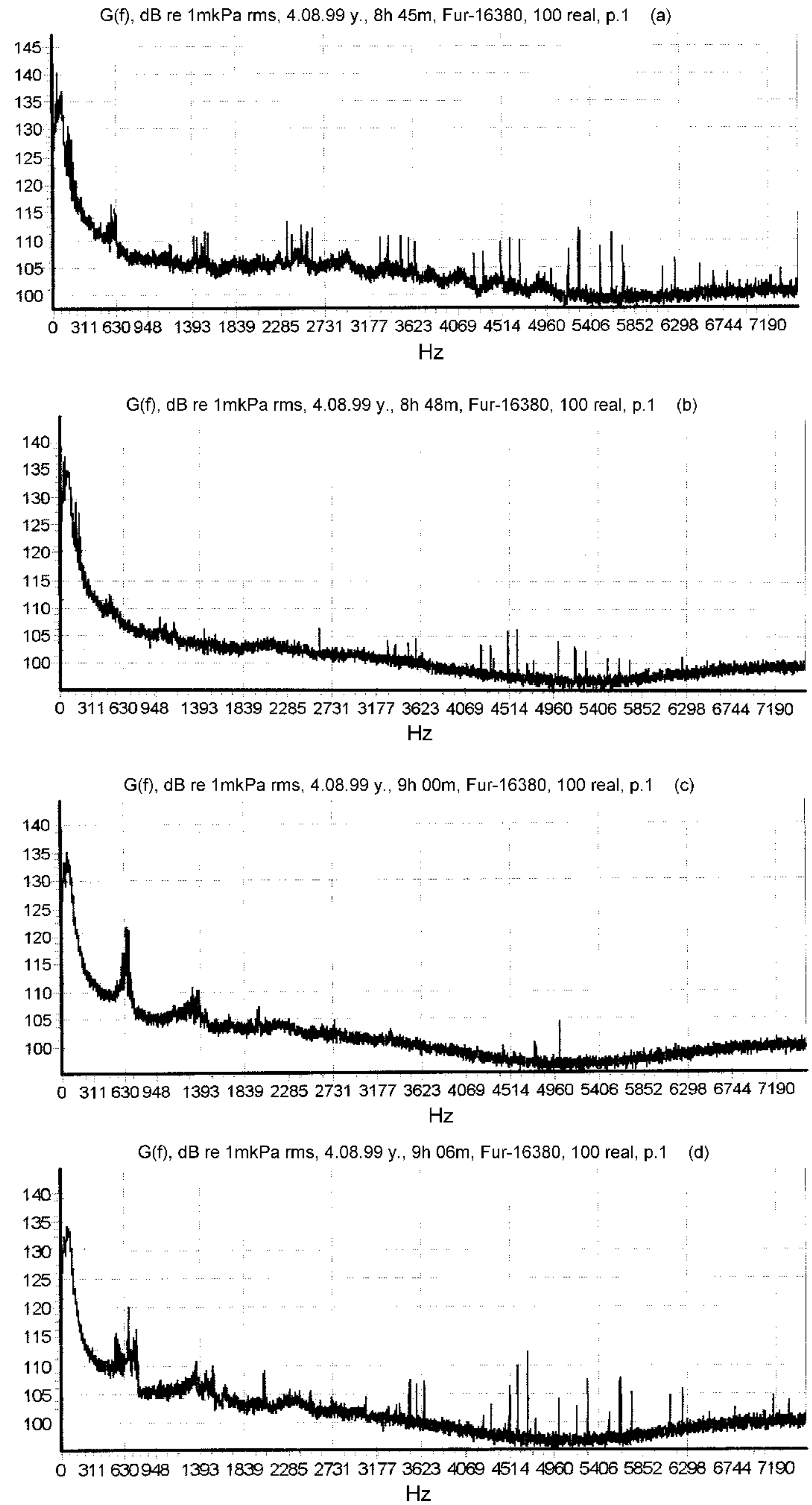
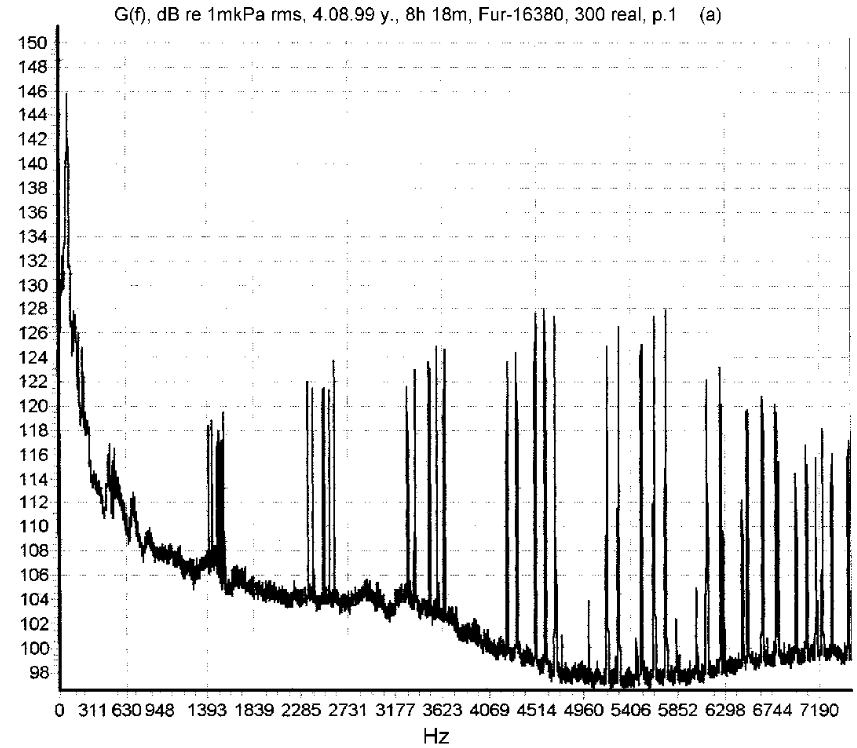


Fig. 32. Estimations of power spectrum of acoustic background measured in divers time at p. 1

spouts, the tow speed was 10 km/hour, at 8:25 we were at a distance of 100 m from the whale, at 8:33 we passed point 1.1 ($\varphi = 52^0 53' 58'', \lambda = 143^0 20' 53''$), at 8:37 we were moving toward point 2.1 at a speed of 10 km/hour, at 9:04 we came to point 2.1 and heaved to. The work done when we heaved to was described earlier, now we only give the coordinates of the boat characterizing the current velocity: 9:08 - $\varphi = 52^0 50' 58.3'', \lambda = 143^0 20' 57.6''$; 9:11-$\varphi = 52^0 50' 53'', \lambda = 143^0 20' 58.6''$; 9:16 - $\varphi = 52^0 50' 56'', \lambda = 143^0 21' 04.2''$. The speed of current is equal 3 м/s, let us discuss the results of acoustic measurements. The $\hat{G}(f)$ plot in Figure 31a characterizes the background conditions of the experiment. Figure 31b corresponds to the moment when we started towing of the transmitter. The power peaks at frequencies of the generated acoustic signals which exceed the background on the average by 15 dB can be easily seen on the $\hat{G}(f)$plot. The $\hat{G}(f)$plot in Figure 31c characterizes the losses during sound propagation from point 1.1 to point 1. Figures 31d and 32 a, b and c illustrate the specifics of propagation of sound with various frequencies in a given area. It should be noted that the transmitter was towed at a speed of 10 km/hour, and since the boat was moving against the current, the actual speed of the transmitter with respect to the water was even greater, therefore, the signals were generated practically from the water surface; that is why when we heaved to and lowered the transmitter on the bottom near point 2.1, the signal levels measured in point 1 increased considerably (Fig. 32d).

Figure 33 shows the $\hat{G}(f)$plots and functions of squared coherency $C_0^2(f)$ between acoustic signals simultaneously measured in points 1 and 2. The $C_0^2(f)$ values characterize the linear relation or interference (if it is known beforehand) between two signals with a given frequency. According



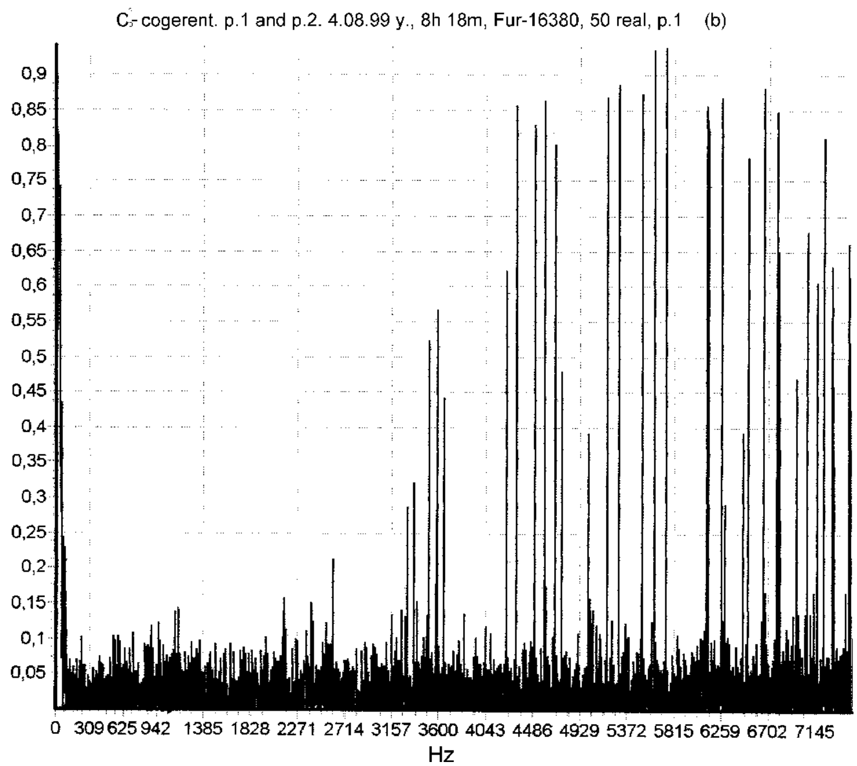


Fig.33. Estimations of power spectrum of acoustic background measured at p. 1 on August 4, 1999 (a). Function of coherence's square C_0^2 between acoustic signals synchronously measured at p.1 and p.2 (b)

to figure 33b, the noise background in the 1-3 kHz range distorted the linear relations between the signals received in points 1 and 2, i.e., their parameters acquired the nature of random quantities due to fluctuations caused by refraction and scatter at uneven sea surface, topography and acoustic irregularities of the bottom and water layer, but a relatively low signal-to-noise ratio in a given frequency range must be also taken into consideration (Fig. 33a).

6.4. Acoustic Signals of Sea Animals

In section 6.1.1 we gave the estimates of power spectra of the noise background measured at night on September 24 near the Molikpaq during the stay at point 4 of a group of sea animals which generated long series of acoustic signals and isolated calls easily heard and visualized. Visual observations were impossible, but we believe that it was a group of killer whales. For example, in July we observed a killer whale near the anchorage of rescue ship *Agat* (Fig. 8).

Figure 34 shows fragments of records of noise background taken at night on September 24 in point 4 and in the day-time on August 4 at the shore near the aggregation of gray whales in point 1 (Fig. 8). As can be seen in the figure, if the sea animals have frequency selectivity in sound perception like human amplitude-frequency characteristic (Fig. 3), their acoustic (probably communication) signals exceed the noise background in a given frequency band.

Figure 35 shows fragments of records of the noise background in points 1 and 2 (Fig. 8) taken simultaneously during radiation of both

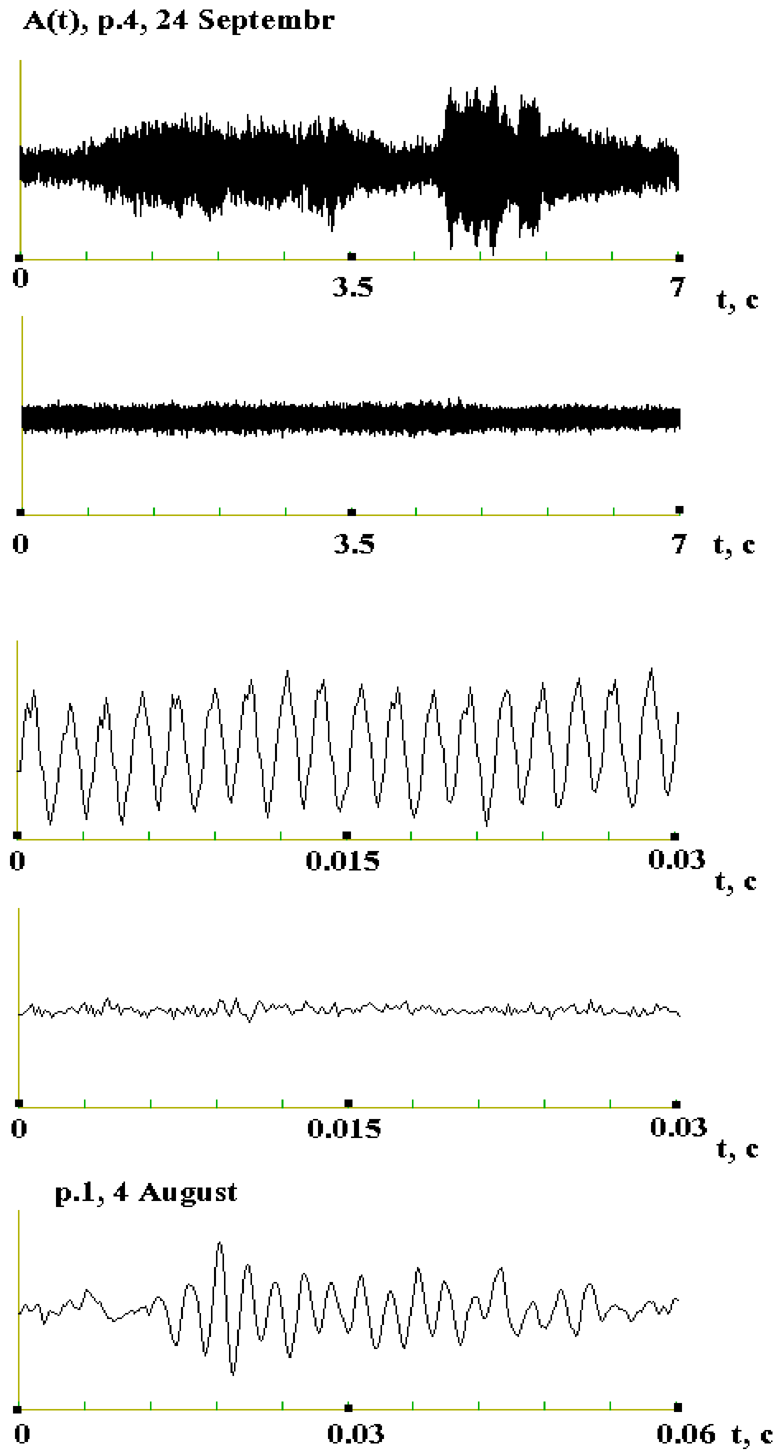


Fig. 34. Acoustic signals of marine mammals recorded near Molikpaq at p.1 and p.4

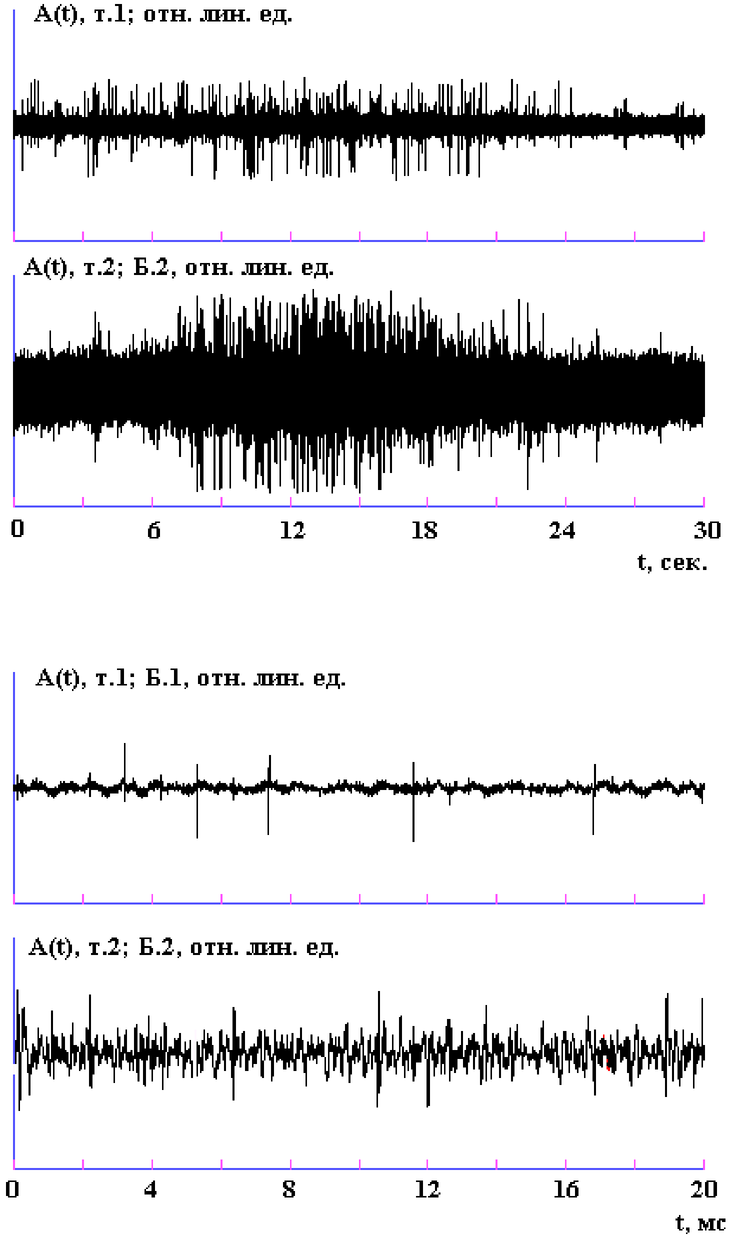


Fig. 35. Fragment of synchronous recording of acoustic background at p. 1 and p. 2 during radiating acoustic signals by gray whales

hydrophones by acoustic pulses generated by gray whales. In this case the pulse amplitudes cannot be measured, because they exceeded the dynamic range of the measuring system.

Discussion

As a result of monthly aerial surveys from July through November 1999 in the vicinity of Piltun Bay, we were able to confirm the presence of feeding gray whales in water depths mostly less than 20 meters (Wursug et. al. 1988; Weller, et. al., 1999). As shown by observations of gray whales made from the research vessel *Vulkanolog* in 1995, in summer about 30% of gray whales were encountered on the 5-10-m isobaths and 45% on the 11-20 m isobaths (Sobolevsky, 1998). In 1999 the distribution of whales in the offshore area was similar. 121 whales (38%) were countered in waters less than 10 m deep and 167 (53%) whales were in water 11-20m deep . In the offshore areas deeper than 50 m gray whales were not encountered from August from November, but small numbers were sighted well offshore in July.

Our 1999 surveys confirmed that gray whales feed primarily in near shore waters less than 20 m deep. It is well known that the gray whales are typical benthophages (Mizue, 1951; Tomilin, 1957; Pike, 1962; Zimushko and Lenskaya, 1970, Sobolevsky, 2000). The investigation of the species composition of macrobenthos made on the research vessel *Vulkanolog* in 1995 in the areas of intensive feeding of gray whales off northeast Sakhalin showed that the amphipodes (34 species) with prevailing *Pontoporeia affinis*, *Anisogammarus pugettensis* and *Eonaustozius eous ceous* were the most abundant food for the whales. Out of the other Crustacean the isopodes (*Synidotea cinerea* and *Saduria entomon*) and the bivalve mollusks were abundant locally. As for macrobenthos, pentagon hirsute crabs *Telmessus cheiragonus* from the *Atelecyclidae* family were sometimes encountered. At a depth of 20 m amphipods and shrimps were less abundant; no bivalve mollusks and the number of isopods was reduced sharply; the sea cockroaches *S. entomon* dominated (Sobolevsky et al., 2000).

According to the quantitative diver's sampling made by employees of the Institute of Marine Biology (Yu. Yakovlev and V. Panchenko) the biomass of macrobenthos was the greatest at a depth of 7 m (427 g/m^2) where bivalve mollusks dominated (308 g/m^2 the total biomass being 427 g/m^2).

At a depth of 12 m where the divers gathered samples among feeding whales the benthos biomass was considerably less: from 85 to 137 g/m^2 (Sobolevsky et al., 2000).

Amphipods appear to be the preferred food of gray whales feeding in coastal waters of northeast Sakhalin. They are also significant as food of gray whales in the Bering Sea (Blokhin and Pavluchkov, 1983; Sokolov and Arseniev, 1994).

Our 1999 surveys showed that the gray whales preferred to feed in 7-12-m water depths. This depth stratum appears to be richest in the amphipod stocks preferred by gray whales (Sobolevsky et al., 2000).

It has been suggested that the daily food requirement of gray whales is about 1,000-1,200 kg (Zimushko and Lenskaya, 1970; Brodie, 1975), and single feeding bouts produce about 200-300 kg (Rice and Wolman, 1971).

Due to low benthos biomass in the Piltun area the gray whales have to feed in the offshore areas with the greatest biomass of food organisms. Most probably, these are the zones in the Piltun area shown on the map (Fig. 2.14). It is these areas where the greatest number of gray whales was encountered during July and August. In the autumnal season (September-October) gray whales also preferred shallow-water zones. In the search for areas rich in food, gray whales swim along the coast toward the north, beyond 53°N. Depletion of the nutritive base in the Piltun area and reduction of benthos biomass toward the end of summer due to intensive feeding may be one of the reasons for such movements.

On the basis of the analysis of the occurrence of gray whales during aerial surveys in different months and tentative calculations we believe that the present number of whales in Piltun area is at most 100 individuals which is about 2-2.5 times less than the number quoted by Vladimirov (1994). According to his data, the number of the Okhotsk-Korean stock may reach 200-250 animals. If his information were true, we should have encountered much more whales during helicopter surveys, because the area of whale summer feeding is limited. In practice the maximum count of whales in the feeding area in August was 47 individuals, it was less on the other days. The count of gray whales given in the previous reports (Berzin et al., 1986; Vladimirov, 1993) must be overestimated and cannot be true.

We disagree with some investigators that the whales of the Okhotsk-Korean stock leave the Piltun area in October. Our aerial surveys on November 18 and 20 showed that many whales remained in Piltun area. We counted 21 whales in two days, though the weather was relatively bad and we missed some whales.

At present the Okhotsk-Korean stock of gray whales which was on the verge of extinction (Rice and Wolman, 1971; Sokolov et al., 1974; Berzin and Yablokov, 1978) is recovering its number and it is most probably that in the near future we will see the enlargement of the feeding area of gray whales in the Sea of Okhotsk.

Our surveys confirmed that the largha is the most abundant species of seal in summer. The distribution of largha off northeast Sakhalin in the summer-autumnal season is somewhat similar to that of other areas of the Far Eastern seas. In summer the seals prefer to stay in closed bays and in the offshore areas where they can find food with minimum effort. The availability of food in the summer season plays an important role in the distribution of such fish-eating seals as largha. Piltun Bay characterized by a relatively large fish biomass and species diversity (34 fish species) is an attractive place for seals in summer. Even continuous disturbance on the part of the lighthouse personnel and local people, nivkhs who hunt seals with guns cannot drive the seals from the Piltun Bay.

There is about the same situation in the Chaivo and Nyisky Bays. Disturbance and sometimes shooting of seals is quite common in the summer-autumnal season. That is why part of seals has to keep to the mouth of the bay and along the shore in the places less accessible to the local people.

The seal distribution during spawning migration of salmons is quite different. The seals leave the open offshore areas and gather near spawning rivers and in the mouths of the bays where they make numerous permanent and temporary rookeries.

Such distributions are typical of the area off northeast Sakhalin, in particular, the Piltun, Chaivo, Nyisky and Lunsky Bays. It is these bays and nearby areas where most larghas concentrate in July-September. According to our estimation, the number of seals during salmon spawning migration in the Piltun, Chaivo and Nyisky Bays can sometimes reach 3-4 thousand. Infrequent sightings of other seals (bearded seal, ringed seal, ribbon seal, northern fur seal and eared seal) suggests that the Piltun area is not good for their habitation in the summer season. It is explained by the fact that the bearded seal and ringed seal do not have a good nutritive base there. The type of their food differs greatly from that of the largha. The bearded seal prefers benthic organisms, the ringed seal large zooplankton. The strong tidal currents in the area of the bays and sand soil considerably reduce the biomass of many invertebrates which play an important role in the nutrition of these seals. The sea otter *Enhydra lutra* was not encountered during the survey. Theoretically, sea otters can inhabit there, because sea otters were sometimes encountered northwest of Sakhalin in the area of Shantar Islands (Sobolevsky, 1999). The absence of dolphins, harbor porpoise, and Dall's porpoise in the summer-autumnal season of 1999 is surprising. Previously we observed dolphins in the area of the Lunsky Bay. The absence of porpoise in 1999 may be associated with a forage reserve. It is known that schools of small fish are the main nutriment for many dolphins (Sleptsov, 1961). The presence of feeding areas south of Sakhalin reduced migration paths of dolphins considerably, that is why we do not observe them in the Piltun area.

The analysis of results of acoustic background measurements offshore north east Sakhalin, in area of Piltun Bay has shown, that sources of the most intensive acoustic noise in the given water area are the supply ships, and also anchored vessels: "Okha" and "Agat". Ships such as "Neftegas" or " Smit Sibu move constantly near "Molikpaq" and tanker " Okha" in the summer-autumn period during day time. Noise generated by these ships has continuous spectra in frequency band up to 5 kHz with the well expressed tonal components. Nois fields generated by the moving ships are easily identified on sonograms of spectrum due to their typical interference figure. The acoustic noise generated by mechanisms working on « Molikpaq» has discrete spectra with the brightly expressed tonal components in low frequencies. Noise generated by "Molikpaq" considerably more stationary than noise from the ships and it practically has not daily variability.

In shallows where gray whales feeding acoustic tonal signal with frequency 26 Hz exceeds background more than on 10 dB. The steady peak of capacity on the same frequency was fixed close to "Molikpaq". It is possible to assume that its source is a mechanism constantly working on the platform. Level of the signal measured in shallow zone was less only on 10 dB than at "Molikpaq". So small losses of sound at distribution with such frequency are explained that its energy is transferred in shallows by seismic waves.

Theoretical research and field observation of distribution's features in shallows of acoustic signals generated in area of "Molikpaq" have shown that the intensity of sound with frequencies 300 - 5000 Hz quickly fades and consequently the ships working close to "Molikpaq" do not considerable influence on gray whales in their feeding grounds. Distance from the platform to feeding grounds of gray whales is more than 20 km. Hence, coastal part of shelf (where the gray whales feed) is the natural filter for acoustic waves coming from "Molikpaq" due to relative low depth of this area (4-8 m). Consequently level and variability of acoustic background in this water area basically is designate by hydrometeorological conditions (wind, rain, hailstones) and local industrial sources - motor boats.

Apparently we can ignore influence on whales of acoustic signals with frequencies low 50 Hz which are distributed in shallows with small losses as seismic waves due to frequency selectivity of gray whale's biosonar. The measurements of acoustic signals radiated by group of killer whales carried out at distance 1.2 km from "Molikpaq" evidenced good adaptation of sea animals to high level of acoustic background.

In the conclusion we have to note that we very much were helped by observation for movement supply ships, which were carried out with radar station of «Agat», and also data about these ships received from J. Robinson. At last correction of the report we took into account remark of reviewers. We want to express the special gratitude to Ph.D. J. D. Hall for his constructive offers, remark and information about work drilling rigs.

Conclusions

1. In the summer-autumnal season it is possible to observe 7-8 species of sea mammals offshore northeast Sakhalin. The gray whale and the largha are the dominant species. Killer whales are encountered from time to time. Ringed seal and bearded seal are quite common, but they do not make aggregations and disperse along the shore. Stellar sea lions and northern fur seals come to this area occasionally, but were not observed in 1999. Sightings of Dall's porpoise and harbor porpoise have become rare in the last few years.
2. The coastal zone opposite Piltun Bay remains the main area of summer feeding of gray whales. The gray whales prefer the shallow-water offshore zones with depths from 6 to 15 m. Most whales were encountered at these depths.
3. The actual distribution of gray whales in the summer feeding areas has some specifics. Most gray whales feed north of the mouth of Piltun Bay and only few whales can be observed south of Piltun Bay. In the entire offshore area the whales are seldom encountered beyond the 20-m isobaths and are practically absent beyond the 50-m isobath.
4. During the feeding period the gray whales do not make dense aggregations but are scattered along the coast. In July-August the area near the mouth of Piltun Bay and shallow-water zones north of 53°N are their favorite feeding areas. In September-October the whales move actively along the shore north of 53°N. It appears to their main autumnal feeding area.
5. The behavior of the gray whales in the Piltun area is normal and does not cause any concern. During the last five years there was not a single case of whale mortality or that dead whales were carried onto the beach. But the fact that gray whales practically ceased to feed south of Piltun Bay in 1999 concerns us especially that the reasons for it are not known.

6. Feeding by gray whales northeast of Sakhalin is not uniform. Shallow-water zones with depths of 7-12 m are the most important (460 g/m^2 benthic biomass). The deeper zones have much less biomass of food organisms which can be used by the whales (110 g/m^2). This may be why the whales mostly keep to the shallow-water zones.
7. The total number of gray whales offshore northeast Sakhalin in the feeding period does not exceed 100 animal units. The total is 2-2.5 times less than according to TINRO data.
8. In the second half of November most whales remain in the summer feeding areas offshore northeast Sakhalin. At the final phase of feeding (November) the gray whales become very secretive, they often dive and stay underwater for a long time so it is difficult to observe them.
9. The investigation of the coastal zone from the helicopter flying at a height of 150 m showed that it is not reasonable to count seals afloat. But flights at such low height proved very useful for photography of seals in the permanent and temporary rookeries with subsequent counting by photographs. The fish-eating seal largha dominates in the shore rookeries in the summer season, the other species, ringed seal and bearded seal account for at most 20-30% of the number of largha.
10. The seal distribution off northeast Sakhalin in the summer-autumnal season strongly depends on the nutritive base and the presence of protected bays and inlets. At the beginning of summer the seals disperse along the shore and do not make large aggregations in the mouths of the bays. In the bays the seals distribute relatively uniformly and mainly keep to the near-mouth part of the bays over a large areas. The diversity of fish fauna and relatively large biomass of fish (navaga, East Siberian char, salmons etc.) in the near-mouth part of the bays create favorable conditions for food procuring and enable the seals to avoid hard intraspecific competition.

11. During salmon spawning runs along the Sakhalin coast the seals normally make rookeries in the mouths of the bays and on the sand spits. The helicopter flights revealed large aggregations of seals in the Chaivo, Nyisky and Piltun Bays. The greatest number of seals was found in the Chaivo Bay (more than 2,000 animal units), there were many fewer seals in Piltun Bay (above 500) and Nyisky (more than 150). The total number of seals in the census area off northeast Sakhalin in the summer season can be estimated at 3-4 thousand animal units.
12. Industrial noise with frequency above 1 kHz generated near the Molikpaq and propagating into the shallow-water zone does not create a noticeable noise background at a distance greater than 30 km in summer hydrological conditions.
13. Narrow-band sounds, with frequencies below 1kHz, produced by industrial sources can be detected practically continuously in the gray whale feeding areas located about 30.5 km from the industrial noise sources.
14. Sounds generated by sea animals considerably exceed the noise background in the same frequency range.

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