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	PROJECT: **PROVISION OF WILDLIFE AND BIODIVERSITY MONITORING SERVICES IN ATYRAU AND MANGISTAU REGIONS**	
	CONTRACTORS: **KAZAKHSTAN AGENCY OF APPLIED ECOLOGY (RoK)** **RUSSIAN FEDERAL RESEARCH INSTITUTE OF FISHERIES AND OCEANOGRAPHY (RF)**	

CASPIAN SEAL RESEARCH
IN THE WATER AREA OF THE NORTH CASPIAN SEA IN 2023

SECTION 1: ASSESSMENT OF THE ABUNDANCE AND FERTILITY OF THE CASPIAN SEAL IN THE WATER AREA OF THE NORTH CASPIAN SEA IN 2023

REPORT

REVISION 01

ABSTRACT

The works were performed under the Contract UI176768. This Report presents a comprehensive assessment of the population of the Caspian seal based on deliverables of aerial surveys of Caspian seals' rookeries and moulting grounds in the 2023 winter-spring period in certain areas of the KSCS and Russia.

The Report presents the calculation of the abundance of pups and adult seals on ice, based on the data of instrumental aerial surveys (IR + photo).

The estimated lower and upper thresholds to assess the total population using multispectral aerial survey data of seal ice rookeries in 2023 ranged from 259.87 to 342.87 thousand Caspian seals.

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1. INTRODUCTION

Caspian seal (*Phoca (Pusa) caspica*) is the only representative of aquatic mammals in the Caspian Sea. Caspian Seal has been the subject of commercial fishing for a long time, especially during the periods of freezing in the North Caspian Sea. At the beginning of the twentieth century, the population size was estimated at about 1 million specimens. In the post-war period (1946-1947), the population was estimated at 340,000 specimens. According to Badamshin and Chapskiy, the total number of Caspian seal herd was about 750 thousand in the 1950s, and 470-600 thousand heads in the mid-60s [Badamshin, 1960, 1966; Chapskiy, 1963]. The first aerial survey of breeding mothers on pupping grounds (on ice) was undertaken in 1973, which made it possible to determine the total number of breeding stock estimated at 90 thousand heads, while the total head count of the herd of the Caspian seal was estimated at 450 thousand specimens [Krylov, 1976]. According to aerial photo survey the seal population did not exceed 375 thousand specimens at the beginning of 2000 (2000-2004) [Report. Agip KCO/2005-0347, 2006].

The intensive hydrocarbon exploration and production in the Kazakhstan Sector of the Caspian Sea was followed by annual visual aerial surveys of Caspian seal. The method of accounting for transects was adapted to the Caspian conditions and used for counts in 2005-2006. For the first time ever this method was applied during official counts of ringed seals in the Baltic Sea, conducted by the Swedish government since 1990. [Härkönen and Heide-Jørgensen, 1990; Härkönen and Lunneryd, 1992]. The 2005/2006 counts' results showed that the birth rate was 20 thousand pups in ice field of the Kazakhstan sector. Accordingly, given the estimated level of reproduction, the total population of the Caspian seal was estimated at approximately 111 thousand specimens [CISS Report, 2006]. Multi-year visual aerial surveys of international team of researchers (CISS Program) demonstrated a widely scattered count results and the birth estimates of the Caspian seal based on those results. Thus, Caspian seal birth rate was estimated at 21000 (2005), 16900 (2006), 5700 (2007), 8000 (2008), 15000 (2009), and 7000 (2010) specimens [Härkönen et al., 2010].

Counts have been carried out annually since 2005, and by 2013 their results showed variable trends in seal reproduction. According to information of the continued mortality caused by commercial hunting and incidental catching in fishing tackles, and loss of habitats, in October 2008, the International Union for Conservation of Nature (IUCN) changed the environmental status of the Caspian seal from "Vulnerable" to "Endangered". In 2020, the Caspian Seal was introduced into the Red Books of the Republic of Kazakhstan and the Russian Federation.

The Caspian seal belongs to pagophilic (ice-loving) group of seals. The following takes place on the ice in the North Caspian Sea: pupping, nursing of calves, mating and moulting. Seals gather on the edges of large plates of flat ice near natural water openings, at hollow spaces between moving ice plates or open water patches. Seals often prefer drifting ice with hummocks, which are relatively stable, inaccessible to predators and well protected from the wind. Therefore, an aerial count is the only actual method of estimating the population size, which makes it possible to analyse extensive areas within a short period of time. However, surveyors are not able to see pups clearly due to their light color masking them on the ice-snow cover. In addition, surveyors are not able to record and therefore miss a significant part of adults during aerial flights. The value of animals missing is influenced by a number of subjective factors (fatigue, decrease of vigilance). Undercounting of animals depends on many other factors: weather conditions, ice conditions and flight parameters.

The population survey problems are being addressed as part of continuous improvement of the methodology for accounting for marine mammals. The experience of using instrumental and aerial surveys of seals in the White, Okhotsk, Bering and other seas creates a good methodological and technical basis for carrying out such work in the Caspian Sea [Chernook, Kuznetsov, Yakovenko, 1999; Chernook et al., 2012; Chernook et al., 2014, Chernook et al., 2018]. The applied instrumental methods have a number of advantages: large thermal contrast of animals against cold underlying surface (from 5 to 15^0C) makes it possible to detect animals on IR images. Due to a high contrast of animals, automatic animal IR recognition and counting methods may be successfully used, a wide-range IR scanner allows expanding the survey range, and instrumented aerial survey makes it possible to record all animal encounters. Instrumental methods of counts make it possible to detect and identify not only adults, but seal pups that have colour camouflage.

In 2020-2023, as part of the joint Kazakhstan-Russian Program (2020-2024), scientists of RFRIFO and KAPE recorded the Caspian seal using multispectral video and photo shooting. Modern software devices were used to process video and photo information.

The 2019/2020 winter belonged to the type of relatively warm early winters. Accounting flights were carried out under good weather conditions, with a minimum area of ice (6.5-2.3%). The estimated lower and upper thresholds for estimating the total population using multispectral aerial survey data in 2020 ranged from 282.3 to 352.4 thousand seal specimens.

The 2020/2021 winter belonged to the type of moderate winters. The duration of freeze-up was 140 days. The maximum area of the ice cover was 80% of the total area of the north-eastern part of the Caspian Sea. The estimated lower and upper thresholds for estimating the total population using multispectral aerial survey data in 2021 ranged from 302.02 to 369.15 thousand Caspian seals.

Winter season 2021-2022 is classified as a mild winter (Table 4.1-1). The sum of the degree-days of frost at sea was about 250-260; the duration of the freeze-up was 82 days. The maximum area of the ice cover was 80% of the total area of the north-eastern part of the Caspian Sea. The estimated lower and upper thresholds for estimating the total population using multispectral aerial survey data in 2022 ranged from 311.4 to 431.4 thousand Caspian seals. High mortality in spring and autumn-winter 2022 from influenza and morbillivirus infections resulted in the death of more than 30,000 Caspian seals of different ages. Stranding of dead seal carcasses were observed along the coasts of all Caspian littoral states.

In 2023, work continued under the joint Kazakhstan-Russian Program (2020-2024) to account for the abundance of Caspian seals. In order to obtain up-to-date data on the number of Caspian seals in the Northern Caspian Sea area, the following scope of work was carried out: multispectral survey of breeding grounds during the winter season and aerial survey of rookeries and moulting grounds in the spring of 2023.

1.1.   Survey Objective

Survey objective: The 2023 estimation of Caspian seal population distribution in the water area of the North Caspian Sea.

Survey tasks:

– multispectral aerial counting of breeding stock and offspring using infrared, video and photo aerial surveys in accordance with the international work programme "Assessment of Caspian seal abundance, distribution and natural reproduction in the Kazakhstan and Russian areas of the Northern Caspian in 2020-2024" approved by the authorized state bodies of the RK and RF;

– determining the pattern and distribution density of ice rookeries;

– determining the females and pups ratio;

– aerial survey of seal rookeries and moulting grounds in spring period;

– primary cameral treatment of the aerial survey materials, verification of materials, their layout and preparation for the Caspian seal abundance estimate;

– seal concentration mapping;

– development of proposals for the population conservation.

1.2.   Document Distribution and Target Audience

Unless otherwise authorized by NCOC N.V., this document shall be intended for internal use by NCOC N.V., and representatives of state bodies in the field of environmental protection.

1.3.   Definitions, Acronyms and Abbreviations

1.3.1.   General Definitions

Company – shall mean North Caspian Operating Company N.V.

Contractor shall mean a party providing services to the Company during the term of the Contract on the basis of Work Orders, including project management and preparatory work, field surveys, analytical studies and reporting.

Supplier (Manufacturer/Supplier) shall mean a party that manufactures or supplies equipment and services to fulfill the obligations specified by the Contractor.

The word "**must"** shall mean that a provision is subject to mandatory execution.

The word "**should**" shall mean that a provision is not mandatory, but is recommended for execution as a rational practice of work.

1.3.2. Special Terms, Definitions, Acronyms and Abbreviations

Term / Acronym / Abbreviation	Interpretation / Definition
IUCN	International Union for Conservation of Nature (IUCN)
NCOC N.V.	North Caspian Operating Company N.V.
RoK	Republic of Kazakhstan
RF	Russian Federation
KAPE	Kazakhstan Agency of Applied Ecology LLC
ATUC LLC	Aviation Training and Drill Center LLC
KSCS	Kazakhstan Sector of the Caspian Sea
GPS	Global Positioning System
GIS	Spatial measurement tool, a modern computer technology for mapping and analyzing real-world objects
PC	Personal computer
IR	Infra-red camera (FLIR A325, Optris pi 450)

1.4. Reference Documents and References

In the absence of reference to specific dates, it shall be required to use the latest edition of each publication, including any changes/amendments/revisions.

Ref. No.	Document Number / Reference	Title / Description
(1)	RoK CODE No. 400-VI of 02.01. 2021 Chapter 16, Articles 245, 256; Chapter 19, Article 269, 274.	RoK Environmental Code
(2)	Federal Law of the Russian Federation No. 166-FZ of 20.12.2004	On Fishing and Conservation of Aquatic Biological Resources
(3)	Federal Law of the Russian Federation No. 53-FZ of 24.04.1995	On Wildlife

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3. FIELD WORK PROGRAM

3.1. Plan of Survey

The survey consisted of two phases: Winter and Spring 2023.

In the 2023 winter, the first survey phase was undertaken – the winter aerial count of the population of seals. The duration of the aerial count was 11 days, from February 17 to February 27. Due to difficult weather conditions (fog, storm), flights were conducted on February 21, 25-27, 2023. The total length of aerial survey flights was more than 4600 km. The aerial surveys were carried out within the same synoptic period to exclude any impacts of the drifting ice on the rookeries in ice.

Over the ice field within the territorial boundaries of Russia, where a part of seal aggregations was observed, the survey was conducted by RFRIFO from 17 through 27 February 2023. The total length of the routes of aerial surveys was more than 4500 km.

The multispectral aerial survey methodology currently used by Russian and Kazakhstani seal researchers in the Caspian Sea habitats was used as a basis for winter surveys. Multispectral aerial count of the number of breeding stock of the population and offspring was conducted using infrared, video and photo shooting from an aircraft.

In the 2023 spring period, the second phase of surveys was implemented, namely, an aerial survey of rookeries and moulting grounds of seals in April. The aerial survey of the Caspian seal employed a selective method with study of the shoreline, sand bars and islands suitable for seal moulting grounds in the North-East Caspian Sea. The duration of the aerial surveys was 6 days – from April 10 to April 16, 2023. The total length of the aerial survey routes was more than 2500 km.

3.2. Field Survey Methodology

3.2.1. Multi-Spectral Aerial Survey (Winter)

When preparing for aerial survey, ice conditions and meteorological conditions in the Caspian Sea were monitored on a daily basis since the beginning of February. All available information of ice conditions in the Caspian Sea was daily presented by NCOC specialists per SHF passive sounding data of SSMI/DMSP satellite system, RADARSAT and Aqua/Terra satellites. Satellite mapping of sea ice coverage, seasonal displacement of ice edge and variability of its position makes it possible to predict distribution of animals during the pupping period [Chernook, Melentyev, 2002]. Ice maps obtained from NCOC per satellite imagery, in combination with available Internet resource materials of previous aerial surveys, were used to predict the location of moulting grounds of seals and plan the flight routes.

Aerial counts of Caspian seals were conducted by a selective method, which explored an ice cover partially, but it was not covered by a full survey. An acceptable proportion of an area to be surveyed may vary from 8 to 10% of the North Caspian Sea ice suitable for moulting grounds of seals. It can be smaller if the network of survey routes is optimized depending on the seal population density in different sections of the water area. To improve the efficiency of aerial surveys, the survey should be more focused on the areas with high and medium density of seal distribution taking into account the areas with low distribution density.

Flight routes were planned with due consideration of long-term data on seal moulting grounds' location and information obtained during preliminary survey flights. The ice and weather conditions were also kept in mind. The flights were undertaken on days with good low wind weather in the daytime. Aerial survey was conducted with good visibility, both in clear and cloudy weather in the absence of fog and precipitation. Mid-term weather forecasts were used to plan the work, as well as operational tracking of changes in ice and meteorological conditions from satellite imagery.

A regular pattern of transects arranged north southward or west eastward in parallel to each other with a fixed space between them (3-5 km) was applied for seal counts. An optimized net of parallel transects with a variable pitch between them can be used when required. The total numbers of routes is limited by the scheduled flight time of aerial survey. The minimum numbers of flights required for instrumental aerial survey of Caspian seal offspring in the North Caspian Sea is 40 flight hours for the aircraft-laboratory. An increase in the total length of aerial survey routes makes it possible to obtain a more accurate estimate of the seal abundance, to reduce the statistical error and to obtain more reliable data on the spatial distribution of the seal population.

The length of transects is determined by the size of the ice areas suitable for seal rookeries, the position of the ice edge and the distance from the coastline. Survey transects should be comparable in length in different parts of each survey area. The percentage of survey coverage of the water area should be of the same order for different areas of the North Caspian Sea.

The aerial survey duration should not be more than 5-10 days and should be conducted in a single synoptic period in order to exclude the impact of drifting on ice rookeries.

The arrangement of transects is preliminary optimized in order to conduct the most effective count of Caspian seals. Wherein, the density of seal distribution from the previous observations, physical and geographical, ice and any other natural features of survey areas, remoteness of work areas from home airports, aircraft performance and any other criteria are taken into account.

Aerial photography is performed at a specified, pre-selected flight altitude, which is selected so that:

- to ensure high resolution of thermal images (no less than 0.3 m) and photos (no less than 0.03 m);
- to provide a wide counting margin (not less than 300 m) for greater coverage of the observed water area;
- not to scare off seals with the noise of a plane flying at a low altitude.

The flying altitude is strictly adhered on each transect to ensure the fixed width of the accounting transect. If necessary (changes in weather conditions and other circumstances), the flying altitude can be changed only between survey transects - during or after turning to the next transect.

Based on the previous work experience, the main flying altitude can be 200 m. Such altitude ensures the requisite contrast of thermal marks for the detection of seals on thermal images of the ice surface and high resolution for reliable identification of adult seals and pups in the photos. The width of the central accounting transect is determined by the viewing angle of camera and the flying altitude, and makes up about one flying altitude at a viewing angle of 55 degrees, that is 200 m (at H = 200 m). The total width of the accounting transect is determined by the "effective" width of the frequency span of the thermal imaging scanner, and according to experimental data, it is about three flight altitudes.

A multispectral aerial survey method implies simultaneous survey of moulting grounds of seals in infrared and visible areas spectrum. Continuous infrared survey of the underlying surface is conducted during the flight at the operational altitude. Seals on ice are recorded by a thermal imager in the form of bright marks on a dark background of snow and ice cover. The flight operator of aerial survey complex monitors the quality of infrared images and photos on a computer screen, and controls the equipment settings at the beginning of each transect to improve the quality of seal display (clearly distinguish between seals against ice, reduce the effect of heated places where seals are accommodated, and in open water areas). At the same time, the equipment settings should not be changed on the transect until the survey is finished.

To identify the marks on thermal images, a regular and selective photo survey is taken in nadir using digital cameras. The choice of the time interval for photographing depended on the density or frequency of occurrence of seals, as well as on the technical capabilities of the equipment. The photo-surveying interval may vary depending on the goals and tasks of the survey. In case when the continuous (regular) survey is interrupted for one reason or another, it is recorded in the flight protocol.

In order to collect more statistics in places of denser seal occurrence, more frequent photo-surveying of animals is carried out. With dense seal concentrations, photo-surveying using the lower cameras is performed after 1 second and the photos come with a slight overlap (about 10%). The photo survey is monitored automatically under the control of the flight operator, who observes the image of the underlying surface on the thermal imager's screen. The thermal imager's camera is installed so that its field of view could be arranged slightly ahead (about 10 degrees) of the field of view of the camera installed in the nadir. For this reason, when the marks of seals appear on the thermal imager's screen, the flight operator has time to make an IR analysis and to send a signal for switching on the lower cameras in the continuous surveying mode with 1-second interval.

At the same time with the instrumental survey, visual observations are carried out from each side of the plane. Visual observations are conducted continuously at a wide viewing angle through convex blisters located on the side of the plane. Surveyors make an overview of seal rookeries, periodically comment on ice and weather conditions and report other useful information (animals' behaviour, presence of predators, contamination, etc.). Surveyors' messages and comments were recorded in audio files for subsequent interpretation in office conditions, and then used for the interpretation of survey results.

At the same time, the flight protocol automatically records time, coordinates, course, altitude, banking angle, plane speed, and other necessary parameters. All jobs are synchronised with high timing accuracy, at least 1.0 sec. In addition, the beginning and the end of flight, the moments of turning the equipment on and off, pauses in observations, and other significant events are recorded, and a schematic map is built on the display. During flight all images and sound messages of surveyors with information about animals detected, as well as ice, weather and other survey conditions are digitally recorded.

The flight results were the survey deliverables in the form of thermal images and photos recorded on digital carriers of thermal images, audio recordings of visual surveyors and messages of other flight participants, flight logbook tables, observation logs, and schematic maps compiled during the flight. All data collected during the expeditionary work is the basis for the subsequent onshore processing.

3.2.2. Aerial Survey of Seal Rookeries (Spring)

Aerial survey of the Caspian seal is carried out by a selective method, when the coastal line, sand bars and islands suitable for seals moulting grounds in the North-Eastern Caspian Sea are surveyed.

Flight route planning is carried out taking into account long-term data on the location of seal rookeries. Weather conditions are also taken into account. Flights are carried out on days with good low wind weather in the daytime. Aerial survey is performed with good visibility, both in clear and cloudy weather with no fog and precipitation. To plan the work, medium term weather forecasts are used, as well as operational tracking of changes in meteorological conditions according to data provided by Atyrau airport meteorological service.

Preliminary planning of flights is carried out in order to most effectively conduct counting of Caspian seals. At the same time, the density of seals according to previous observations, the physical-geographical and other natural characteristics of the survey areas, the remoteness of the work areas from the hub airports, the technical characteristics of the plane and other criteria are taken into account

Aerial photography is performed at a specified, pre-selected flight altitude, which is selected so that:

- to provide high resolution photos (not less than 0.03 m);
- to provide a wide counting margin (not less than 300 m) for greater coverage of the observed water area;
- not to scare away seals with the noise of a low-flying plane/helicopter.

The flight altitude is maintained strictly constant along the route of the aircraft / helicopter, ensuring a fixed width of the accounting transect. Based on previous work experience, the flight altitude can be 200 m. Such altitude provides a high resolution capacity for reliable identification of adult seals and pups in photos. The width of the central counting margin is determined by the viewing angle of the camera and the flight altitude and is at a viewing angle of 2 x 45 degrees about one flight altitude, i.e. 200 m (at H = 200 m). The total width of the counting margin is determined by the effective width of the large-format camera vision range and is 300 m, Figure 3.2.1.
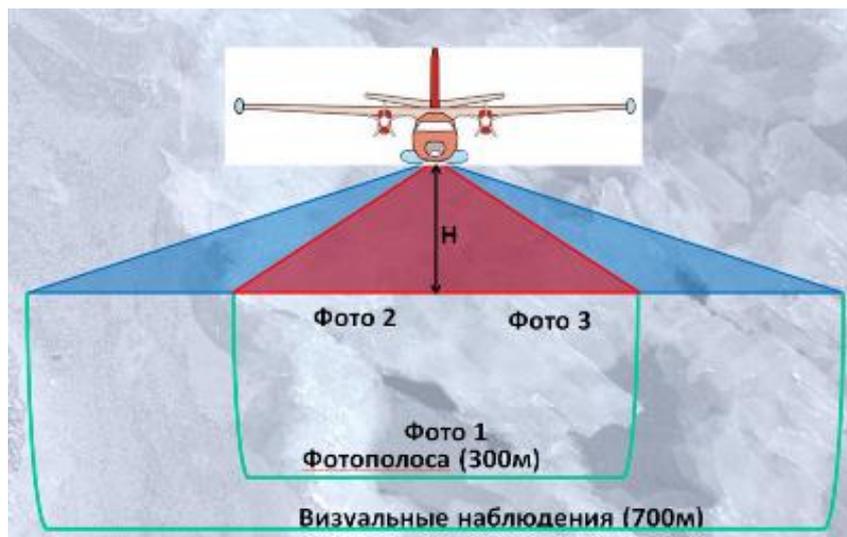
Figure 3.2.1   Aerial Counting Scheme

During the aerial survey regular and selective photo-surveying is performed using digital cameras. The choice of the time interval for photographing depends on the density or frequency of occurrence of seals, as well as on the technical capabilities of the equipment. The photo-surveying interval may vary depending on the goals and tasks of the survey. In case when the continuous (regular) survey is interrupted for one reason or another, it is recorded in the flight protocol.

In order to collect more statistics in places of denser seal occurrence, more frequent photo-surveying of animals is carried out. With dense seal concentrations, photo-surveying using the lower cameras is performed after 1 second and the photos come with a slight overlap (about 30%). At the same time, photo-surveying control is carried out automatically by the flight camera operator.

At the same time with the instrumental survey, visual observations are carried out from each side of the plane. Visual observations are conducted continuously at a wide viewing angle through convex blisters located on the side of the plane. Observers review the situation at the breeding grounds of seals, periodically comment on weather conditions during the flight, and also report other useful information (animal behaviour, predators, pollution, etc.).

At the same time, the flight protocol automatically records time, coordinates, course, altitude, banking angle, plane speed, and other necessary parameters. All jobs are synchronised with high timing accuracy, at least 1.0 sec. In addition, the beginning and the end of flight, the moments of turning the equipment on and off, pauses in observations, and other significant events are recorded, and a schematic map is built on the display.

The result of the flights is material obtained in the form of photos recorded on digital media, data recorded in the field log, and schematic maps of the flight. All data collected during the expeditionary work is the basis for the subsequent onshore processing.

3.2.3.   Hardware and Software

During surveys, instruments were used by which the requisite features of the Caspian seal's rookeries were obtained. To compare the quantitative data obtained using a camera and a personal navigator, as well as information received by observers from different sides; all devices involved in the counts were synchronized in time.

Hardware used in conducting surveys is listed in Tables 3.2-1 – 3.2-2.

Table 3.2-1   List of Hardware

Equipment	Parameter (type)	Designation
Multispectral survey (Winter)		
GPS navigator	Garmin Oregon 550, Garmin GPS Map 64	Positioning
Satellite phone	Thuraya SG-2520	Mobile communication
Digital camera	Nikon D850,	Photo documentation of seals and their vital activity traces

Equipment	Parameter (type)	Designation
	Nikon D850	
Video camera	GoPro 9 GoPro 11 (2 pcs). OSMO 7 ACTION	Flight video recording
IR-camera	FLIR A325, Optris PI450	IR-image recording
Binocular	Olympus 10X50 DPS I, Canon 12x36 IS III	Observation over seals
High-accuracy lidar	Lidar	Determining flight altitudes to an accuracy of 1 cm
Notebook computer	Lenovo G770, Lenovo G770	Recording, processing and storing information
Pack of batteries	«Varta» AA	For GPS navigation and voice recorder
Charger	Garmin	To charge accumulator batteries
Aerial survey (Spring)		
GPS navigator	Garmin GPS Map 64	Positioning
satellite phone	Thuraya SG-2520	Mobile communication
Digital camera	Canon EOS 800D, Nikon D850 (2 pcs)	Photo documentation of seals and their vital activity traces
Video camera	GoPro 11 (2 pcs). OSMO 7 ACTION	Flight video recording
Binocular	Binocular Bushnell PowerView 10X50 (2 pcs)	Observation over seals
High-accuracy lidar	Lidar	Flight altitude determining
Notebook computer	HP 470 G3 notebook computer Lenovo IdeaPad 3 17ITL6 notebook computer	Recording, processing and storing information
Battery set	Varta AA 2100mah	For GPS navigation and voice recorder
Charger	Varta 57677	To charge accumulator batteries

Table 3.2-2 Aerial Survey Hardware Specifications for Multispectral Shooting

Airborne camera	Resolution, matrix	Focal length of the lens	Line of sight	Inclination from vertical to the right / left
Photo-camera Nikon D850 leftward	46 Mp	50 mm	38°x25°	19° leftward
Photo-camera Nikon D850 rightwards	46 Mp	50 mm	38°x25°	19° rightwards
Thermal imager- Flir A325 leftward	320 x240	18 mm	25°x19°	14° leftward
Thermal imager- Optris PI450 rightwards	382 x288	17 mm	28°x23°	15° rightwards
Overview camera HERO GoPro 11	27 Mp	-	110°x74°	0°

A software package was used for aerial survey and processing of deliverables collected. Software packages designation and their purpose are listed in Table 3.2-3.

Table 3.2-3 Software

Title	Function
Arctica*	Reception and recording of navigation data. Receiving information and recording environmental parameters from sensors. Flight route visualization.
Auto Recorder v3.0	Recording and archiving of visual and audio information.
MapViewer	Flight route planning. Visualization of aerial survey results.
MalS*	Visualization and recording of thermal imaging data.
PI Connect and Therma CAM Researcher Pro 2.9	Thermal imaging data processing.
Camera Control Pro 2	Visualization and recording of photo data
Golden Software Surfer 8	Thermal imaging data processing. Visualization of aerial survey results.
ImageJ Jpegproj*	Photo processing. Counting seals by photographs, behavioural analysis.
Google Earth	Flight route planning. Visualization of aerial survey results. Survey data processing.
Garmin BaseCamp	Software allows analyzing the routes and points downloaded from a GPS navigator to computer for viewing and editing in the ArcGIS programme. BaseCamp makes it possible to export files to DXF format for further use in other software.
ESRI ArcGIS (ver. 10.2)	GIS software for creating, managing, integrating and analyzing geographic data.
EXIF Image Viewer	Software makes it possible to group photo images by EXIF information of the original file, add comments and export the results to CSV format for their further use in third-party software.

Note: *software specially designed for aerial shooting.*

GIS-applications were used at all phases of aerial survey deliverables processing as data analysis and preparation tool. The products "MapViewer 7" and "Google Earth" were used as a software environment for GIS applications.

GIS made it possible to:

- map the aerial survey count routes;
- make spatial reference of thermal and photo images;
- make spatial reference of graphical satellite ice maps SSMI, Terra and RADARSAT;
- plot the maps of seal density distribution.

4.   OBSERVATION RESULTS

4.1.   North Caspian Sea Ice Conditions

Formation of pupping rookeries of the Caspian seal and therefore the conduct of aerial count work highly depend on the North Caspian Sea ice cover. Ice conditions here vary by years and significantly change depending on the winter nature (severe, moderate, and mild).

In the North Caspian Sea, duration of the winter season increases from south to north and can be 140-150 days long. Frosty days can average 90 days and air temperatures can reach -29^0C – -30^0C. The timing of ice formation beginning depends on atmospheric processes in pre-winter period. In the years when ice formation begins in the end of October – beginning of November, there are strong inflows of cold Arctic air into the sea area. In the North Caspian Sea, in the mid-severity pre-winter, ice formation starts in the first half of November. In mild pre-winter periods, ice appears in the first half of December. In abnormally and extremely warm pre-winter period, ice formation process along the entire shallow northern coast occurs only in the second half of December and may be delayed until the first half of January [Project "Sea", 1992].

The process of ice formation in the North Caspian Sea is generally oriented from the shallow coast to relatively deep central areas. In November, the ice border is either slightly off the coast (mild winters) or up to 2m isobath (during severe winters). In mild winters, the first complete freezing occurs in the shallow northeastern region before the beginning of December. In extremely cold pre-winter periods, fixed ice covers the shallow coast in the first half of November and the water area becomes completely frozen up to 3-5 m depth by the third ten days period of November. In extremely warm winters in the North Caspian Sea, the water freezing process is 20-25 days late. In such winters, only unstable ice brought from shallow waters can be observed in the open sea areas with depths more than 3-5 m.

The Caspian ice thickness has high heterogeneity in the sea area, covered in ice and considerable variability during winter. During the whole ice season a continuous transition of ice age types age-related to other types is observed as follows: nilas - grey - gray-white - white ice. The frequency distribution of occurrence of age-related floating ice types indicates a certain pattern of their development during the ice season and depends on the thickness of coast ice. In the beginning of pre-winter period, thin nilas ice is formed in the form of ice rind (windless weather) or pancake formations (when windy). By mid-November, as a result of increased ice rind growth, the ice rind goes into the grey (up to 15 cm) and grey-white (15-30 cm thick) ice stages. Floating ice more than 30 cm thick (white ice) is most often formed as a result of coast ice break-in, less often due to thermal factors. White ice is preserved during winter in the form of large ice pieces and ice fields.

In the initial period of ice cover development; there is rapid movement of young ice boundary and growth of coast ice area and thickness. In the second half of ice season, dynamic factors increase their influence on the ice cover resulting in coast ice breakage, compression and thinning, as well as layering and ridge-building conditions. In the open part of the North Caspian Sea, ice breaking and moving is observed during winds of different directions. The most intensive bursting of coast ice and retreat of its southern border to the north is observed in warm winters with high repeatability of southern winds and light frosts.

It is believed that in milder winters, the ice edge extends significantly to the northeast and ice moves constantly to the Ural Furrow, as in the west.

During severe winters with frequent cold northeastern winds, ice edge in the east descends to Urdyuk Cape (Mangyshlak Peninsula), and to Makhachkala in the west. In such winters, ice movement occurs in the western part of the North Caspian Sea, while movement in the Ural Furrow is not observed in severe winters. Currents in potential location of pupping rookeries are very weak and ice is moved exclusively under the influence of winds (Figure 4.1.1).
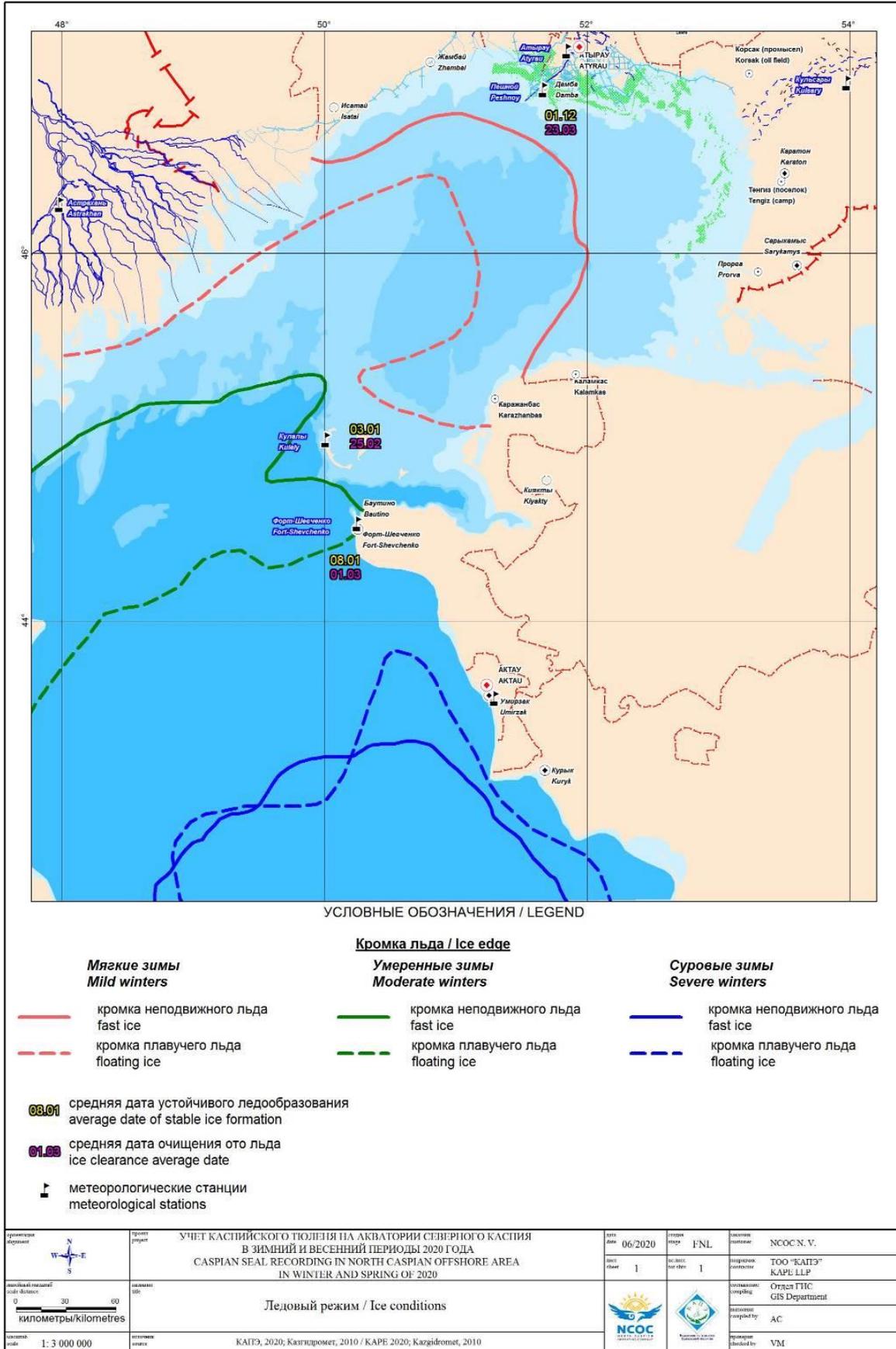
Figure 4.1.1   Ice Distribution in the Caspian Sea in Winters of Various Severities

Thus, pattern of seal rookeries distribution highly depends on ice and weather conditions. The location of land fast ice edge, boundaries of drifting ice and their concentration are also important. Seals choose relatively old solid ice for their pupping, trying to penetrate deep into the ice massif along openings and cracks. In warm winters, breeding of the Caspian seal takes place in the eastern part of the North Caspian Sea with an ice area from 10 to 30% of the total area of the North Caspian Sea. In moderate winters, when the ice cover ranges from 40 to 80%, the distribution of pupping grounds occurs throughout the entire ice area in the eastern part of the North Caspian Sea. In cold winters, the pupping grounds are located compactly along the ice edge from east to west. The ice cover in the North Caspian Sea in these winters may vary from 80 to 90%.

Mothers normally breed one pup and feed it with milk. The breeding and lactation of Caspian seals on the ice of the North Caspian Sea is time-consuming: begin in late January and continue until mid-February. The peak of mass pupping falls on the first decade of February [Kuznetsov et al., 2013]. As a rule, by this time the total ice cover, ice thickness, and hummockiness reach their maximum values. In the first days of pupping the most dense and compact aggregations are formed. Subsequently, under the influence of winds and currents, the ice moves and splits, which results in the formation of more sparse rookeries occupying large areas? Rookeries formed on drifting ice are more susceptible to "pulling apart". Rookeries formed on soldered ice last longer. Rookeries formed under the conditions of mobile weak ice are scattered over a large area. Males, dry females and immature seals form isolated rookeries of "shoal" animals (**Appendix A. I. Adult Seals**). Unlike pupping mothers, they stick to the edges of the ice or along cracks and water-leads [Ivanov, Sokolsky. 2000]. During the nursery period, adult seals spend a significant part of their time on the ice, but at the same time females keep apart and a pup can often be seen next to the mother (**Appendix A. II. Mothers with Pups**).

A newborn Caspian seal is covered with white hair with greenish-yellow tint and is called "greens" on the first day. After 2-3 days, its cover turns white and the pup turns into a "white-coat seal", which avoids water in the early days. **Appendix A. III. White Coat Pup**). Two weeks later, its hair begins shedding and spine wool begins to peel in shreds **(Appendix A. IV. Seal Pups at Different Stages of Moulting)**. At this time a pup is called "tulupka". After moulting at the age of 3-4 weeks, a pup's hair becomes grey and the pup is now called "sivar". The sivar mainly keeps on ice for a while, then gradually descends into water and begins eating on its own. Mothers' lactation lasts 3-4 weeks, after its end a calf weighs about 12-16 kg and starts feeding independently [Huraskin, 1989].

Mass mating begings in the second half of February, and molting of adults on drift ice occurs in March-April. The area of these seal rookeries and density of seals on them varies depending on ice conditions. As the ice cover disappears, seals still needing moulting move to shallow water and small sand islands to stay there till complete moulting.

In recent years, the duration of ice cover in the Caspian Sea has significantly reduced, and generally, a trend towards less severe winters and smaller ice cover is observed. P.I. Bukharitsin's classification (Table 4.1-1), [Ivkina et al., 2015] is the most objective and accessible information. Using P.I. Bukharitsin's classification, where the sum of temperatures and days of frost is used to calculate the severity of winters, 55 cold periods from 1961 to 2016 were considered. To calculate the type of winter, the sums of negative air temperatures for this period were calculated and a graph was plotted based on the calculations received (Figure 4.1.2). Analysis found out that during the period under review (1961-2016) the repeatability of very severe winters has decreased. In the last decades, it has been noted that the repeatability of mild and moderate winters has increased. For example, in 2015-2016, the ice period lasted almost 2 months less than in 2011-2012 [Ivkina et al., 2017].

Table 4.1-1   P.I. Bukharitsin's Classification of the Degree of Severity of Winters

Very severe winter	Severe winter	Moderate winter	Mild winter	Very mild winter
> 900	900…700	700…400	400…100	< 100
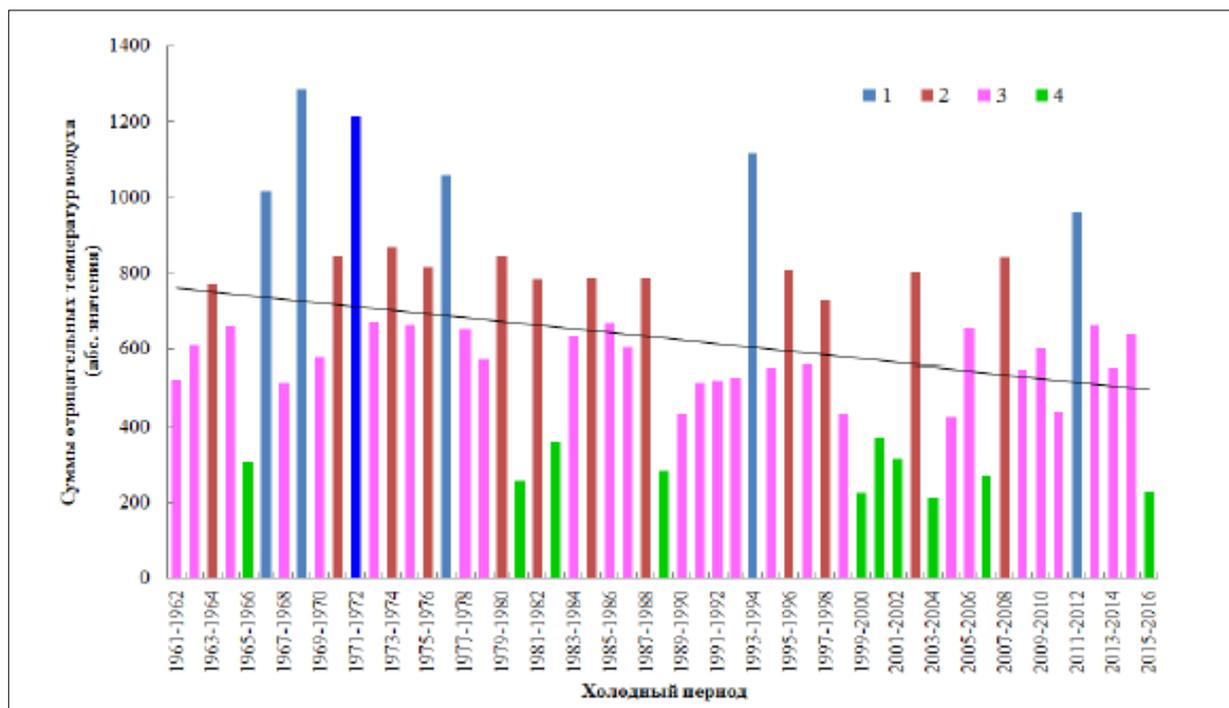
1 - very severe, 2 - severe, 3 - moderate, 4 - mild winter

Figure 4.1.2   Negative Air Temperatures Sums in Winter Seasons from 1961 to 2016 [Ivkina et al., 2017]

In Kazakhstan, the 2022-2023 winter was close to the climatic norm. The first half of December was relatively warm. In the second half of the month, the temperature dropped to -10 – -25^{0}C at night, to -4 – -13^{0}C at day time. January was the coldest month, at night in the northern part of Kazakhstan, the temperature dropped to -35 – -40^{0}C, in the south to -22 – -30^{0}C.

Comparison of satellite information with the existing classification of the severity of winter in the Caspian region, enables to attribute the 2022-2023 winter season to winters with a moderate nature (Table 4.1-1). The sum of the degree-days of frost at sea was about 250-260; the duration of the freeze-up was 92 days. Under the conditions of a moderate winter, the ice cohesion ranged from 1-3 to 6-9 points, and their thickness was 5-45 cm.

Low temperatures and strong winds contributed to ice formation in the northeastern part of the Caspian Sea, in the second decade of December, the area of the ice cover was about 61%. In the last ten-day period of December, the area of the ice cover varied from 60 to 84%. The maximum ice cover area - 81.8% was recorded on December 31. Under the influence of lower temperatures, ice growth gradually increased and by 31 December the ice cover was 82%, ice thickness in the Kashagan area reached 20-30 cm (Figure 4.1.3).

In January, intensive ice formation continued, covering the entire northern part of the Caspian Sea. The maximum area of the ice cover was formed by January 31 and amounted to 98-100% of the total area of the north-eastern part of the Caspian Sea with a maximum thickness of ice in the Kashagan field area 35-45 cm (Figure 4.1.4).

In February, the weather conditions were stable. At the beginning of the month, the ice field was 97-100%, and by February 28 it decreased to 74% of the North Caspian Sea area. The sea temperature ranged from sub-zero at night to positive during the day. In the middle of March, the ice extent was 2.7-0.3%. Some grounded hummocks melted by March 17, 2023.
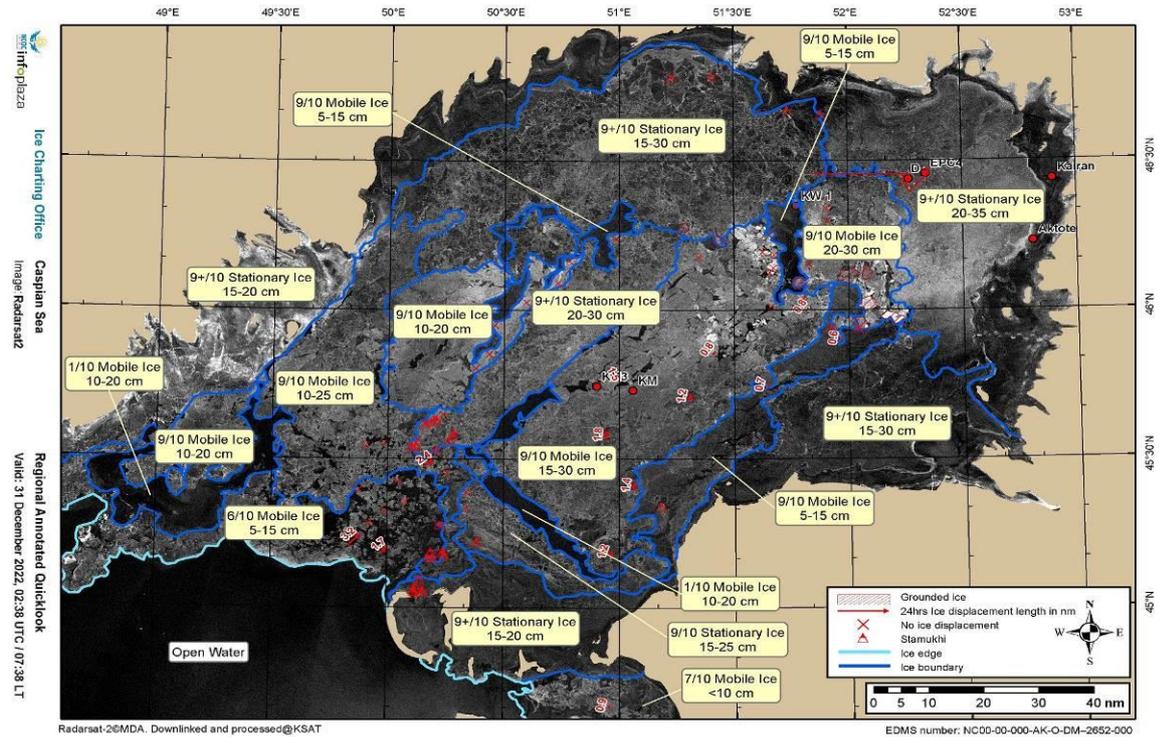
Figure 4.1.3   Ice Distribution in the North Caspian Sea on 31 December 2022.
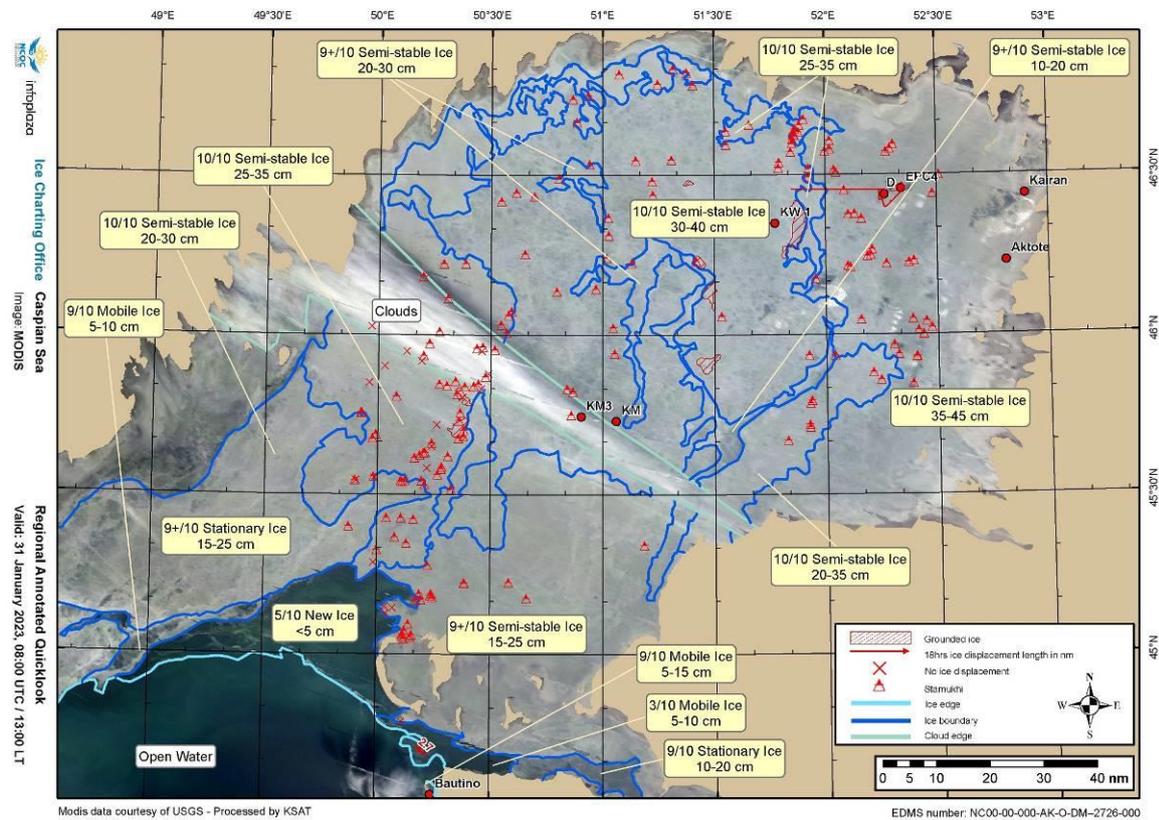
Figure 4.1.4   Ice distribution in the North Caspian Sea on 31 January 2023
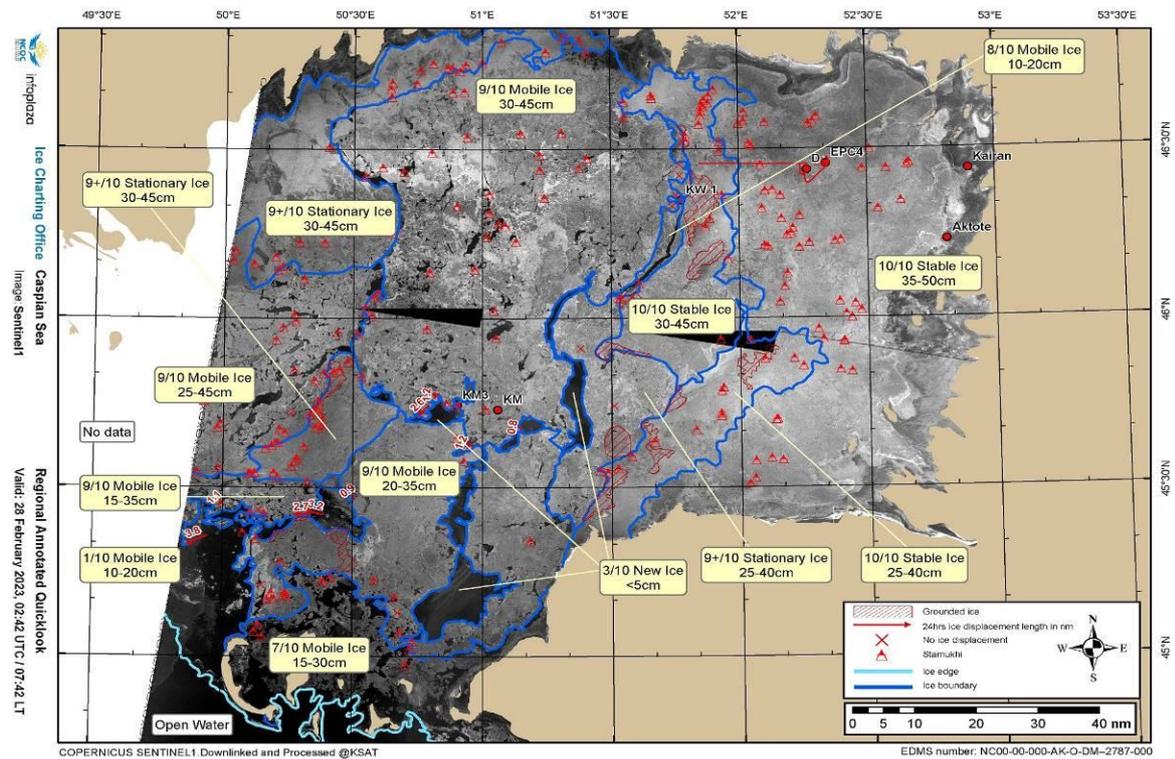
Figure 4.1.5   Ice distribution in the North Caspian Sea on 28 February 2023

4.2.   Multispectral Aerial Survey of the Caspian Seal Ice Rookeries

4.2.1.   Piper PA-34 Aircraft Equipment with Aerial Survey Complex

Piper PA-34 w/o No. UP-P4302 small aircraft was used to perform aerial surveys of the ice rookeries of the Caspian seal (Figure 4.2.1).

The aircraft was equipped with equipment for conducting air surveys (thermal imagers, cameras, on-board computers, etc.), (Figure 4.2.2). After the installation of the aerial shooting complex on the aircraft in the hangar, its functioning from ground power sources was checked. Flight tests were carried out on 17 February, the survey complex worked normally and in flight did not affect the operation of the standard equipment of the aircraft. Due to unstable weather conditions, the first flight to determine the boundaries of pupping grounds was carried out on 21 February 2023, from 24 to 24 February flights were carried out to obtain data on numbers of Caspian seals in the Kazakhstani area, the timing of the survey coincided with the surveys of previous years 2020-2022.

Figure 4.2.1   Piper PA-34 Plane

The participants in the survey were: KAPE LLC (RoK) - F.V. Klimov, E. Loskutov; RFRIFO (RF) - V.I. Chernook, A.N. Vassiliev Pilots: Ye.G. Zhukov, S.Yu. Unzhakov (Figure 4.2.2).

Research team (left) and scientific equipment (right)

Figure 4.2.2   Work in the Flight

Key specifications of Piper PA-34 Aircraft:

– practical flight range, km   1300;

– flight speed during aerial survey, km/h   200-240;

– cruising speed, km/h   240;

– maximum flight duration, hr   6;

– basic altitude of the aerial survey, m   170.

Equipment installed on the aircraft for aerial surveys:

– onboard automated system (BAS) on the basis of two computers;

– satellite navigation equipment;

– 2 thermal imagers Optris PI450 and Flir A325;

– 2 Nikon D850 high resolution cameras;

– overview camera Gopro 11 (2 pcs);

– laser altimeter, Lidar SF 30/D.

Figure 4.2.3 shows a flowchart of Piper PA-34 aircraft survey system and shows functional relationship between instruments.

All flight parameters (time, coordinates, course, altitude, speed, etc.) were automatically recorded every second using GPS satellite navigation system and precisely were "referenced" to aerial survey deliverables (IR-images, photographs, etc.). The beginning and end of accounting transects, moments of equipment switching on/off, weather and other survey conditions were recorded. The transect width was calculated separately for each type of equipment, based on flight altitude and lens' viewing angle.

The main instrumental aerial survey of seals was performed using two thermal imagers (Flir A325, Optris PI450) and three cameras (two Nikon D850 and an overview camera GoPro 11), which were fixed in lower section of hull. Swaths of aerial survey cameras are shown in Figure 4.2.4.

The accounting shooting of seals on the ice was performed with 2 Nikon D850 high-resolution cameras with viewing angles separated by 20° to the right and left of the nadir. During the entire flight cameras continuously kept shooting at intervals of 2.5 seconds (at a speed of 190 km/h – every 140 m). The time interval was chosen so that each subsequent snapshot did not overlap the previous one.
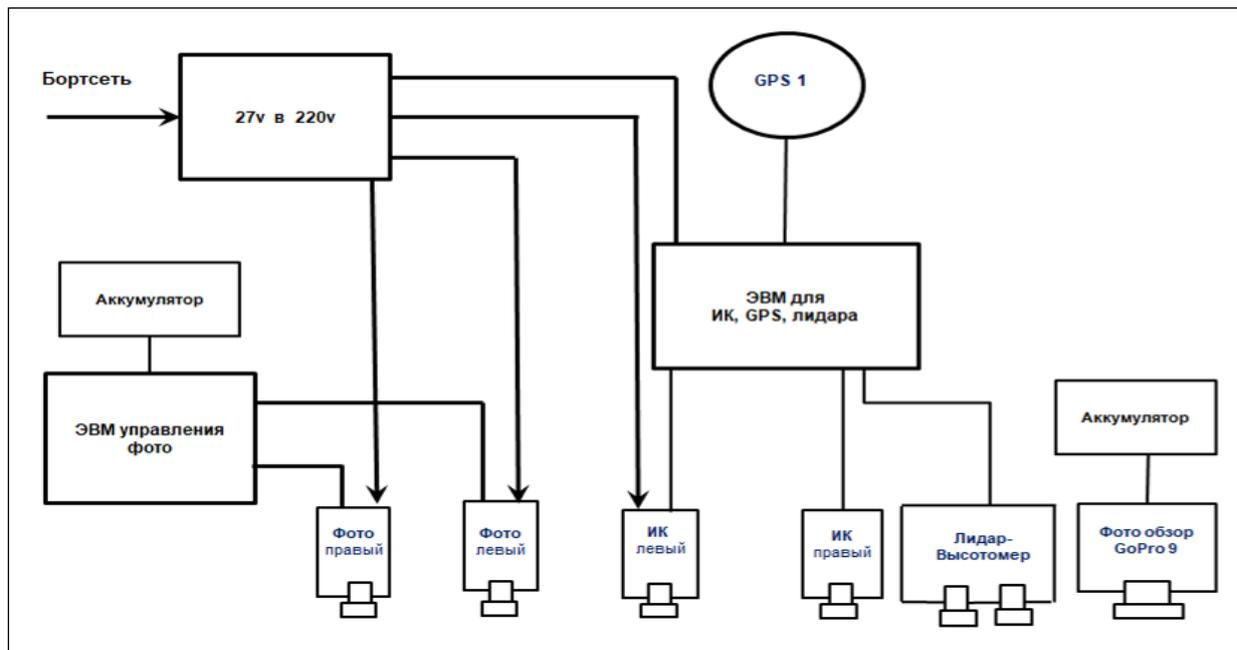
Figure 4.2.3   **Piper PA-34 Aerial Survey Complex Flowchart**

Figure 4.2.4   **Aerial Survey Equipment Swaths**

Nikon D850 cameras with a full-format 46 MP matrix and with an F=50mm lens enable to get high-quality images with a spatial resolution of 2-3 cm (for a 180 m altitude), the quality of which enables to reliably find and identify adult and baby seals on ice, as well as to determine the stages of pups: white-coat seals, tulupka, sivar (Figure 4.2.5).

During the period of the accounting aerial survey (February 17-28, 2023), the air temperature ranged from -12^{0}C (in the morning) to +9^{0}C (in the afternoon). The ice was mostly shallow and wet (melted, soaked with water, wet), grey in colour. It is not easy to see seals among such ice. However, the quality of the photographic materials allowed us to consider not only animals, but also other signs of their presence on the ice (Figure 4.2.6).

Two Nikon D850 cameras (F= 50 mm) ensured shooting of the central part of the accounting transect. The aggregate viewing angle of the cameras was 78 degrees. These 2 cameras triggered simultaneously. GoPro 11 cameras took frame-by-frame and panoramic images (Figure 4.2.7).

Figure 4.2.5   Seals' Photo on the Shallow Ice of the Caspian Sea

Figure 4.2.6   Fragment of a photograph of seals on the ice of the Caspian Sea
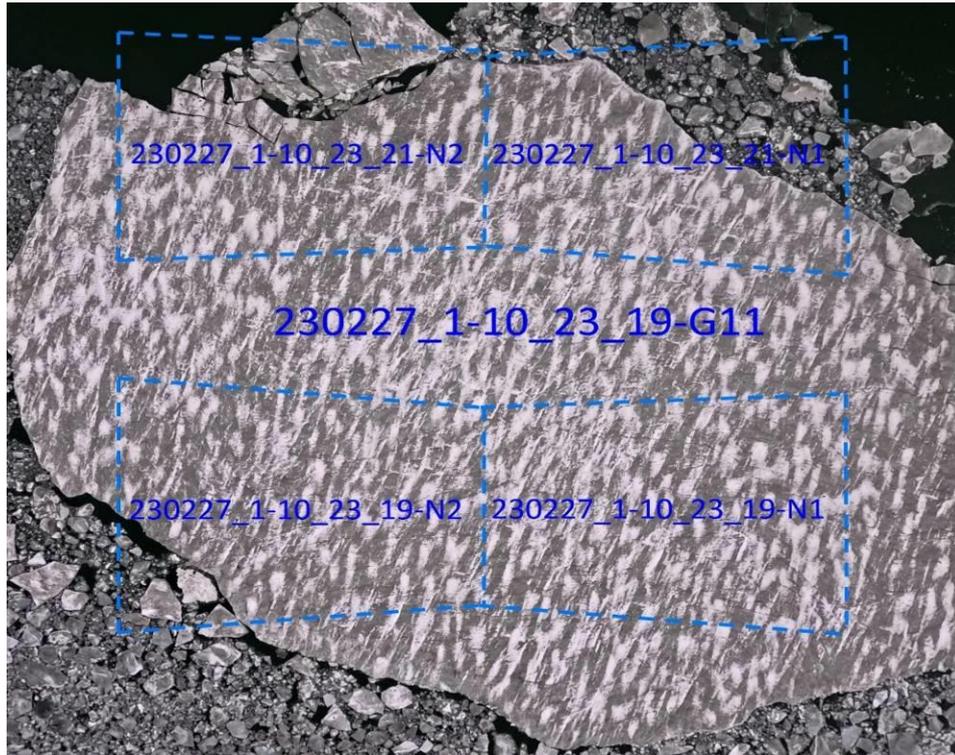
Figure 4.2.7   GoPro Cameras Ratio, Left and Right Nikon D850 Areas of Photographs (27.02. 2023, 10:23:19)

Thermal imaging was performed by two thermal imagers Optris PI450 and Flir A325, which enable to record IR imageries of the underlying surface. The review bands of the two thermal imaging videos are equal to 1.12 flight altitude in total (Figure 4.2.8).
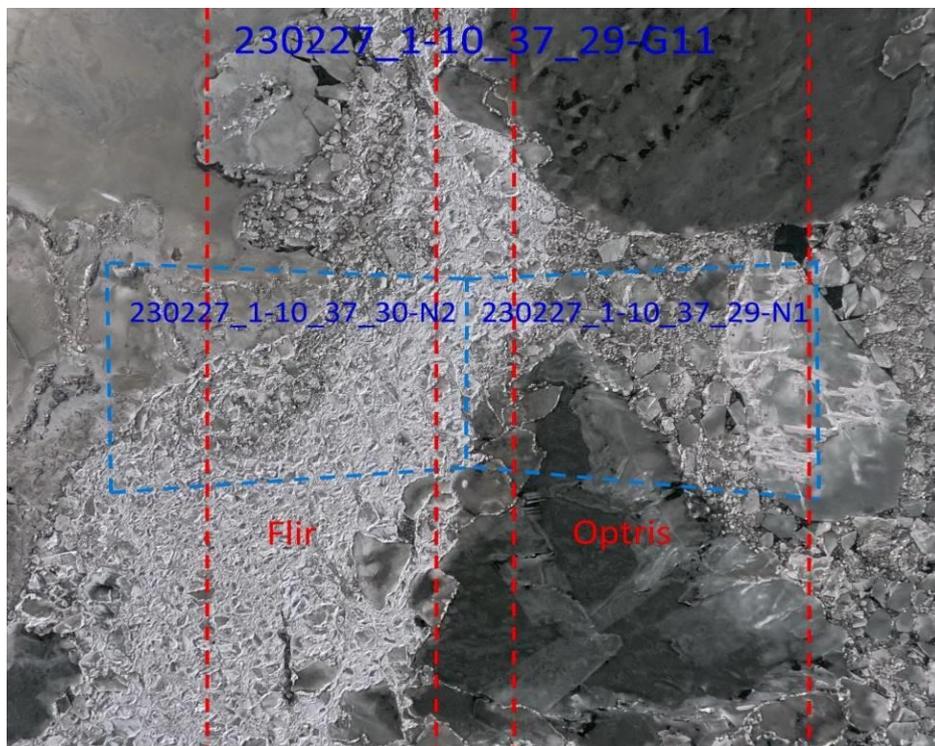
Figure 4.2.8   GoPro Cameras Ratio, Left and Right Nikon D850 Areas of Photographs and Video Recordings of Flir and Optris Thermal Imagers (27.02.2023, 10:37:29)

The sensitivity of thermal imagers is better than 0.1°C, the dynamic range of the radiometric signal is 14 digits. The maximum resolution of thermal imagers is 1.5 millirad, which corresponds to a spatial resolution on the surface of at least 30 cm at a flight altitude of 180 m.

Thermal imaging is the most effective for detecting seals on ice, which is due to the significant difference in body temperatures of a warm-blooded seal and the snow-ice cover of the sea. In addition, thermal imaging has shown the effectiveness of detecting warm-blooded animals even under the conditions of loose fog, when it is difficult to identify seals in a photograph with certainty (Figures 4.2.9 and 4.2.10).
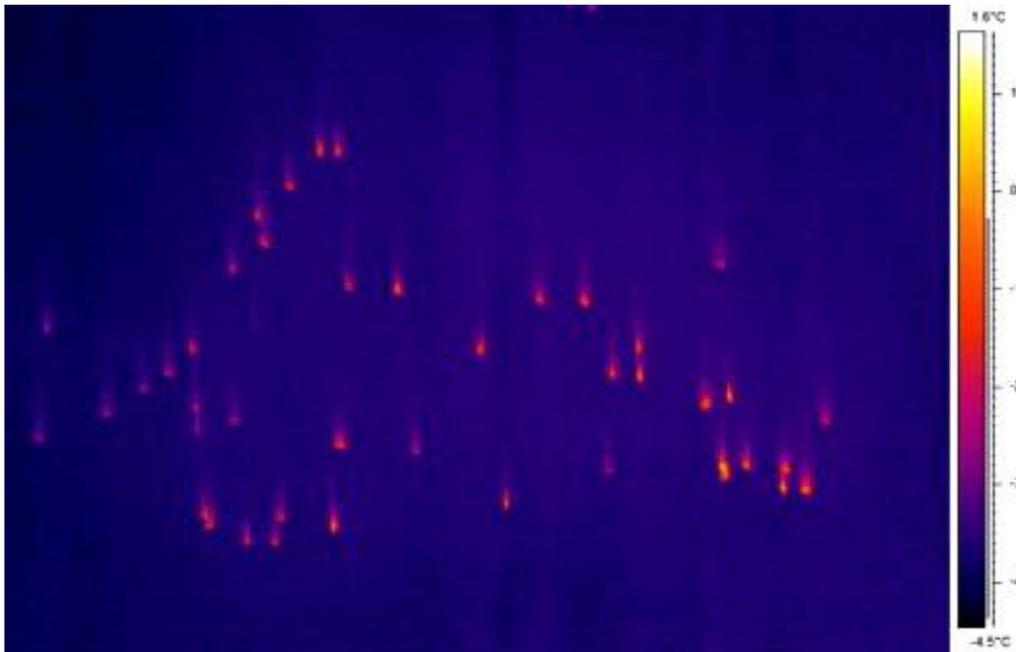
Figure 4.2.9   **IR Image of Seal Gatherings on the Ice (25.02. 2023, 13:25:41, Flir A325 Thermal Imager)**

Figure 4.2.10   **A Fragment of the Respective Photograph (25.02.2025, 13:25:41, Nikon D850)**

According to the infrared survey with an Optris PI450 thermal imager, the temperature contrast of Caspian seals with the surrounding ice during the 2023 shooting varied in the range between 2°C and 8°C, depending on the time of day and weather conditions.

The volume of collected photo, video material and thermal imaging was 1.31 TB, including: on Nikon D850 – 668.6 GB (39 thousand images), on thermal imagers – 95.943 GB, on Go Pro cameras – 540.46 GB.

4.2.2. Aerial Survey Flights Undertaken in February 2023

The survey period was 10 days, from February 18 to February 27, 2023. Due to difficult weather conditions (fog, strong wind), flights were conducted on February 21, 24, 25, 27 (twice), 2023.

On 18th of February the Piper PA-34 aircraft arrived in Atyrau. On the same day, the aerial shooting complex was installed on the aircraft. Permission from the military services for aerial survey flights for the aircraft was received on 21st of February.

Aerial survey of 21.02.2023:

Satellite information regarding the ice situation was thoroughly analysed before the flight. Based on satellite images of ice distribution, the route of the survey flight was developed. The survey was planned to be carried out in the western part of the distribution of the ice cover. Transects were set through 8 km in the meridional direction (north-south). Specialists decided to start the survey from the west, the border of the Republic of Kazakhstan with the Russian Federation and then to move along transects to the east.

In the morning there was low cloudiness, fog and wind 10 - 14 m/s. The aircraft took off at 12:10, landed at 16:46 Atyrau time. The flight duration was 4 hours and 36 minutes. The flight altitude along the accounting transects was maintained at about 180 m; the mean speed was 200-220 km/h.

The purpose of the flight was to obtain data on the distribution of Caspian seals on ice, as well as to check the settings of cameras, thermal imagers, navigation, on–board computers and flight software for accounting of Caspian seals. The results of this flight showed that the entire aerial shooting complex was operational, thermal imagers and Nikon D850 cameras worked reliably.

After the flight, all the information obtained was carefully analysed and adjustments were made in the configuration of aerial cameras and software operation.

The scientific team composed of F. Klimov, Ye. Loskutov, V. Chernook, A. Vasiliev successfully worked in this experimental flight. Figure 4.2.11 shows the working moment during the survey flight.

Figure 4.2.12 shows the distribution of ice on 20.02.2023 and the route of the survey flight of 21.02.2023.

The major seal gatherings were at the ice edge, and they consisted of shoal rookeries. An example of a shoal rookery is displayed in Figure 4.2.13.

There were seals at all 10 transects. A lot of pups were found on ice. There were rare blood spots on the ice from the birth of cubs – there were few of them, less than 10.

Aerial Survey on 22-23.02.2023:

On 22 and 23 of February the weather was bad, there was fog in the sea, and the airport weather service did not give permission for the flight. Therefore, on these days the flight deliverables for 21st of February were analysed and processed.

Figure 4.2.11   Operators' Work on Piper PA-34 Board, Cameras and Thermal Imagers are Installed under the Table
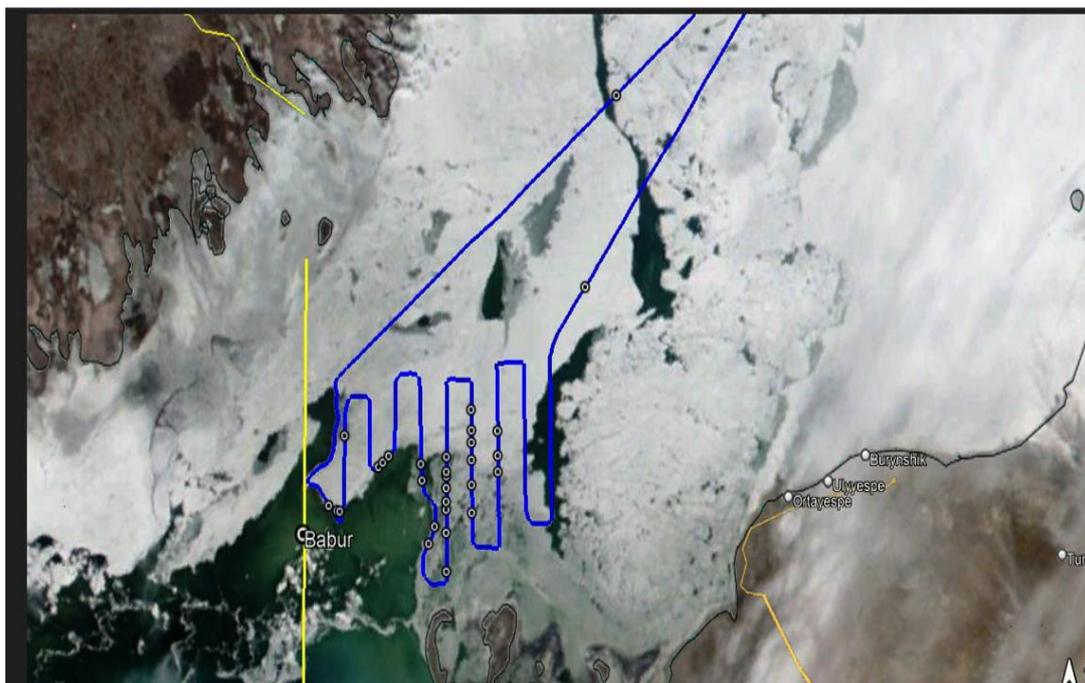
Figure 4.2.12   Survey Flight Route of 21.02.2023 on the Satellite Map of Ice Distribution (MODIS, 20.02. 2023)

Figure 4.2.13   Perspective Photograph of a Shoal Rookery at the Ice Edge

Aerial survey of 24.02.2023:

On 24th of February the aircraft took off at 14:00, finished the flight at 18:05 in Atyrau. The duration of the flight was 4 hours 05 minutes. The flight altitude was maintained in the range of 160-180 m, the speed was 200-220 km/h. Weather: low cloudiness, fog in the west. Air temperature from +9°C to +6°C, south wind, 3-4 m/sec. The distribution of ice, low cloudiness and fog in the morning on 24rd of February is shown in Figure 4.2.14.

The flight transects on 24rd of February were performed as a continuation of the flight of 21st of February (from the 4th flight transect on February 21 to the east). Aerial survey of pupping rookeries was conducted on a regular grid of parallel transects oriented in the north-south direction with a distance between transects of 8 km (Figure 4.2.15).

The flight made it possible to clarify the distribution of seals in the eastern part of the ice cover. Surveyors flew 8 transects, which allowed identifying the main area of pupping grounds.

Figure 4.2.14   Satellite Image of Ice and Fog Distribution (MODIS, 23.02.2022)
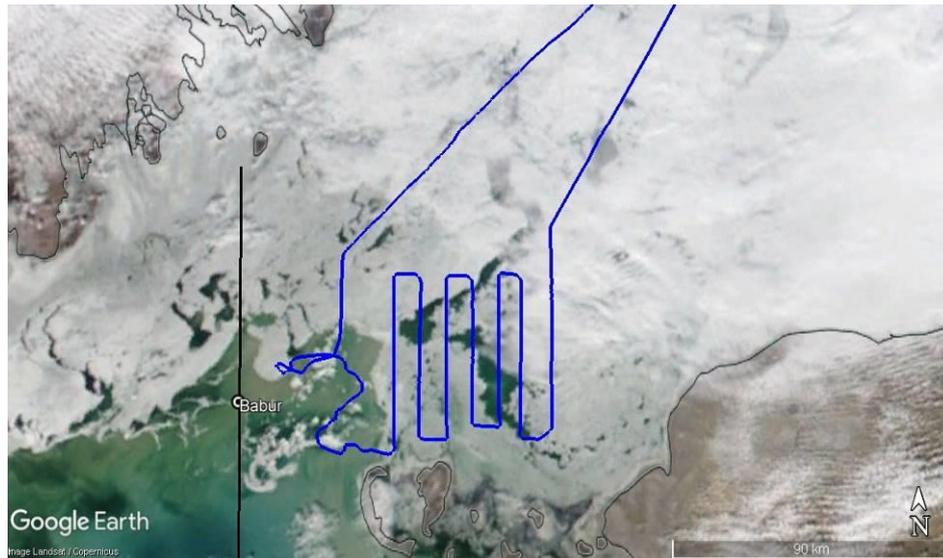
Figure 4.2.15   Survey Flight Route of 24.02.2023 on the Satellite Map of Ice Distribution (MODIS, 20.02. 2023)

Aerial survey of 25.02.2023:

On 25th of February, the aircraft took off at 11:09, finished the flight at 15:19 in Atyrau. The flight duration was 4 hours and 10 minutes. The flight altitude was maintained in the range of 160-180 m, the speed was 180-240 km/h. Weather: mist, fog in the west. Air temperature from -2°C to +1°C, south wind, 15 m/sec. Ice distribution at day time on 25 of February is shown in Figure 4.2.16.

The flight transects of 25 February were performed as a continuation of flights of the Russian colleagues west of the border with the Russian Federation (from the 1st transect and to the east). Russian colleagues flew over the border area on 24 February. Aerial survey of pupping rookeries was conducted on a regular grid of parallel transects oriented in the north-south direction with the distance of 4 km between transects (Figure 4.2.16).
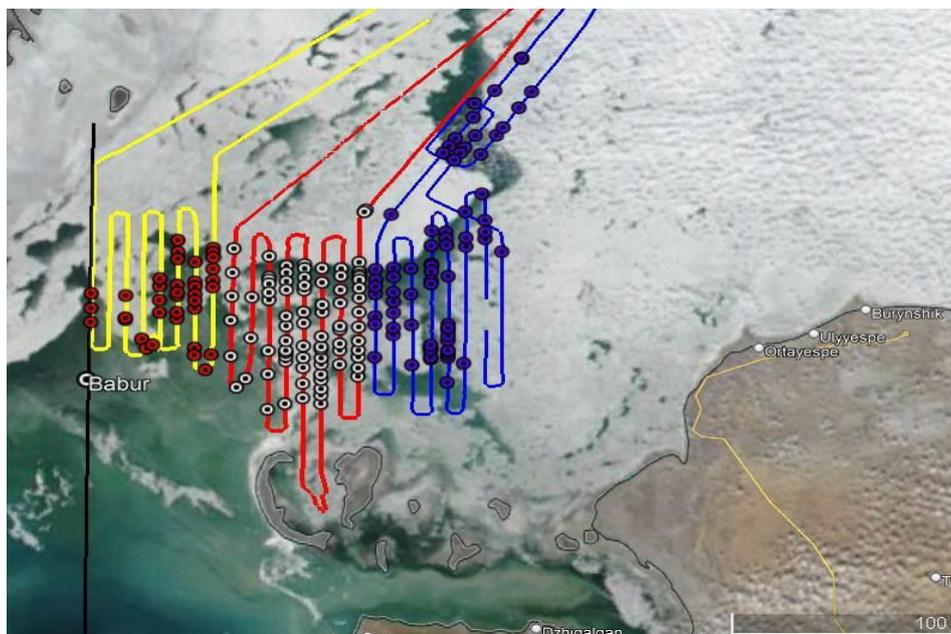
Note: *Flight routes: yellow - 25 February, red - 27 February (9:00-14:00), blue - 27 February (15:00-19:00). The circles indicate areas with high density of Caspian seal encounters.*

Figure 4.2.16   Flight Pattern and Distribution of Seal Aggregations on 25 and 27 February 2023

The flight on 25 February allowed clarifying the distribution of seals in a part of the ice cover on the border with Russia. This was done as part of work coordination with RFRIFO. Eight transects were completed. In general, this flight included male haul-outs, which were mostly on the ice edge. An example of a shoal rookery is displayed in Figure 4.2.17.
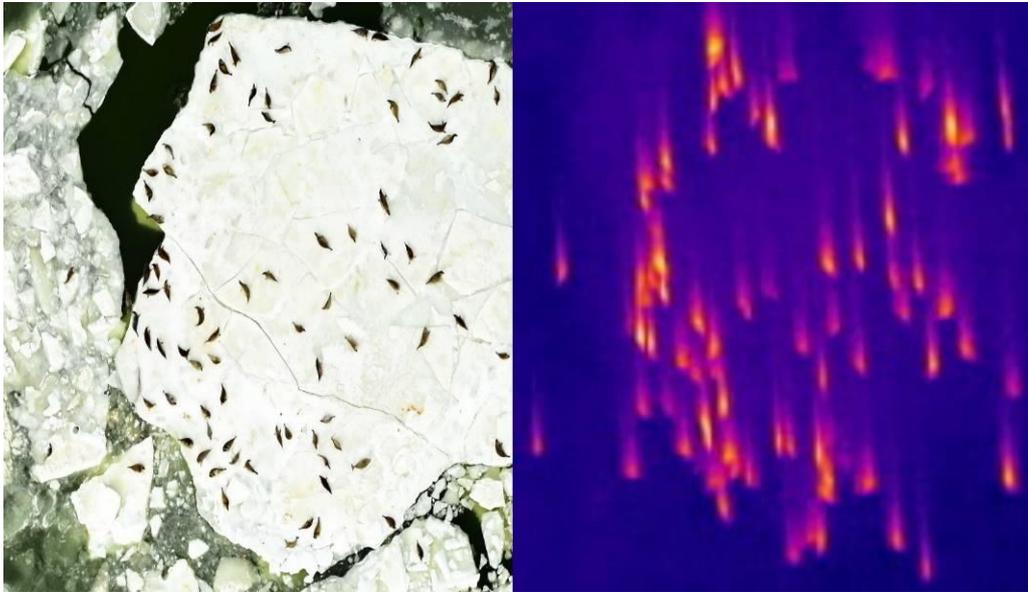
Figure 4.2.17   Photo and IR Image of Seal Gatherings on Ice (25.02.2023, 13:23:37, Flir A325 Thermal Imager)

Aerial survey of 26.02.2023:

On 26 of February, the weather was bad, there was strong wind up to 23 m/s and fog in the sea, and the airport weather service did not give permission for the flight. Therefore, on this day, the flight deliverables for 25 of February were analysed and processed.

Aerial survey of 27.02.2023:

The flight route was developed based on results of two previous flights and satellite images of the ice distribution. 2 flights were made on 27 February. The first flight, the aircraft took off at 09:09, finished the flight at 13:20 in Atyrau. The flight duration was 4 hours and 20 minutes. The second flight, the aircraft took off at 14:11, finished the flight at 18:38 in Atyrau. The flight duration was 4 hours and 27 minutes. The flight altitude was maintained in the range of 170-190 m, the speed was 200-230 km/h.

The weather was good, the air temperature was +4°C to +7°C, south-westerly wind, 1-6 m/sec.

To capture the distribution of seals in the central part of the ice, 16 transects were performed (2 flights). The distance between transects was 4 km. With this flight the central and eastern part of the ice was additionally surveyed and the entire ice area, where seals could be present, was covered by aerial surveys. The flight route is displayed in Figure 4.2.16.

During 3 flights of February 25 to 27, almost all areas with seal rookeries in the North Caspian Sea were surveyed using the regular transect grid with a distance of 4 km between them, and a total number of transects equal to 28. Some transects in the central part of the ice cover were repeated on different flight dates.

Data on visual survey of 21.02.2023 -27.02.2023.

According to the data of visual count from the starboard side of the aircraft in the strip of 300 m 10943 adult Caspian seals were counted, the count of pups on transects was not conducted due to a significant error, as some pups had light colour and blended in the surface of the ice field (Table 4.2-1).

Table 4.2-2   **Visual Aerial Count of Adults from the Starboard Side of the Aircraft, specimen/transect**

No. of transect	21.02.2023	No. of transect	24.02.2023	No. of transect	25.02.2023	No. of transect	27.02.2023 (flight 1)	No. of transect	27.02.2023 (flight 2)	Seals in total
1	0	1	691	1	26	1	227	9	426	1370
2	14	2	434	2	69	2	526	10	258	1301
3	396	3	164	3	102	3	349	11	79	1090
4	279	4	99	4	36	4	754	12	352	1520
5	365	5	116	5	87	5	1014	13	431	2013
6	444	6	103	6	282	6	394	14	29	1252
7	12	7	203	7	491	7	501	15	45	1252
8	0	8	19	8	590	8	325	16	20	954
9	135									135
10	56									56
Total	**1701**		**1829**		**1683**		**4090**		**1640**	**10943**

4.3.   Aerial Survey of Caspian Seal Moulting Rookeries, April 2023

The second stage of survey was conducted in the spring 2023, namely, aerial counting of seals rookeries and moulting grounds in April.

Aerial counting was performed on Piper UP-P3402 plane (Figure 4.3.1) using the video and photo survey. The main flight altitude was 200 m.

The following KAPE LLC specialists took part in the survey – F.V.Klimov, I.A. Belokobylskiy, V.V. Boyko. Pilots were S. Unzhakov and Ye. Zhukov. (Figure 4.3.1).

The photo fixation was maintained with two Nikon D850 cameras with a full-format 46 MP matrix and with an F=50mm lens in infinite focus mode, ensuring photography of the central part on the transect. The total viewing angle of these cameras was 78 degrees. The operation of these 2 cameras occurred simultaneously. GoPro 11 and DJI Osmo Action 4K widescreen video cameras were also used.

Alongside the instrumental survey, visual observations from the left and the right side of the aircraft were conducted. According to photo and video recording and visual observations moulting grounds were observed on 32 of 54 surveyed islands/sand islands in the North-Eastern Caspian Sea.

Flight parameters (time, coordinates, course, altitude, speed, etc.) were automatically recorded every second using a Garmin GPS satellite navigation system. The coordinates of the flight points were obtained in the format degrees with decimal fractional part (45.36158, 52.25318). All cameras and GPS were synchronized in time with an accuracy of 1 second. Prior to flights the equipment was calibrated and tested on the ground.

A file directory was created for each flight. A coordinate is defined for each image. The files were synchronized in order to identify the overlapping zones of two cameras to avoid duplication of the counting of seals in different photos.

UP-R3402 research aircraft   Field team

Figure 4.3.1   **Spring 2023 Field Survey**

The total length of the seal count route was more than 2500 km. During the aerial survey period 18002 photographs and 97 video clips of 376.52 GB were taken along the route. Alongside the instrumental survey, visual observations from the left and the right side of the aircraft were conducted.

At the first stage files were viewed in order to identify images of the Caspian seal on them. On the second stage, these images were processed in a graphical program with a counting function (Figure 4.3.2). Parts of sand bars in different photos were "stitched together" in Adobe Photoshop CC 2019 to visualize and prevent repeated counts of seals. At the final stage an MS Excel 2010 spreadsheet was compiled with the name of the photo, the time of shooting, the coordinates of the GPS image, the number of seals. The maps were created in the Geographic Information System QGIS 3.10.0.

Figure 4.3.2   Seals Counting at Sand Bars

4.3.1.   Aerial Survey Flights, April 2023

The duration of the aerial counting was 6 days from 10 to 16 April, 2023.

The total length of aerial counting routes was more than 2500 km.

Aerial Survey of April 10, 2023:

Mobilisation of personnel, installation of equipment on Riper-34, checking of equipment operation, adjustment, quality control. Meeting with customer representatives, briefing on safe work practices, discussion of the scope of work.

Aerial Survey of April 11, 2023:

The first flight:

The aerial survey was carried out to count the number of Caspian seals on islands, sand bars and shoals of the north-eastern Caspian Sea within the boundaries of the Kazakhstan sector of the Caspian Sea (Kashagan area, Aktoty, Kairan, Prorva, Durnev Island, and Remontnye Shalygi). Several significant groups of seals were observed (Remontnye Shalygi islands located above and below the Prorva channel), with a total number of more than 20,000 different-aged Caspian seals. The total length of the routes was 870 km. The flight route is shown in Figure 4.3.3.

The second flight:

The aerial survey was carried out to count the number of Caspian seals on islands, sand bars and shoals of the north-eastern Caspian Sea within the boundaries of the Kazakhstan sector of the Caspian Sea (the area of Tyulenyi islands, marine sand bars, and Tupkaragan coast).

Several significant groups of seals were observed (Remontnye Shalygi islands located above the Tyulenyi islands), with a total number of more than 18,000 different-aged Caspian seals. Old discards of dead seals were recorded on Kulaly Island, on the coast - 33 specimens. The total length of the route was 805 km. The flight route is shown in Figure 4.3.4.

Aerial Survey on April 12-13, 2023:

Waiting for the weather. Dust storm. Due to weather conditions (dust storm, wind up to 18 m/s), flights were postponed to April 14.

Aerial Survey of April 14, 2023:

A survey of marine sand bars south of the North Caspian, new Durnev Islands, Remontnyye Shalygi along the coast of the Buzachi Peninsula in the direction to Morskoy Island was carried out, Figure 4.3.5. The total length of the route was 759 km.

Aerial Survey on April 15-16, 2023:

Office study, work with photo and video materials of the Caspian seal survey in the north-east of the Caspian Sea within the boundaries of the northern Caspian Sea. Transfer of primary photo and video recording results for the period April 10-15, 2023, to NCOC.

On 15-16 April 2023 demobilisation of specialists, equipment and aircraft to the places of permanent deployment.

The results of the 10-15 April 2023 flights identified 32 marine sand bars (Figure 4.3.6) where Caspian seal moulting took place in April 2023 (Table 5.2-1).
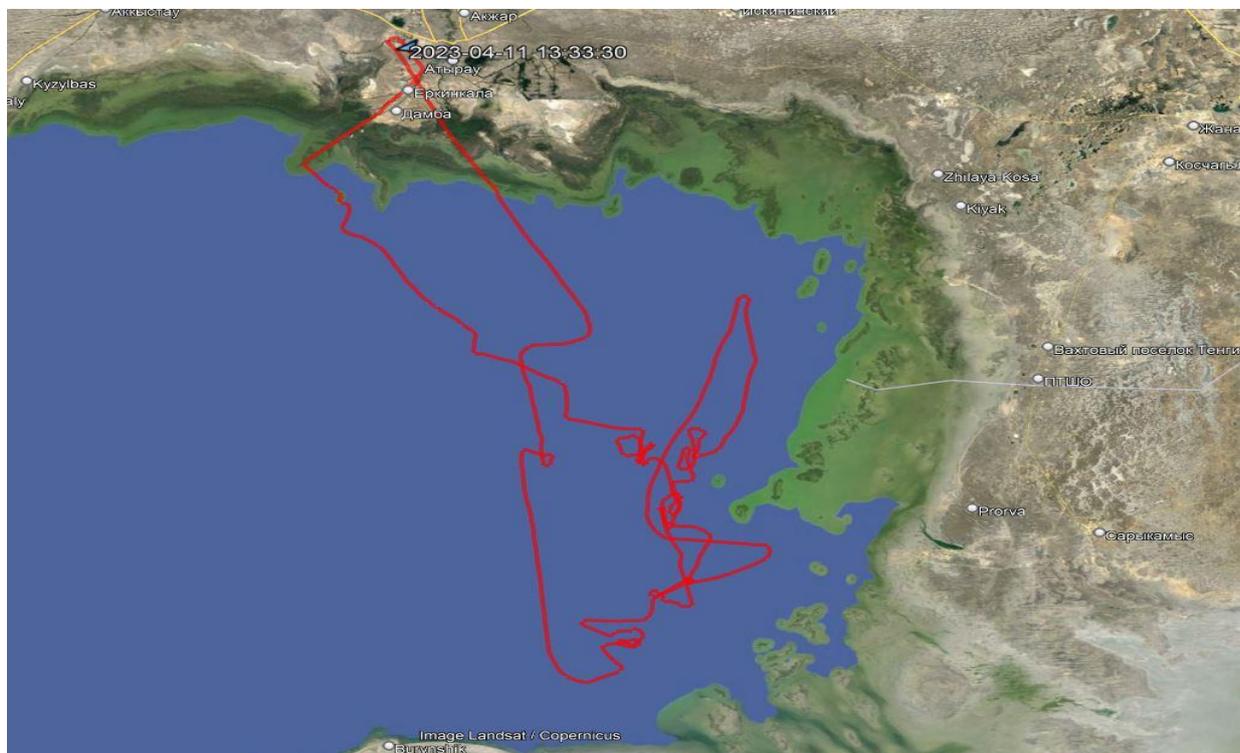
Figure 4.3.3   Flight Routes, 11 April 2023 (first flight)
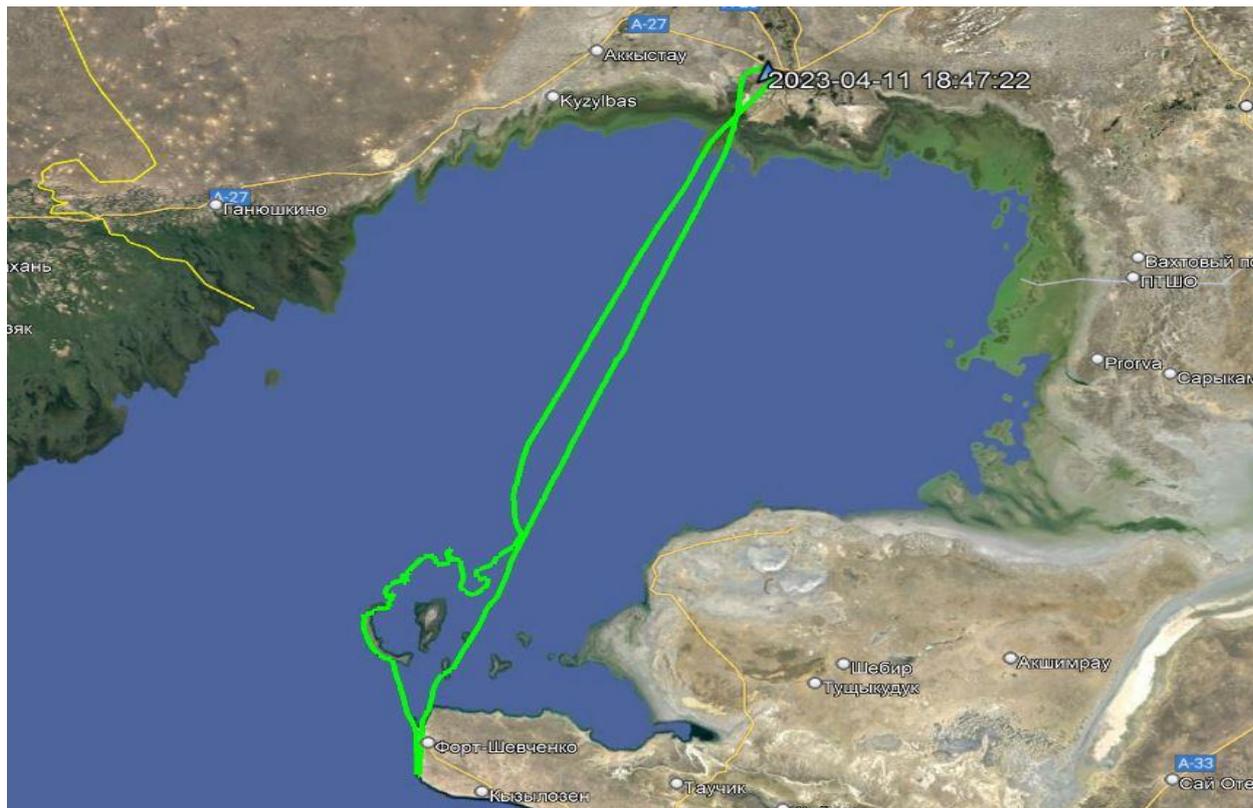
Figure 4.3.4   Flight Routes, 11 April 2023 (second flight)

Figure 4.3.5   Flight Routes, 14 April 2023
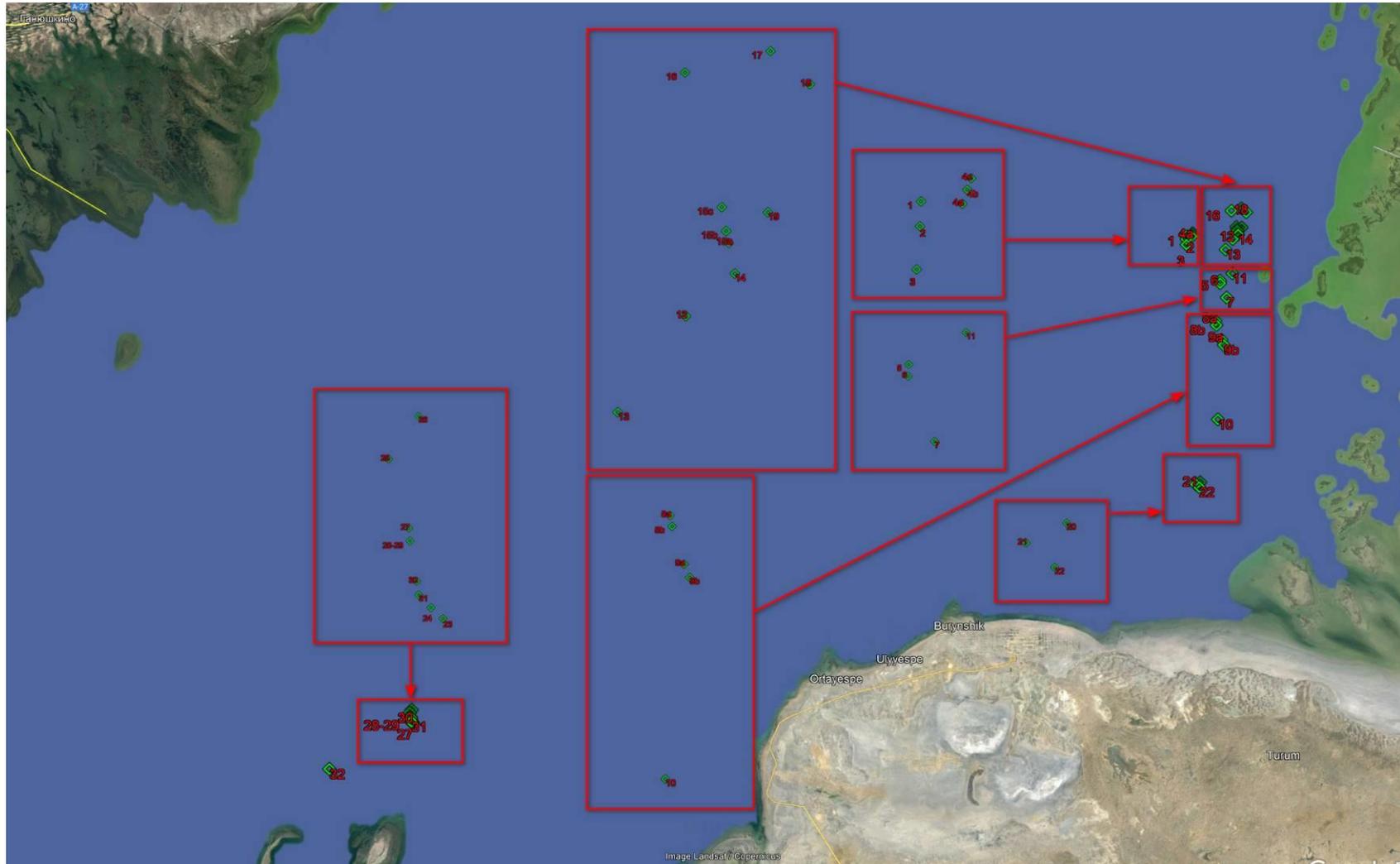
Figure 4.3.6   Location of Seal Moulting Rookeries on Marine Sand Bars of the North-East Caspian Sea, April 2023

4.4.   Discussion

The comparison of satellite information with the existing classification of the severity of winter in the Caspian region makes it possible to attribute the 2022-2023 winter seasons to winters with a mild nature. The sum of the degree-days of frost at sea was about 250-260; the duration of the freeze-up was 82 days. Under the conditions of mild winter, the ice cohesion ranged from 1-3 to 6-9 points, and their thickness was 5-40 cm.

In the winter period (February 2023) the first stage of surveys was implemented – multispectral aerial photography of Caspian seal rookeries. Aerial photography of seal rookeries on ice was taken from Piper PA-34 aircraft. Accounting flights were performed under good weather conditions. The main instrumental aerial photography of seals was performed using two Optris PI450, Flir A325 thermal imagers and cameras (Nikon D850 and GoPro11) fixed in the lower part of the aircratf fuselage.

During the aerial survey period all the ice was in the north-eastern and north-western parts of the North Caspian Sea. Seal rookeries on ice were in the zone of Kazakhstan and Russia. During the flights of 21-28 February almost all areas with seal rookeries in the Northern Caspian Sea within the borders of the Republic of Kazakhstan and the Russian Federation were surveyed on a regular grid of transects with a distance of 4 km and a total number of 84 transects. Some transects in the central part of the ice cover were repeated at different flight dates. As a result of aerial photography, a large amount of data on distribution and abundance of seals in the 2023 winter period was obtained. According to the data of the aerial survey no dead seals were found on the ice field.

In the spring period (April 2023), the second stage of surveys was implemented – an aerial survey of rookeries and moulting grounds of the Caspian seal. The aerial survey was undertaken on Piper PA-34 aircraft using video and photography (two Nikon D850 cameras, DJI Osmo Action and GoPro 11 video cameras).

The coast of the North Caspian Sea, the North Caspian Sea Canal (artificial islands), marine sand bars, Tyulenyi Archipelago islands, Durnev Island, the coast of Buzachi Peninsula, Tyupkaragan, Mangyshlak from Bautino settlement to Saury settlement were surveyed.

According to the results of aerial surveys of April 10 to April 16, 32 marine sand bars were identified, where the Caspian seal moulted in April 2023. The number of Caspian seals on marine sand bars, islands, including shallow waters, in areas of seal rookeries, was 43,063 different-aged specimens and ranged from 6 to 5,814 specimens per sand bar.

In the spring period of 2023 carcasses of seals died in winter of 2022-2023 from the epidemic of plague of carnivores and influenza infection, were recorded on Kulaly Island, Tyupkaragan Spit, in the amount of 44 pieces.

In the spring period, no Caspian seal rookeries were found along the coast of Buzachi and Tupkaragan peninsula; there were massive gatherings of flamingos, pelicans, swans and other seabirds.

5. AERIAL SURVEY DELIVERABLES PROCESSING

5.1. Multispectral Aerial Survey of the Caspian Seal Ice Rookeries

5.1.1. Primary Processing of Aerial Survey Deliverables

Once the aerial survey of the Caspian seal has been accomplished, the initial processing of aerial deliverables was made, consisting of several stages. The most time-consuming stage is the counting of seals on IR and photographic images, the volumes of which was continuously increasing with increase in resolution of aerial photography equipment. Instrumental aerial photography is performed simultaneously in the visible and infrared bands.

A flowchart of the technology for processing of aerial photography materials is shown in Figure 5.1.1.
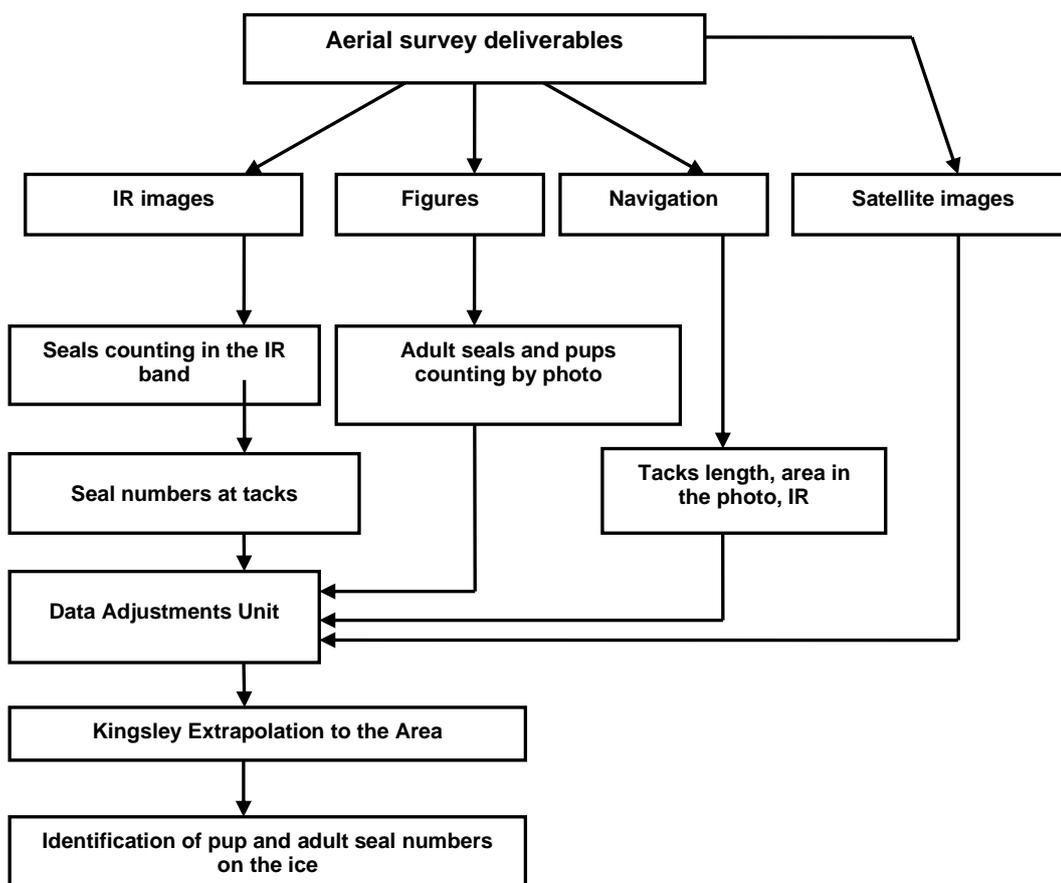
Figure 5.1.1   Seal Aerial Survey Materials Processing Technology Flowchart

At the preparatory stage of the desk processing, the primary analysis is performed, including viewing, sorting and selection of deliverables; all collected deliverables are catalogized. The dates of the accounting aerial surveys are set, and on the basis of the deliverables collected the number of pups and adult seals will be counted.

The error of the time set in the camera relative to the time of the PDF file is determined, and with this in mind, all photos are renamed by a specially developed software. Photos are assigned names of the following type: Year_month_day hour-min-sec_ camera code.jpg (L – left, R – right).

Analysis of the deliverables of comprehensive aerial photography is performed:

– promptly during the period of aerial survey work based on the materials of each aerial survey flight – in order to assess the quality of survey materials, mapping of the distribution of seals and optimal planning of routes for subsequent survey flights;

– in laboratory conditions – a long stage of comprehensive ground processing, starting with viewing and systematization of all accumulated material, selection of high-quality images suitable for analysis of various spectral ranges, cataloging of all collected material. Once images of various spectral ranges have been preliminarily processed separately, they are jointly analyzed with the decoding of the shooting objects – adult seals and baby seals.

5.1.2.   Joint Processing of Photographs and IR Materials

The previously developed technology of comprehensive processing of instrumental survey materials was applied to the aerial survey materials of the Caspian seal rookeries.

Phase 1. All IR images are viewed. Flights covering all possible locations of Caspian seal rookeries by aerial photography in a short time – on February 25 and 27, 2022 - are selected. During the flights, the major distribution area of dense pupping grounds was covered with accounting tacks; the boundaries of seal rookeries were clearly fixed. High-quality synchronous photo and thermal imaging of seal gatherings was taken.

Phase 2. A joint analysis of IR images with "hot spots" and respective digital photographs for the detection of marine mammals is performed.

Data is processed using IR images and photographing of the Caspian seal. Seals in the IR images and photographs were counted by two operators independently of each other. Previously, each operator was specifically trained. The training of operators began with training in the detection of thermal spots of seals in IR images and their separation into adult and baby seals using relevant photographs. For the purpose of training, the operators independently viewed selectively the photography materials and thermal imaging, highlighting the nature of ice condition features and the location of seals, and deciphered adult animals and baby seals.

Simultaneous use of IR and photography makes it possible to increase the reliability and accuracy of determining the seal numbers, but at the same time complicates the processing of materials. It is necessary to process materials of each spectral channel and, in addition, their mutual analysis and correction in the presence of various factors complicating the processing: changes in the scale of the underlying surface image from the centre to the edges of the survey strip in both photographic and infrared images, different degree of distinguishability of animals in different spectral channels under different weather conditions, etc.

Materials of the visible and infrared bands (Figure 5.1.2) complement one another, greatly facilitating the detection of animals on the ice. IR images enable to quickly detect seals, and photographs enable to identify adult seals and baby seals, to filter out various disturbances in the IR image (spots of heated ice in the place of animals that have gone into the water or changed their resting place immediately before the moment of shooting, holes, sun glare from mirror–smooth ice floes, etc.). All suspicious IR spots were examined in detail in the photographs, after which identification was made – whether it was a seal or not.

The use of IR images is especially effective when searching for seal pups. Even an experienced researcher does not always manage to see a baby seal in a photograph, since baby seals have a white masking colour, and often hide from the wind in hummocks. The joint analysis of IR and photo images due to better detection of cubs increases the reliability and authenticity of accounting for animals on ice.

When processing data from different spectral channels of aerial photography and counting the number of animals recorded by instrumental photography, the following sequence of actions is used:

a)   Reference to the IR image of an arbitrarily selected photo of one of the cameras (specialists are guided by the time of photographing, the time on the IR image, by the configuration of characteristic ice floes, as well as by the location of animals on the ice - Figure 4.2.17).

b)   Selection of photos with animals (when selecting, specialists focus on the IR images).

c)   The operator, comparing the images in the photo and IR, based on the characteristic features of the ice and the location of seals on them, determines the position of the viewing bands of cameras and thermal imagers relative to each other.

d)   Identification of "Adult seal/Baby seal" and the installation of animal tags on photographs are performed on two computers using three high-resolution monitors. On one computer, the operator finds thermal highlights on the IR image, then on the second computer, using the reference photo, he

identifies an animal (adult seal or baby seal), and sets labels of different colours for each type of object on the photo image using the mouse manipulator. An example of a photo image with tags of adult seals (red colour tags) and baby seals (green colour tags) is shown in Figure 5.1.2.

An over-moulted pup-sivar is characterized by two parameters, by which it is identified in photographs:

– silver-grey colour of the fur, which is present in specimens only in the first year of life. With subsequent moulting, the colour of the fur acquires a structure similar to adult specimens;

– sivars have a length of 80 to 96 cm (average length - 88cm), and yearlings have an average length - 123 cm.
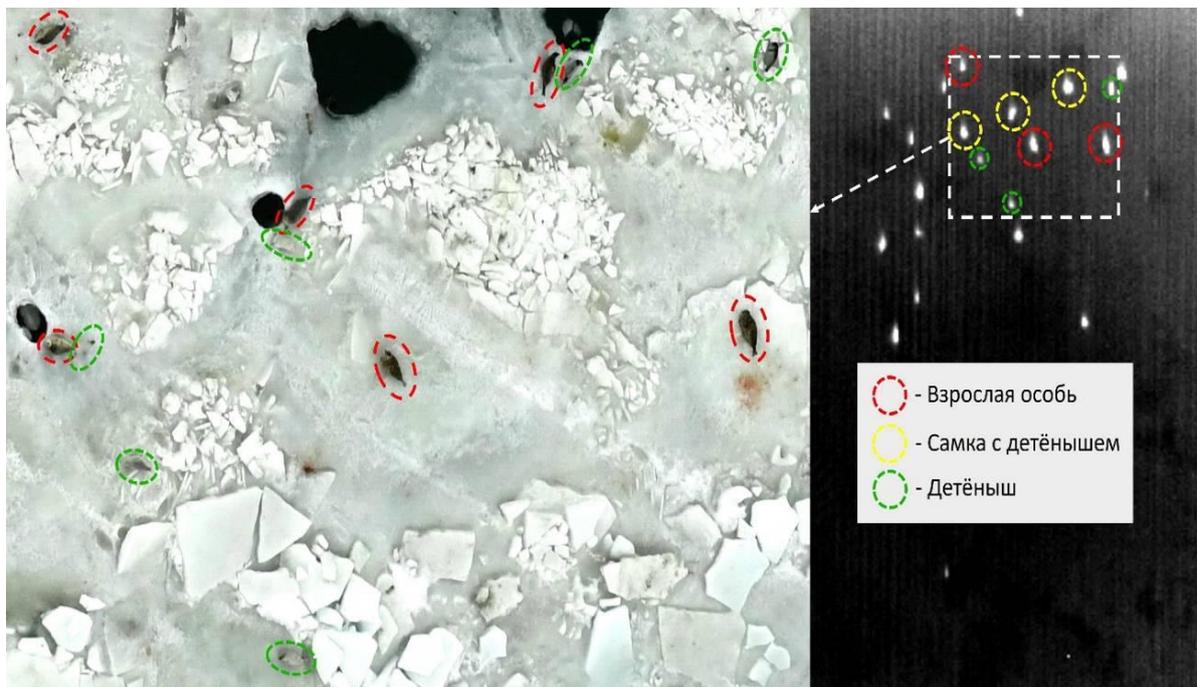
Figure 5.1.2   Fragments of Infrared Image and Photo of the Seal Rookery on Ice (27.02.2023, 11:59:21) Green Ovals Indicate Pups and Red Ovals Indicate Adults. On the fragment of the infrared image, ovals of yellow colour highlight "hot spots" from females with pups lying next to each other

Information of the placed tags is saved by the "jpegproj" software in the output text file, which enables to subsequently display a photograph with tags of any operator displayed on it, as well as to place tags on the map in GIS software. The software "jpegproj" provides the ability to edit information of tagged objects and introduce additional information, for example, about behavioural characteristics of seals, ice characteristics, etc.

MapViewer 7 and Google Earth were used as a software environment for GIS applications.

The use of GIS made it possible to map the routes of accounting aerial surveys (see Figure 4.2.16), to make a spatial reference of thermal and photographic images, to make a spatial reference of graphic satellite ice maps MODIS satellite system, to build maps of the distribution of seals.

5.1.3.   Generalization of Instrumental Accounting Results, Winter 2023

During 3 flights from February 25 to 27, 2023, almost the entire ice cover with seal rookeries was surveyed along 28 transects with a distance of 4 km.

To identify the number of seals on transects, counting was performed using IR images and high-resolution photographs from Nikon D850 cameras. Two experienced specialists counted adult seals and pups independently. The final results of counting of seals placed on ice in the north Caspian Sea are listed in Table 5.1-1 and Table 5.1-2.

In the period from February 25 to 27, 2023, the ice situation stabilized. In Figure 4.1.16, the flight routes, which results are used to calculate the number of Caspian seals, were superimposed on two different satellite images – for February 25 and 27, 2023.

Figures 5.1.3 and 5.1.4 show cartographic diagrams of seal distribution densities on the surveyed ice.

Table 5.1-1   **Ratio of Adult and Baby Seals Found on Ice of the Caspian Sea on February 25-27, 2023**

Flight date	Adults, specimens	White-coat seals, specimens	Moulting, specimens	Sivari, specimens	Total, specimens	Including baby seals, specimens	Share of baby seals, %
25.02.2023	859	7	18	29	913	54	5,9
27.02.2023 (flight 1)	2588	242	436	489	3755	1167	31,0
27.02.2023 (flight 2)	1085	172	187	216	1660	575	34,6
Total	**4532**	**421**	**641**	**734**	**6328**	**1796**	**28,3**

Table 5.1-2   **Ratio of White-Coat Seals, Moulting Calves and Sivari Detected in Photographs on Caspian Sea Ice during Flights on 25 and 27 February 2023.**

Date of flight	White-coat seals, specimens	White-coat seals, %	Moulting, specimens	Moulting, %	Sivari, specimens	Sivari, %	Total baby seals
25.02.2023	7	12,9	18	33,3	29	53,7	54
27.02.2023 - flight 1	242	20,7	436	37,3	489	41,9	1167
27.02.2023 - flight 2	172	29,9	187	32,5	216	37,5	575
Total	**421**	**23,4**	**641**	**35,6**	**734**	**40,8**	**1796**

Analysing the distribution of Caspian seal pups for 25 and 27 February (see Figure 5.1.4), it can be noted that main pupping grounds of Caspian seals in the zone of Kazakhstan were well covered by survey transects. There were no seals in the north of the surveyed area boundary. In the south, in the Kulaly area (shallow water), no baby seals were found either. In the west, near the Russian border, single pups were recorded and the ice was well surveyed. There were almost no pups on the 3 eastern transects of the area. Sporadic pups were recorded in the north-east of the area in ice lanes at the ice edge.
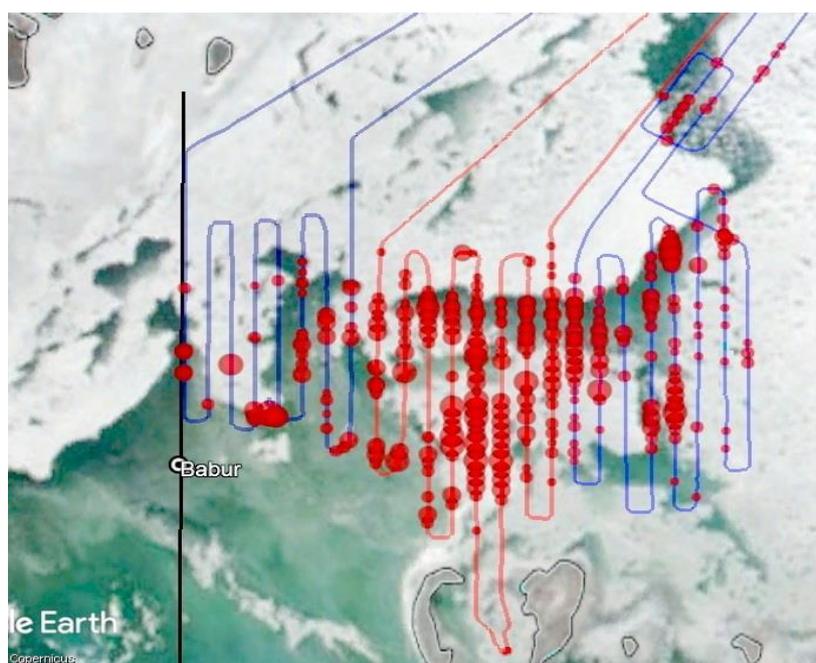
Figure 5.1.3   **Distribution density of adult seals on the flight routes on 25 February (navy), for the 1st flight 27 (red), for the 2nd flight 27 February (blue), overlaid on a satellite image of ice distribution (MODIS for 25.02.2023).**
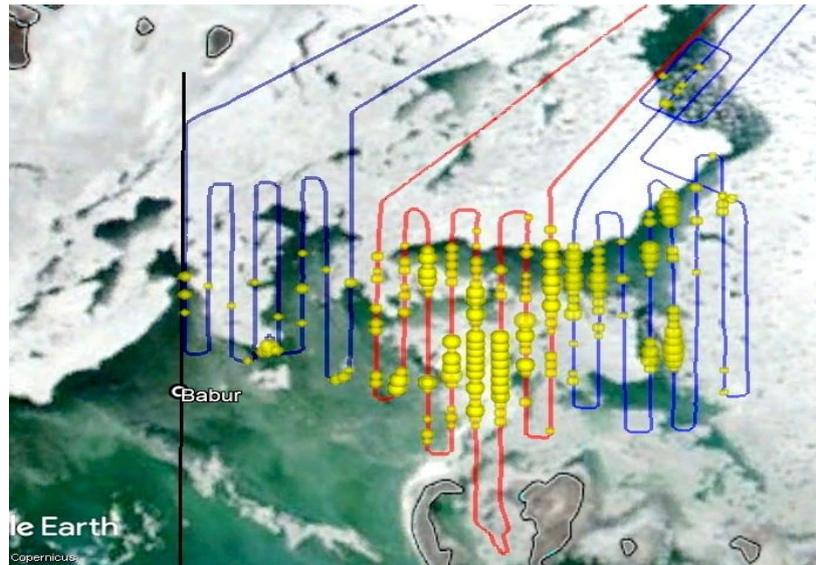
Figure 5.1.4 **Distribution density of baby seals on the flight routes on 25 February (navy), for the 1st flight 27 (red), for the 2nd flight 27 February (blue) superimposed on the satellite image of ice distribution (MODIS for 25.02.2023)**

5.1.4. Calculation and Estimation of Caspian Seal Numbers on Ice Field

The scheme of accounting transects with their numbering is shown in Figure 5.1.5. The end-to-end numbering of tacks for calculating the number of seals is indicated on top from left to right. The tack numbers within each flight in the format "number_date" indicate the sequence of transects passed during the flight (25 February flight - lilac lines, 1st flight of 27 February - red lines and 2nd flight of 27 February - blue lines). Navigation data of 28 accounting transects are listed in Tables 5.1-3 and 5.1-4. The number of parallel transects was 28, the study area where the surveyed pupping grounds were located was 5,237 square kilometres.

On the area of Russia 48 transects were conducted from 20 to 27 February 2023, the scheme of survey transects with their numbering is shown in Figure 5.1.6. The survey was carried out by two groups of scientists from RFRIFO and "Chistiye Morya" (with the involvement of scientists from IPEE RAS). The area where the Caspian seal pupping grounds were observed was more than 5000 square kilometres.
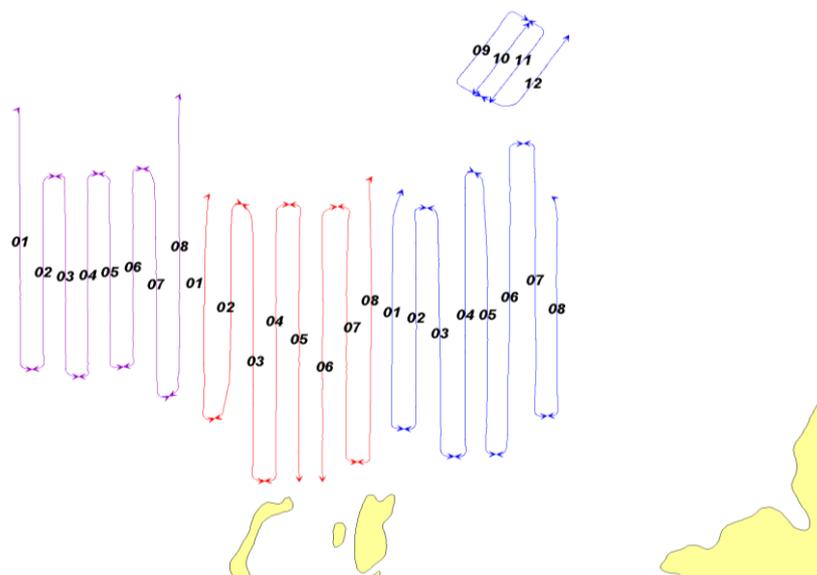
Figure 5.1.5 **Scheme of Survey Transects for Aerial Surveys of the Caspian Seal in 2023 in the Zone of the Republic of Kazakhstan**

The shooting was done on parallel transects of different lengths, but of the same width, since the altitude in each flight was maintained in a constant mode. The interval between tacks was the same and was equal to 4 km. This made it possible to extrapolate the results of adult seals and cubs counting on transects to the entire surveyed water area with an estimate of the number of adult seals and cubs using the Kingsley method [Kingsley et al, 1985]. The results of the extrapolation are specified in **Appendix B** (Table B.1-B.2). The calculation results are listed in Table 5.1-2.
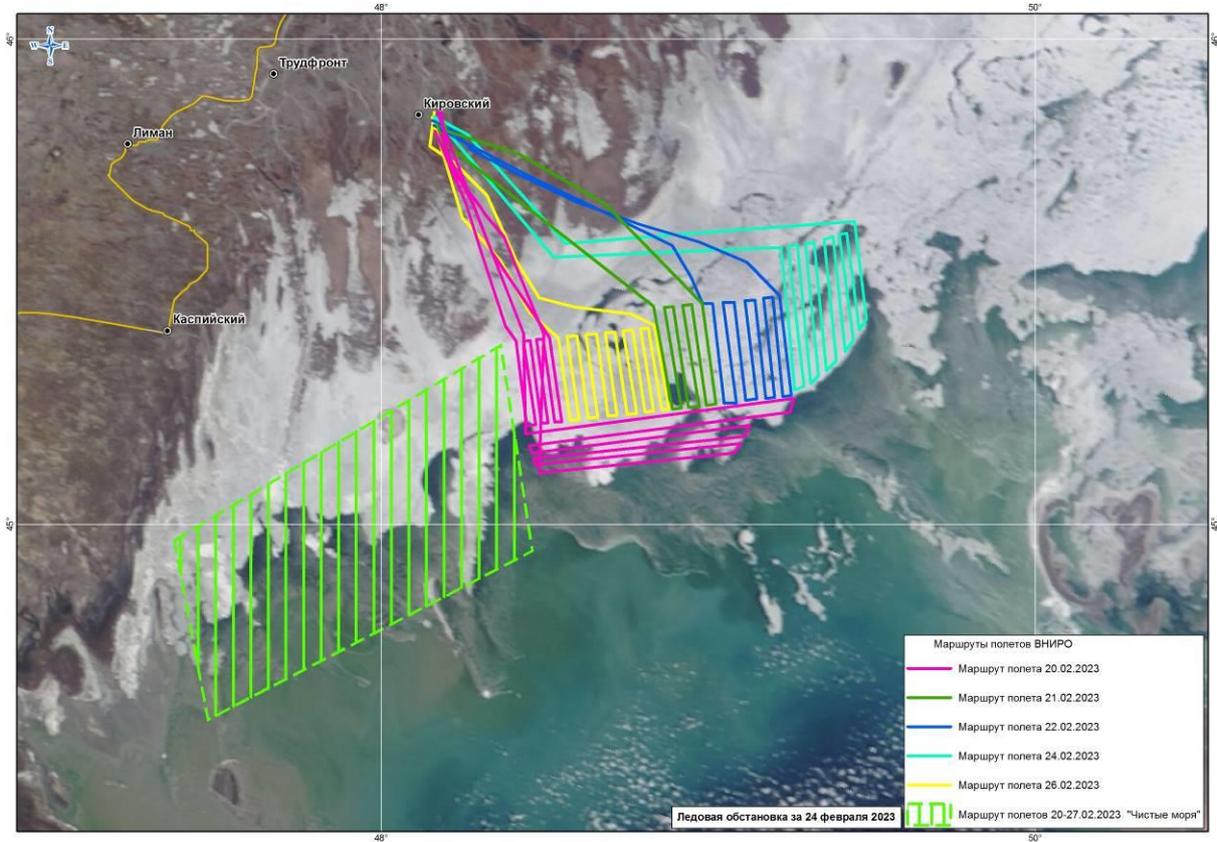
Figure 5.1.6   Scheme of Survey Transects for Aerial Surveys of the Caspian Seal in 2023 in the Zone of the Russian Federation

Table 5.1-3   Calculation of Adult Abundance on Caspian Sea Ice (based on flight data for 25 and 27 February 2023), Kazakhstan sector

Tack No., date, flight	Tack length, km	Flight altitude, m	Accounting transect width, m	Accounting strip area, sq.km	Number pf seals. specimens	Observed population density, specimens/sq. km	Sector width, km	Sector area, sq. km	Extrapolation numbers in the sector, specimens	Statistical extrapolation error
1_25	52,92	158	177	9,4	36	3,8	4,00	212	801,6	240
2_25	40,75	151	170	6,9	15	2,1	4,00	163	349,7	291
3_25	42,33	167	188	8,0	44	5,5	4,00	169	925,4	304
4_25	42,59	170	191	8,1	58	7,1	4,00	170	1216,3	539
5_25	41,22	158	178	7,3	6	0,8	4,00	165	135,2	1681
6_25	41,54	168	189	7,9	163	20,8	4,00	166	3453,5	1905
7_25	47,59	156	175	8,3	68	8,1	4,00	190	1543,3	3664
8_25	60,02	146	165	9,9	440	44,4	4,00	240	10671,0	4653
1_27-1	45,95	174	196	9,0	253	28,2	4,00	184	5176,8	1499
2_27-1	44,22	167	188	8,3	250	30,0	4,00	177	5302,6	296
3_27-1	56,38	162	183	10,3	338	32,9	4,00	226	7409,0	939
4_27-1	57,3	168	188	10,8	439	40,7	4,00	229	9322,7	7237
5_27-1	55,9	135	152	8,5	905	106,3	4,00	224	23779,0	10429
6_27-1	55,54	169	190	10,6	397	37,5	4,00	222	8336,4	7282
7_27-1	53,06	180	203	10,8	338	31,4	4,00	212	6661,7	931
8_27-1	58,01	178	200	11,6	288	24,8	4,00	232	5757,3	770
1_27-2	48,9	168	189	9,2	217	23,5	4,00	196	4599,4	173
2_27-2	46,57	170	191	8,9	221	24,8	4,00	186	4615,2	1685
3_27-2	51,66	155	174	9,0	56	6,2	4,00	207	1286,2	2304
4_27-2	58,44	156	175	10,2	202	19,7	4,00	234	4604,2	3842
5_27-2	57,14	161	182	10,4	519	50,1	4,00	229	11447,1	6268
6_27-2	64,07	154	173	11,1	35	3,2	4,00	256	810,9	5895
7_27-2	56,72	162	183	10,4	67	6,4	4,00	227	1455,8	648
8_27-2	44,56	153	172	7,7	11	1,4	4,00	178	255,9	478
9_27-2	25,41	149	168	4,3	8	1,9	4,00	102	190,4	210
10_27-2	17,25	170	192	3,3	22	6,6	4,00	69	457,2	194
11_27-2	20,31	151	169	3,4	12	3,5	4,00	81	283,5	134
12_27-2	22,84	146	164	3,8	8	2,1	4,00	91	194,9	86
Total	**1309,19**			**237,4**	**5415**			**5237**	**121042**	**18938**
Extrapolation estimation of the seal abundance and its relative statistical error									121042	0,156
Confidence (95%) interval for estimating adult seal abundance									88168	162203

Table 5.1-4   **Calculation of Baby Seal Abundance on Caspian Sea Ice (based on flight data for 25 and 27 February 2023), Kazakhstan sector**

Transect No., date, flight	Tack length, km	Flight altitude, m	Accounting transect width, m	Accounting strip area, sq.km	Number pf seals. specimens	Observed population density, specimens/sq. km	Sector width, km	Sector area, sq. km	Extrapolation numbers in the sector, specimens	Statistical extrapolation error
1_25	52,92	158	177	9,4	6	0,7	4,00	212	145,7	56
2_25	40,75	151	170	6,9	2	0,3	4,00	163	50,0	36
3_25	42,33	167	188	8,0	1	0,1	4,00	169	10,6	49
4_25	42,59	170	191	8,1	5	0,6	4,00	170	101,4	52
5_25	41,22	158	178	7,3	2	0,3	4,00	165	45,1	73
6_25	41,54	168	189	7,9	9	1,1	4,00	166	186,7	89
7_25	47,59	156	175	8,3	3	0,4	4,00	190	79,8	161
8_25	60,02	146	165	9,9	19	2,0	4,00	240	470,8	401
1_27-1	45,95	174	196	9,0	45	5,0	4,00	184	916,2	334
2_27-1	44,22	167	188	8,3	59	7,1	4,00	177	1259,1	585
3_27-1	56,38	162	183	10,3	139	13,4	4,00	226	3032,0	935
4_27-1	57,3	168	188	10,8	207	19,1	4,00	229	4387,1	2910
5_27-1	55,9	135	152	8,5	384	45,1	4,00	224	10078,1	3600
6_27-1	55,54	169	190	10,6	264	25,0	4,00	222	5547,9	2284
7_27-1	53,06	180	203	10,8	186	17,3	4,00	212	3667,4	788
8_27-1	58,01	178	200	11,6	195	16,7	4,00	232	3885,5	590
1_27-2	48,9	168	189	9,2	106	11,5	4,00	196	2241,9	602
2_27-2	46,57	170	191	8,9	73	8,2	4,00	186	1528,4	699
3_27-2	51,66	155	174	9,0	11	1,2	4,00	207	251,0	1098
4_27-2	58,44	156	175	10,2	97	9,5	4,00	234	2217,9	3403
5_27-2	57,14	161	182	10,4	391	37,7	4,00	229	8606,0	5185
6_27-2	64,07	154	173	11,1	10	0,9	4,00	256	227,0	4610
7_27-2	56,72	162	183	10,4	20	2,0	4,00	227	447,9	244
8_27-2	44,56	153	172	7,7	0	0,0	4,00	178	0,0	189
9_27-2	25,41	149	168	4,3	0	0,0	4,00	102	0,0	81
10_27-2	17,25	170	192	3,3	6	1,8	4,00	69	127,0	88
11_27-2	20,31	151	169	3,4	0	0,0	4,00	81	0,0	72
12_27-2	22,84	146	164	3,8	0	0,0	4,00	91	0,0	0
Total		**1309,19**		**2374**	**2240**				**5237**	**49511**
Extrapolation estimation of seal abundance and its relative statistical error									**49511**	**0,193**
Confidence (95%) interval for estimating baby seal abundance									**33437**	**70686**

5.1.5. Results of the Caspian Seal Winter Aerial Surveys in 2023

Kazakhstan sector of the northern Caspian Sea water area:

The area of the ice cover was large, which, combined with good weather conditions, enabled conducting the aerial photography in a short time – from February 21 to 27, 2023. The ice movement during this period was minimal.

The aerial survey was conducted in the optimal period - the pupping period basically ended (there were almost no blood spots on ice). In the total number of cubs, the proportion of white-coat seals was 24%, the proportion of moulting seals was 35%, and moulted seals (sivari) - 41%.

The calculation is based on 28 transects with a distance of 4 km between them. The estimated number of adult seals on ice was 121,042 specimens with a statistical error of 15.6%. The number of cubs is 49,511 with a statistical error of 19.3%.

The total estimated number of seals on ice within the Kazakhstan sector of the northern Caspian Sea water area during the period 21-28 February 2023 was 170,553 specimens.

Russian sector of the northern Caspian Sea water area:

The area of the ice cover was large, which, combined with good weather conditions, enabled RFRIFO scientists to conduct the aerial photography in a short time – from February 20 to 27, 2023. The ice movement during this period was minimal.

The aerial survey was conducted during the optimal period - the pupping period basically ended (there were almost no blood spots on the ice). In the total number of cubs, the proportion of white-coat seals was 11%, the proportion of moulting seals was 46%, and moulted seals (sivari) - 43%.

The calculation is based on 42 transects with a distance of 4 km between them. The estimated number of adult seals on ice was 19,704 specimens with a statistical error of 9.1%. The number of baby seals is 4,062 specimens, with a statistical error of 8.4%.

The total estimated number of seals on ice within the Russian sector of the northern Caspian Sea water area during the period 20-27 February 2023 was 19,704 specimens.

Thus, the total estimated number of seals on the ice of the Kazakhstan and Russian sectors of the northern Caspian Sea during the period 17-28 February 2023 was 130,973 specimens, 55,573 of which were baby seals.

5.2. Aerial Photography of Caspian Seal Spring Moulting Grounds

Breeding and moulting of seal offspring do not take much time in a short ice season in the North Caspian Sea. Mass coupling takes place in late February and followed by moulting of adult animals in March and April on drifting ice floes and marine sand bars. The area of ice rookeries and the density of seals on them varies depending on ice conditions. As the ice cover disappears, seals still needing moulting move to shallow water and small sand islands to stay there till complete moulting.

The spring count of seal abundance during the period of moulting in the KSCS was performed from April 10 to April 17, 2023. The surveys covered the coast of the Kazakhstan sector of the North Caspian Sea from the coast of Buzachi peninsula, Tyupkaragan, Mangyshlak from Bautino to Saury and islands (Durnev Islands, Tyulenyi Islands, islands in the areas where the mouths of Zhaiyk and Zhem rivers exit, marine sand bars, artificial islands in the North Caspian Sea Canal, protective barriers at the Kashagan field). The total length of aerial counting routes was more than 2500 km. According to the survey data, dead seals in the surveyed area of the North-East Caspian Sea were found on the coast of Kulaly Island and Tupkaragan peninsula.

According to the results of the aerial surveys, 54 sand islands and marine sand bars were identified (**Appendix C**), where the Caspian seal moulted in April 2023 (Table 5.2-1).

Table 5.2-1   Caspian Seal Abundance on KSCS Sand Bars, April 2023

No.	Facility	North latitude	East longitude	Number of seals, specimens
1	Stretched out sand bar	N46° 08' 07.2"	E52° 25' 26.7"	352
2	Elongated submerged sand bar	N46° 07' 44.6"	E52° 25' 25.1"	397
3	Elongated sand bar	N46° 07' 06.0"	E52° 25' 20.7"	512
4a	Submerged elongated sand bar (divided into three parts for accounting)	N46° 08' 03.9"	E52° 26' 18.3"	539
4b	Submerged elongated sand bar (divided into three parts for accounting)	N46° 08' 16.7"	E52° 26' 24.7"	148
4c	Submerged elongated sand bar (divided into three parts for accounting)	N46° 08' 27.2"	E52° 26' 29.9"	1161
5	Elongated sand bar	N46° 02' 47.2"	E52° 30' 19.3"	4203
6	Oval submerged sand bar	N46° 02' 28.7"	E52° 30' 17.1"	103
7	Elongated sand bar	N46° 00' 46.9"	E52° 31' 09.2"	2654
8a	Elongated sand bar (divided into two parts for accounting)	N45° 58' 05.4"	E52° 29' 02.9"	1001
8b	Elongated sand bar (divided into two parts for accounting)	N45° 57' 35.5"	E52° 29' 09.3"	722
9a	Elongated sand bar (divided into two parts for accounting)	N45° 55' 52.5"	E52° 29' 45.9"	1096
9b	Elongated sand bar (divided into two parts for accounting)	N45° 55' 16.9"	E52° 30' 04.1"	344
10	Elongated submerged sand bar	N45° 46' 45.3"	E52° 28' 12.1"	1975
11	Stretched out sand bar	N46° 03' 35.2"	E52° 32' 23.8"	2307
12	Submerged elongated sand bar with a rectangular plot	N46° 07' 38.1"	E52° 32' 55.0"	387
13	Narrow elongated sand bar	N46° 06' 24.8"	E52° 31' 37.1"	156
14	Submerged elongated sand bar	N46° 08' 11.0"	E52° 33' 51.4"	5814
15a	Chain of submerged sand bars (divided into three parts for accounting)	N46° 08' 36.0"	E52° 33' 46.3"	1192
15b	Chain of submerged sand bars (divided into three parts for accounting)	N46° 08' 45.8"	E52° 33' 44.1"	931
15c	Chain of submerged sand bars (divided into three parts for accounting)	N46° 09' 05.5"	E52° 33' 40.5"	1838
16	Narrow elongated sand bar	N46° 11' 00.9"	E52° 33' 05.6"	274
17	Narrow elongated sand bar with an oval plot	N46° 11' 17.4"	E52° 34' 46.2"	192
18	Submerged elongated sand bar	N46° 10' 47.4"	E52° 35' 29.1"	853
19	Oval sand bar	N46° 09' 00.1"	E52° 34' 32.2"	2549
20	Elongated sand bar	N45° 39' 42.3"	E52° 24' 40.4"	4775
21	Elongated sand bar	N45° 39' 28.5"	E52° 23' 58.8"	819
22	Elongated sand bar	N45° 39' 10.2"	E52° 24' 27.7"	2472
23	Elongated submerged narrow sand bar	N45° 14' 10.6"	E50° 22' 44.7"	137
24	Oval sand bar	N45° 14' 15.0"	E50° 22' 37.8"	468
25	C-shaped narrow sand bar	N45° 15' 17.5"	E50° 22' 12.5"	319
26	Narrow elongated sand bar	N45° 15' 36.4"	E50° 22' 30.2"	218
27	Narrow small sand bar	N45° 14' 47.9"	E50° 22' 24.7"	591
28-29	2 parallel narrow elongated sand bars	N45° 14' 42.6"	E50° 22' 25.6"	1007
30	Narrow elongated sand bar	N45° 14' 25.8"	E50° 22' 29.5"	169
31	U-shaped sand bar	N45° 14' 20.2"	E50° 22' 30.8"	382
32	C-shaped narrow sand bar	N45° 09' 13.2"	E50° 10' 15.7"	6
	Total:			**43063**

Uninhabited sand bars showed the recent traces of seals. It could be assumed that moulting was over, and the most seals had left sand bars. Filling of twenty-six surveyed sand bars varied from 6 to over 5814 seal specimens. The density depended on the nature of sand bars. The survey recorded both very dense and sparse rookeries. Seals were very active. The total number of seals counted on sand bars was 43,063 specimens.

5.2.1. Generalization of the Aerial Survey Results in April 2023

The number of Caspian seals on the ice field in Kazakhstan and Russian sectors of the Caspian Sea according to survey data in February 2023 was 130,973 specimens; in April (spring) - 43,063 specimens were recorded on sand bars. A decrease in the number of the Caspian seal, in 2023 spring, may indicate the onset of forage migrations. If we take into account that a significant number of seals have already migrated to southern regions, then no more than 32.88% of those recorded in February 2023 remained on the surveyed sand bars and artificial island.

According to visual observations young seals were in a moderate fat condition. The high proportion of offspring (43,063 specimens, 32.88%) in the structure of seal rookeries in 2023 winter testified to the successful reproduction of seals in the eastern part of the North Caspian Sea, as well as the stable status of reproduction of the Caspian seal, as a whole.

The work in the water area of the Kazakh sector of the North Caspian Sea was carried out in April, when a significant part of adult specimens and their older juveniles migrated to the southern regions of the Caspian Sea. During the aerial surveys from April 10 to April 16, 2023, seal rookeries were recorded only on marine sand bars of the North-East Caspian Sea (see Figure 4.3.5). According to the results of desk processing, the total number of recorded seals on 32 sand bars located northward and southward of the NCSC, northward of Tyulenyi Islands was 43,063 specimens; filling of sand bars varied from 6 to 5,814 seal specimens.

In the winter period of 2023 no dead seals were recorded on the ice field, in the spring period of 2023 the carcasses of seals died in the winter of 2022-2023 from the epidemic of plague of carnivores and influenza infection were recorded on the coast of Kulaly Island and Tyupkaragan peninsula, the total number of 44 specimens during the survey period.

6. TOTAL POPULATION OF CASPIAN SEALS, 2023

6.1. Reproduction Conditions Features When Assessing the Abundance of Caspian Seals

The Caspian seal breeding areas are located in the ice-covered part of the North Caspian Sea. In winter, pubescent females come onto the ice for reproduction and lactation. The lactation period is extended in most cases and lasts from the second half of January till the end of February. The pupping processes and pupping duration depend on harsh winter conditions. Winters affecting the reproduction processes and distribution of mature Caspian seal mothers can be divided into 3 types: warm, moderate and cold.

In warm winters, breeding of the Caspian seal takes place in the eastern part of the North Caspian Sea with an ice area from 10 to 30% of the total area of the North Caspian Sea. In this case, the pup deposits are located compactly, which allows the most accurate determination of the total number of adults and offspring (baby seal, sivar) during the period of aerial instrumental aerial photography. During the office processing, there is a difficulty in separating the offspring at the sivar stage from adult seals and shoal animals (immature specimens starting from two or more years old), filmed at an altitude of 150-200 m. With a minimum ice area, the pupping grounds are mixed with adults and young specimens.

In moderate winters, when the ice cover ranges from 40 to 80%, the distribution of pupping grounds occurs throughout the entire ice area in the eastern part of the North Caspian Sea. During the period of the instrumental aerial surveys, the large extent of the pupping grounds may increase the error in the results of the assessment of seals' numbers.

In cold winters, the pupping grounds are located compactly along the ice edge from east to west. The ice cover in the North Caspian Sea in these winters may vary from 80 to 98%. Adult seals and shoal animals keep at a great distance from the pupping grounds and their mixing does not occur. Such winters are the most optimal for the implementation of instrumental aerial surveys and enable to obtain the most objective data on the assessment of seals' numbers, both adults and offspring at different stages of development (baby seal, sivar). However, during these winters, the pupping grounds fall simultaneously within responsibility of the Russian Federation and the Republic of Kazakhstan, and an objective assessment is difficult due to the internal political reasons of the two Caspian states.

The 2022-2023 winter can be attributed to cold winters with a mild nature. Instrumental aerial surveys of the Caspian seal in the KSCS were conducted on February 21-27, 2023; most of the offspring at the sivar stage had size and weight indices similar to those of older age groups. With a moderate ice area (about 76-98% of the area of the North Caspian Sea), at the end of February, a part of the offspring mixed with a shoal animal at the southern boundaries of the ice field, which made it difficult to distinguish the offspring from the rest of the population.

The breeding of the Caspian seal in the 2020/2021/2022/2023 winters was in a satisfactory mode. This may be evidenced by the length, fatness and colour of pups (**Appendix A**). The photographs fixed many well-fed barrel-shaped seals (adults and pups), which also indicates a good status of the seal population. In 2023, the number of Caspian seals (adults and pups) on the ice amounted to 191.659 thousand specimens, which was 2 times more than the number of seals on the ice in 2012 (88.6 thousand specimens), [Report.CISS-2012-001, 2013]. Relative to 2022 (242.9 thousand specimens), the numbers decreased slightly, by 51.2 thousand specimens, respectively.

6.2. Retrospective Data on the Abundance and Biological Indices of the Caspian Seal Population

A method of direct accounting during aerial surveys of the Caspian seals offspring on the ice surface of the North Caspian Sea is the basis for the calculation. A new-born pup is not able to stay in the water for a long time during a calendar month and does not make extended migrations. One producing mother in the litter brings one pup. According to this strict dependence, the number of offspring is equal to the number of producing mothers.

The first estimates of the number of producing mothers of the Caspian seal and offspring can be attributed to the early 70s of the XX century. Until that time, fisheries science during the state fishing during the ice period of its life was engaged in systematization of the features of biology, behaviour, collecting field deliverables on age-sex structure, morphology, size-weight indices, and nutrition.

The first aerial survey of seals was conducted from an IL-14 aircraft in 1973. Subsequent aerial surveys of seals (1976, 1980, 1986, 1989) were conducted at intervals of 3-6 years, photographing was performed by area or route methods; only adult seals were taken into account.

When calculating the number of Caspian seals based on the results of aerial surveys in 1976, 1986, and 1989, a correction factor - 0.35 - was applied, calculated on large factual material of the 1976 aerial survey. Calculations of seal numbers per deliverables of the 1973 aerial survey used a coefficient - 0.4. According to most experts, the total number of Caspian Sea seals between 1973 and 1980 did not exceed 600,000 specimens.

In 2012, as a result of the calculated data, a relative proportion (%) of sexually mature mothers participating in reproduction or producing mothers in the population of the Caspian seal had an index equal to 21%. With a minimum level of infertility, the population of the Caspian seal in the long-term trends in changes in the modern period tends to grow (Table 6.2-1), [Melentyev et al., 2012; Kuznetsov, Chernook, Shipulin, 2013; Sokolsky et al., 2008; Chernook et al., 2015; Kuznetsov, 2017b.; KAPE, RFRIFO, 2020-2021].

Table 6.2-1   Aerial Survey Results for 1965-2022, Thousand Specimens

Parameters	Years										
	1965	1973	1976	1980	1986	1989	2012	2020	2021	2022	2023
Producing females numbers	82,4	90,4	102,3	106,0	60,0	46,8	50,0	58,2	62,3	67,3	53,6
Total population size	no more than 600				520	470	269	282	302	311	259,9
% of producing mothers in the population	15,0	15,1	17,1	17,7	11,5	10,0	21,0	20,6	20,6	21,6	20,6

In 2012, the Caspian seal stock was identified for the first time using modern multispectral aerial photography. The results of the survey were not in doubt among Russian and foreign researchers. The estimated population size was assessed in the range from 270 to 320 thousand specimens and was comparable to the numbers, which were identified by a vessel route accounting method in 2001-2012. Currently (2013-2022), the Caspian seal stock is formed only under the influence of natural loss and death from poaching. The mean density of the concentration of sea animals according to route accounting in the year of multispectral survey can be considered as an independent index of abundance, with which it is possible to compare the densities obtained from the survey results in 2013-2021, as well as to assess changes in abundance towards increase or decrease.

The breeding efficiency of the Caspian seal, the survival rate of the offspring and moulting depend on the quality of ice (hummockiness) at breeding grounds. In the period of 2010-2018, at the time of mass reproduction of producing mothers, the ice cover did not fall below 61% [Kuznetsov, Shipulin, 2019].

In winter 2019, ice areas in January ranged from 63 to 83%, and in the first ten days of February they averaged 75%. In 2020, the coldest month was January, the ice cover in the first and second ten days changed from 24 to 66%, averaging 48%, In the last ten days of January, the ice cover dropped to 21% (31.01. 2020), and in the first ten days of February, there was a noticeable warming and the area of the ice field decreased from 21% (01.02.2020) to 9% (07.02. 2020). The subsequent cold snap (09 - 15.02. 2020) increased the area of the ice cover to 40-48%. According to the results of aerial photography, it was determined that under the influence of the 2019-2020 winter nature, the period of mass reproduction of mature mothers of the Caspian seal was shifted to an earlier date. The moment of mass reproduction of mature mothers occurred in the third ten-day-period of January - the beginning of February 2020, with maximum ice cover (46-59.7%). The 2021 winter period was marked by low temperatures and a high percentage of the ice field in January ranging from 79.8 (15.01. 2021) to 90.6% (22.01. 2021). In the first half of February, the ice cover was 72% [KAPE, RFRIFO, 2019; 2020; 2021]. In 2022, at the time of mass reproduction of producing mothers (late January – early February), the ice cover was 67% (Figure 6.2.1), in 2023 - 98 to 100%.
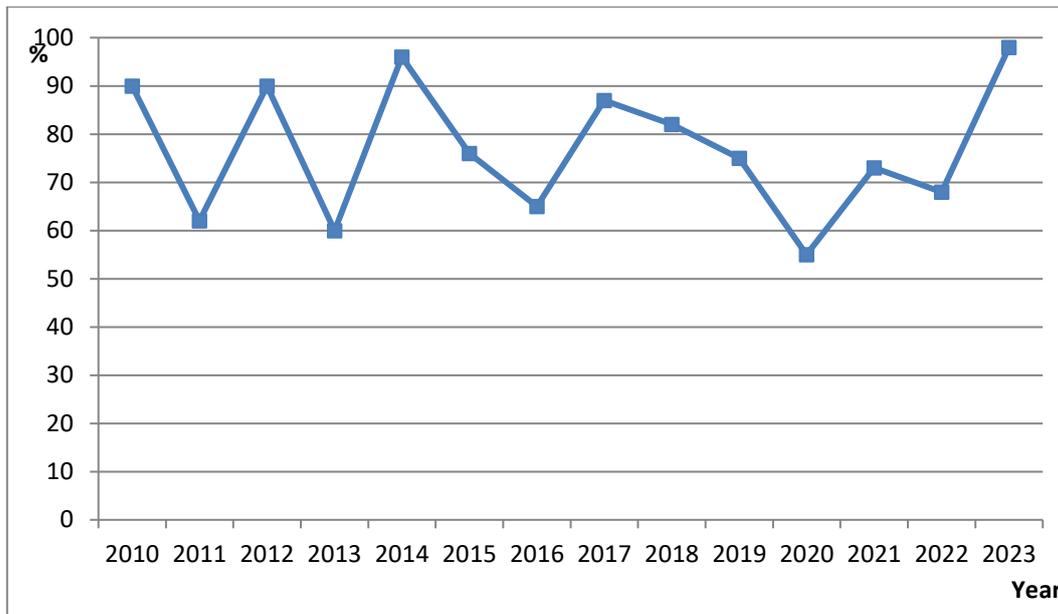
Figure 6.2.1   Ice Coverage (%) of the North Caspian Sea During the Breeding Period of Caspian Seal, in the Long-Term Aspect

In different years, depending on the habitat conditions and the physiological state of producing Caspian seal mothers, their relative share does not have the same values. According to literature data, in different years, 30 to 60% of mothers may not take part in reproduction [Vorozhcov et al., 1972; Badamshin, 1966a]. Changes in fertility indices may reflect the impact of local environmental factors, for example, the abundance/quality of food resources and ice conditions. Boyd [Boyd, 2000] suggested that the development of pregnancy depends on the fat reserves that are continuously accumulated in the body of a pregnant mother. It is during this period that environmental factors, such as abundance of food and weather conditions, are most important. Similar fluctuations in the annual reproduction level were recorded in the population of the Greenland seal in the Barents Sea – a sharp decline in the reproduction of the population was recorded following sharp drops in the numbers of the Barents Sea capelin [Report. NCOO-SDD-H91-RE-0014-000. 2012].

Negative changes in the structure of the Caspian seal population may originate during the period of intensive industrial fishing. The specialized official fishing of offspring in the ice, which existed for 30 years (1967-1997), had its negative sides for the structure of the population of the Caspian seal. The introduction of a ban in 1967 on the production of adult seal specimens in the long term resulted in a significant aging of the breeding stock. Average age of mature mothers and adult seals in 1989 had maximum values - 23.0 and 21.8 years, respectively, subject to the potential life activity of seals in 30-35 years. There was an annual replenishment in the population, but it was clearly insufficient. Analysis of the long-term trends in changes in the age structure of mature mothers shows that for a long time from 1964 to 1989, the aging of the breeding stock took place. This process was especially active in 1974-1989. The age of the broodstock began to increase sharply, whilst infertility with sexually mature mothers increased to 80% in subsequent years (Figure 6.2.2).
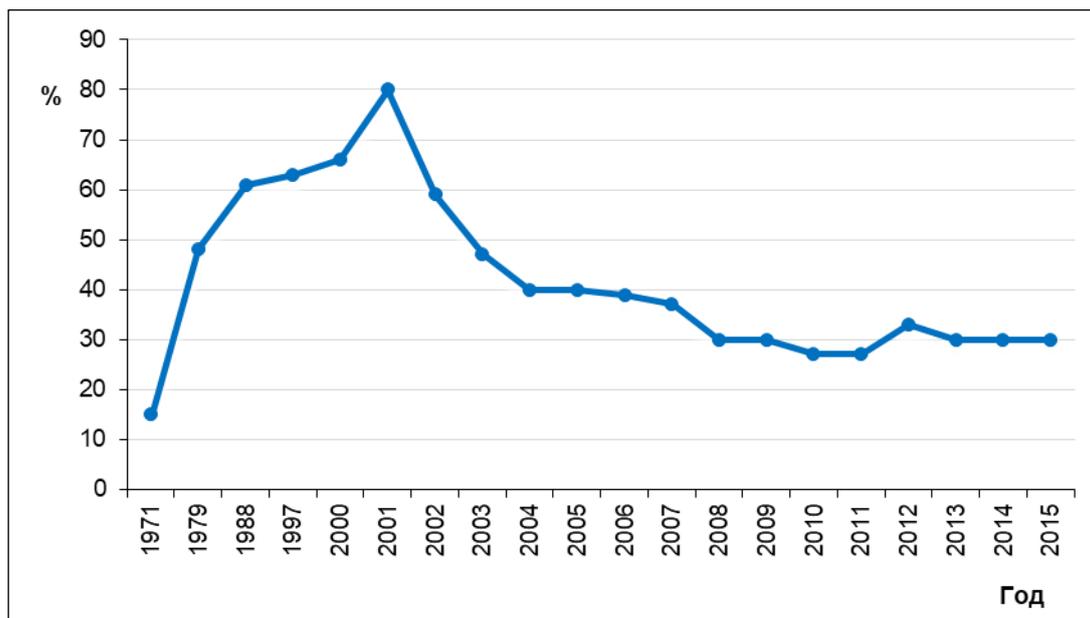
Figure 6.2.2   Mothers' Proportion not Involved in Reproduction Among Sexually Mature Mothers

Old specimens were susceptible to various kinds of diseases and infected healthy specimens. Mature mothers produced sick and weak pups that could have a low survival rate in the Caspian ecosystem. The stabilizing factor of the population size during this period was natural mortality, as a result of which most of the waste was represented by old and sick seal specimens [Kuznetsov, 2017a].

For many years (1971-2015), infertility of mature mothers was identified during the capture of seals for biological test according to the allocated scientific quota in the autumn period. Seals were trapped in the western part of the North Caspian Sea. The last time such work on the removal of seals from their habitat for biological tests was carried out in 2015. In the period from 2016 to 2021, seals were not captured in order to identify an infertility index in the population of the Caspian seal for technical reasons. To calculate the total population of the Caspian seal in the Caspian Sea, the average annual value of infertility for the period from 2006 to 2015 is taken (31.3% of the number of mature mothers, and their share is 0.313).

According to RFRIFO databases, the Caspian seal has been represented mainly by 25 age groups over the past 20 years, its zoological length during the 1989-2005 autumn observations varied between 89-141 cm (Table 6.2-2), [Khuraskin et al., 2004; 2005; 2006; KAPE, RFRIFO, 2020]. The number of specimens older than 25-35 years was extremely small.

Table 6.2-2   Seals' Zoological Body Length (from the Nose to the Tip of the Tail Along the Curve of the Body from the Back) by Age, 1989-2022. (October-November)

Age, year	Zoological body length, cm	
	fluctuations	medium
1	89-98	93
2	92-105	99
3	102-115	108
4	109-115	112
5	115-125	119
6	124-128	126
7	126-136	134
8	128-132	131
9	129-133	131
10	134-138	136
11	130-138	136
12	130-138	136
13	125-133	130
14	122-130	125

| Age, year | Zoological body length, cm | |
	fluctuations	medium
15	132-138	135
16	132-140	138
17	134-140	138
18	132-138	137
19	132-138	136
20	130-136	134
21	128-132	130
22	130-135	133
23	135-138	136
24	135-141	137
25	128-138	131

As the data of the Table show, already from the age of four, the extreme values of height indices merge in the nearest age groups, and specimens older than 6 – 8 years may already have the maximum height, which is also found in specimens of 10, 15 or 25 years old. The different growth rate from the first years of life complicates the identification of the conditional age of the animal through its dimensions obtained from photographs. Age can be identified only by the fangs or claws of dead animals. The conditional age with live specimens of the Caspian seal can be estimated from photographs of the claws of the hind legs, which are less worn off during its life.

6.3.   Calculation of the Total Population of the Caspian Seal

In 2023, calculation formulas tested on populations of Greenland seals in the White Sea and Caspian seals in the Caspian Sea from 2012 to 2022 were used to calculate the total population of the Caspian seal. To assess the stock of the Caspian seal population, a strict dependence of replenishment on the number of lactating mothers is applied (a mother produces one pup). Knowing the number of offspring per one year, it is possible to switch by calculation to the total number of the entire population of the Caspian seal [Shafiqov, 2008; Report. KAPE, RFRIFO, 2019, 2020, 2021, 2022].

$$S = P * K$$

where, S – population size, thousand spc.;

P – the number of offspring in the reporting year, thousand spc.;

K – conversion factor per population.

$$K = 1 + 2 * \frac{Jmax}{(1 - k) * (Jmax - Jmin)}$$

where, J_{max} – maximum age of mothers, years, J_{max}=25;

J_{min} – age of sexual maturity of mothers, years, J_{min}=6.1;

k – proportion of barren seals among sexually mature mothers, k=0.27.

To calculate a conversion factor (k), the indices of the maximum age and the age of sexual maturity of adult mothers are constant values. The average annual (10 years) value for 2006 – 2015 perod, with the 2020-2022 amendments, is taken as a infertility index among sexually mature mothers. According to calculations, it is k = 0.216.

At the same time, it should be understood that the lower threshold of the estimate of a birth rate of the offspring (53573 specimens) and the total population (259872 specimens) in reality turned out to be underestimated, since at the time of the aerial surveys, part of the offspring grounds were mixed with adult seals. This made it impossible to identify part of the offspring during the desk processing of deliverables obtained. Taking into account this circumstance, the upper threshold of the total population of the Caspian seal was also calculated.

To calculate the upper threshold of the estimate of the number of seals, data of 2020-2022 were used on the ratio (%) of offspring and adult seals in the overall aerial surveys of seals in the North Caspian Sea. The total number of seals in February 2020-2022 on the ice was 177,200 specimens, and

242,873 specimens, respectively, among which 38.6% accounted for offspring, 61.4% for adult seals. In 2023, the total number of seals on the ice (offspring, adult seals) was 184,546 specimens, therefore, by analogy with 2020-2023, the upper threshold of the birth rate of offspring may be at the level of 38.40 % of the total number of all recorded specimens, or 70,862 specimens.

$$K=1+2*25/((1-0,27)*(25-6,1))=1+2*1,9254005=4,850801$$

S_l = 53573 * 4.850801= 259872.0 ≈ 259872 spc,

S_u = 70682 * 4.850801 = 342865.5 ≈ 342866 spc.

Where, S_l –the lower threshold of the total population;

S_u – the upper threshold of the total population.

Taking into account the current status of the Caspian seal population in 2023, the age structure, the time for puberty onset and the percentage of mothers' infertility, a conversion rate per population was adopted at the level of 4.85. The estimated total population in 2023, taking into account the lower (53.573 thousand) and upper (70.682 thousand) thresholds of offspring was 259.872 and 342.866 thousand specimens, respectively (Table 6.3-1).

Table 6.3-1 **Estimation of Birth Rate and the Total Population of the Caspian Seal According to the Results of a Multispectral Aerial Survey in 2023 (Kazakhstan Sector)**

Possible thresholds for seal population estimation	Offspring numbers	Total population, specimens
Lower threshold of estimate for seal numbers	53573	259872
Upper threshold of estimate for seal numbers	70682	342866

Analysis of available data for 2012, 2020, 2021, and 2022 showed a decrease in the number of reproduction of pups in the current year (2023) by 2.94% compared with 2012 data and by 20.5% compared with 2022 data. The relative share (percentage) of producing mothers in the population of the Caspian seal in 2020 and 2021 had an index equal to 20.6%, in 2022 – 21.6%. The total population in the 2022 winter has a slight increase (7.5%) and its lower threshold of the number is 311.381 thousand specimens of the Caspian seal. In 2023, as a result of the pandemic, deaths in fishing nets and natural decline, the total number of Caspian seals decreased to 259.872 thousand specimens.

Table 6.3-2 **Estimation of the Birth Rate and the Total Population of the Caspian Seal**

Accounting method	Pup numbers, thousand specimens	Total population, thousand specimens
Multispectral aerial count in 2012	50,00	268,80
Multispectral aerial count in 2020	58,24	282,32
Multispectral aerial count in 2021	62,26	302,03
Multispectral aerial count in 2022	67,31	311,38
Multispectral aerial count in 2023	53,57	259,87
Discrepancy of results between the survey years: 2012/2023	2,94% (increase)	3,3% *(decrease in the total number)
Discrepancy of results between the survey years: 2022/2023	20,5% (decrease)	26,5% *(decrease in the total number)

Note: ** Decrease in total numbers due to natural mortality, epidemics of plague of carnivores, pneumonic infection and trapping in fishing nets.*

7. RECOMMENDATIONS FOR THE CONSERVATION AND REHABILITATION OF THE CASPIAN SEAL POPULATION

The estimated lower and upper thresholds to assess the total population using multispectral aerial survey data of seal ice rookeries in 2023 ranged from 259.872 to 342.866 thousand Caspian seals. Nevertheless, taking into account the estimates of the first half of the last century, when the total population was estimated at 1 million specimens [Badamshin, 1966], the current status of the population still causes various disputes among the scientific community.

In this regard, in order to preserve the Caspian seal, it is necessary to:

– continue joint multispectral aerial surveys of reproductive ice rookeries of seals throughout the water area of the North Caspian Sea, both in the territorial waters of the Russian Federation and the Republic of Kazakhstan in order to objectively assess the total population. The results of long-term monitoring of mature mothers will most reliably reflect the direction and trends in changes of population numbers in the time interval of 5-10 years, provided there is no fishing;

– strengthen the monitoring of adult and young specimens of the Caspian seal by satellite tagging to study and identify forage and seasonal migrations in the western and eastern parts of the Northern and Middle Caspian Sea, as well as new habitats and recreation on sand bars;

– conduct mapping of active islands and sand bars that seals could use for resting;

– recommend the seaports of Russia and Kazakhstan to introduce restrictions for maritime navigation in the area of the actual resting places of seals;

– identify the possibilities of creating artificial places for seals to rest, to constantly monitor these and other active places of rest in the Northern and Middle Caspian Sea;

– develop long-term programmes for accounting and investigating the stranding of dead seals along the coast of the Caspian Sea. To determine size and weight indices and arrange sampling for age composition during a long-term period with dead specimens as part of periodic ejections of dead seals on the coasts of Dagestan (RF) and Mangyshlak Peninsula (Kazakhstan);

– carry out work to study the size indices of seals remotely using unmanned aerial vehicles (UAVs) and quadrocopters on island mixed seasonal rookeries of different ages d seals in the Northern and Middle Caspian Sea in order to obtain up-to-date data on the relative proportion (%) of immature specimens in the overall structure of the population of the Caspian seal.

An effective tool for implementation of these plans for the conservation and rehabilitation of the Caspian seal population is the coordinated multi-year Interstate Kazakh-Russian Survey Program (**Appendix D**).

CONCLUSION

In the 2023 winter, a multispectral survey of the pupping rookeries was conducted to further form a database on the abundance and location of Caspian seal gatherings in the water area of the North Caspian Sea. Moreover, aerial photography of rookeries and moulting grounds in the spring period was taken.

In the winter period (February 2023), the first stage of surveys was implemented – multispectral aerial photography of Caspian seal rookeries. Aerial photography of seal rookeries on the ice was taken from the Kazakh Piper PA-34 aircraft.

The aerial surveys were performed in good weather conditions. The main instrumental aerial photography of seals was performed using two Optris PI450 thermal imagers, and three cameras (Nikon D850 and GoPro11) fixed in the lower part of the aircraft fuselage. The ice cover of the North Caspian Sea, at the area of Russia and Kazakhstan, was uniformly surveyed by the accounting tacks. A large amount of data has been obtained, tens of thousands of seal images in the visible and IR bands, as well as images of the ice cover, which enabled to produce objective information of the status of the Caspian seal population.

The use of one technology of instrumental (IR+Photo) aerial survey of ice forms of seals in 2012, 2020, 2021, 2022 and 2023, as well as the work of the same survey team, made it possible to minimize the interannual error in accounting of pups, and to identify trends in assessing the status of the Caspian seal population.

The 2022-2023 winters can be attributed to winters with a mild, moderate nature. Instrumental aerial surveys of the Caspian seal in the KSCS were conducted on February 20 to 28, 2023; most of the offspring at the sivar stage had size and weight indices similar to those of older age groups. With a moderate ice area (about 76-98% of the area of the North Caspian Sea), at the end of February, a part of the offspring mixed with a shoal animal at the southern boundaries of the ice field, which made it difficult to distinguish the offspring from the rest of the population.

In the spring period (April), the second stage of surveys was implemented – aerial survey of rookeries and moulting grounds of the Caspian seal. The aerial survey was conducted on Piper PA-34 airplane using video and photography (2 Nikon D850 cameras, GoPro11 video camera and DJI Osmo Action). A survey of the coast of the North Caspian Sea from Kurmangazy village to the Zhaiyk River, sand bars on the Ural coast, further east to Zhem River, the North Caspian Sea Channel (artificial islands), marine sand bars northward and southward of the NCSC, Durnev Island, the coast of the Buzachi Peninsula, Tyupkaragan, Tyulenyi Islands, marine sand bars at Kalamkas, Prirazlomnoye-3, Karazhanbas offshore oilfield areas.

The good quality of the photography materials enabled to obtain additional information of seals (size, fatness, colour). The photographs demonstrate a lot of well-fed barrel-shaped seals (adults and pups), which also indicates a good status of the population.

The work in the water area of the Kazakh sector of the North Caspian Sea was carried out in April, when a significant part of adult seals and their older juveniles migrated to the southern regions of the Caspian Sea. During the aerial survey of 10-16 April 2023, 32 seal rookeries on sand bars were observed only in the western part of the North Caspian Sea Canal, and in the areas of marine sea bars to the north and south of the NCSC, sand bars at Kalamkas, Prirazlomnoye-3, Karazhanbas offshore field areas. According to the results of desk processing, the total number of recorded seals on 32 sand bars was 43,063 specimens; the filling of sand bars varied from 6 to 5,814 Caspian seals.

In the spring period of 2023 carcasses of seals died in winter of 2022-2023 from the epidemic of plague of carnivores and influenza infection were recorded on Kulaly Island, Tyupkaragan Spit, in amount of 44 pieces.

The number of Caspian seals on the ice field according to survey data in February 2023 was 259,872 specimens, in spring – 43,063 specimens were recorded on sand bars. A decrease in the abundance of the Caspian seal from winter to spring may indicate the onset of forage migrations, and migration of the main part of the population to the southern regions of the sea. If we take into account that a significant number of seals have already migrated to southern regions, then no more than 16.9 % of those recorded in February 2023 remained on marine sand bars.

Taking into account the current status of the Caspian seal population in 2023, the age structure, the time for puberty onset and the percentage of mothers' infertility, a conversion rate per population was adopted at the level of 4.63. The estimated total population in 2023, taking into account the lower (53.573 thousand) and upper (70.682 thousand) thresholds of the offspring was 259.872 and 342.866 thousand specimens, respectively.

Analysis of available data for 2012, 2020, 2021, 2022, and 2023 showed a decrease in the number of reproduction of pups in the current year (2023) by 3.3% compared with 2012 data and by 26.5% compared with 2021 data. The relative share (percentage) of producing mothers in the population of the Caspian seal in 2020, 2021 and 2023 had an index equal to 20.6%, in 2022 – 21.6%. The total number of the population in winter 2023 due to the death of different-aged Caspian seals from natural mortality, epidemic of plague of carnivores, lung infection and hanging in fishing nets is 259.872 thousand Caspian seals.

In order to identify trends in changes in the population of the Caspian seal, it is necessary to conduct regular records of seals in the Caspian Sea using modern methods and means of aerial photography and processing of the obtained deliverables.

As the distribution of the Caspian seal breeding grounds among the zones in Russia and Kazakhstan significantly varies from year to year depending on severity of winters and the current ice conditions, seal numbers shall be recorded throughout the North Caspian water area.

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APPENDIX A PHOTO REFERENCE TO A SINGLE AIRCRAFT TIME

I. Adult Seals

230225-12_54_29-N1

230225-13_21_36-N2

230225-13_21_38-N1

230225-13_25_35-N2

230225-13_25_40-N2

230227_2-15_19_03-N2

230227_2-16_02_00-N2

230227_2-16_13_13-N2

230227_2-16_13_24-N2

230227_2-16_21_45-N2

230227_2-16_22_38-N2

230227_2-16_22_46-N2

230227_2-16_23_04-N2

230227_2-16_23_06-N2

230227_2-16_23_26-N2

230227_2-16_23_41-N2

230227_2-16_33_26-N2	230227_2-16_38_12-N2	230227_2-16_43_24-N2
230227_2-16_48_47-N2	230227_2-16_49_14-N2	230227_2-16_50_11-N2
230227_1-10_11_44-N1		230227_1-10_12_50-N1

230227_1-10_15_19-N1	230227_1-10_22_54-N1	230227_1-10_23_05-N1
230227_1-10_27_36-N1	230227_1-10_28_35-N1	230227_1-10_30_29-N1
230227_1-10_37_12-N1	230227_1-10_56_39-N2	230227_1-12_14_26-N1

II.   Mothers with Pups

230227_1-10_38_27-N2

230227_1-10_56_19-N2

230227_1-10_37_30-N2

230227_1-11_12_07-N2

230227_1-11_41_10-N2

230227_1-11_41_48-N2

230227_1-11_20_30-N2

230227_1-11_20_30-N2

230227_1-11_40_55-N2

230227_1-11_42_51-N1	230227_1-12_17_20-N1	230227_1-12_00_38-N2
230227_2-16_01_05-N2	230227_2-16_01_11-N2	230227_2-16_06_57-N2
230227_2-16_07_10-N2	230227_2-16_07_25-N2	230227_2-16_12_46-N2

230227_2-16_13_13-N2	230227_2-16_13_15-N2
230227_2-16_13_26-N2	230227_2-16_13_28-N2

(continued)

	230227_2-16_13_13-N2	230227_2-16_13_15-N2
230227_2-16_13_26-N2	230227_2-16_13_28-N2	230227_2-15_17_55-N2
230227_2-15_18_46-N2	230227_2-15_20_51-N2	230227_2-16_13_32-N2

230227_2-16_13_43-4N2	230227_2-16_16_30-N2	230227_2-16_16_46-N2
230227_2-15_17_44-N1	230227_2-16_01_11-N1	230227_2-16_14_10-N1
230227_2-17_15_26-N1	230227_2-17_15_26-N1	230227_2-16_49_16-N1

III.   White Coat Pups

230225-12_46_07-N2

230225-13_22_08-N2

230225-13_25_35-N2

230225-13_25_35-N2

230225-14_22_05-N2

230225-13_23_36-N1

230225-13_48_25-N1

230227_1-10_15_19-N2

230227_1-10_20_21-N2

230227_1-10_37_27-N2	230227_1-10_37_43-N2	230227_1-10_38_18-N2
230227_1-10_38_44-N2	230227_1-10_38_44-N2	230227_1-10_39_13-N2
230227_1-10_56_41-N2	230227_1-11_12_18-N2	230227_1-11_13_48-N2

230227_1-11_17_30-N2	230227_1-11_20_19-N2	230227_1-11_59_25-N2
230227_1-12_15_50-N2	230227_1-10_36_54-N1	230227_1-10_38_35-N1
230227_1-11_12_29-N1	230227_1-11_40_57-N1	230227_1-11_42_56-N1

230227_1-11_59_21-N1	230227_1-11_59_25-N2	230227_1-12_12_45-N1
230227_2-16_07_27-N2	230227_2-16_13_21-N2	230227_2-16_13_30-N1
230227_2-16_13_43-N1	230227_2-16_23_37-N1	230227_2-16_23_37-N1

IV.   Seal Pups at Different Stages of Moulting

230225-13_20_43-N2	230225-13_23_39-N2	230225-13_25_48-N2
230225-12_47_42-N1	230225-12_49_14-N1	230225-13_25_42-N1
230225-14_21_19-N1	230227_1-10_15_28-N2	230227_1-10_23_12-N2

230227_1-10_27_38-N2	230227_1-10_38_46-N2	230227_1-10_38_49-N2
230227_1-10_45_48-N2	230227_1-10_56_28-N2	230227_1-10_56_50-N2
230227_1-11_12_31-N2	230227_1-11_15_58-N2	230227_1-11_16_40-N2

230227_1-11_16_48-N2	230227_1-11_41_50-N2	230227_1-11_42_36-N2
230227_1-11_59_23-N2	230227_1-12_00_25-N2	230227_1-12_18_17-N2
230227_1-10_20_03-N1	230227_1-10_28_42-N1	230227_1-10_37_18-N1

230227_1-10_39_06-N1	230227_1-11_02_55-N1	230227_1-11_12_09-N1
230227_1-11_12_44-N1	230227_1-11_16_11-N1	230227_1-11_17_50-N1
230227_1-11_19_13-N1	230227_1-11_20_08-N1	230227_1-11_42_40-N1

230227_1-11_43_42-N1	230227_1-11_59_21-N1	230227_1-12_17_36-N1
230227_2-15_17_51-N2		
230227_2-15_35_48-N2	230227_2-16_01_20-N2	230227_2-16_23_26-N2

230227_2-15_25_54-N1	230227_2-16_13_26-N1	230227_2-16_14_19-N1

V.   Sivars

230225-13_22_15-N2	230225-13_25_37-N2	230225-13_25_40-N2
230225-13_25_46-N2	230225-13_25_37-N1	230225-13_58_20-N1
230225-13_25_37-N1	230227_1-10_13_25-N2	230227_1-10_16_45-N2

230227_1-10_16_54-N2

230227_1-10_30_08-N2

230227_1-10_45_51-N2

230227_1-10_57_08-N2

230227_1-10_57_28-N2

230227_1-11_03_41-N2

230227_1-11_11_54-N2

230227_1-11_12_22-N2

230227_1-11_12_47-N2

230227_1-11_15_20-N2	230227_1-11_40_35-N2	230227_1-11_40_51-N2
230227_1-11_42_43-N2	230227_1-12_17_05-N2	230227_1-12_17_14-N2
230227_1-10_23_16-N1	230227_1-10_30_21-N1	230227_1-10_38_55-N1

230227_1-11_12_11-N1	230227_1-11_14_06-N1	230227_1-11_15_16-N1
230227_1-11_15_56-N1	230227_1-12_04_55-N1	230227_2-15_03_05-N2
230227_2-15_19_38-N2	230227_2-15_05_58-N1	230227_2-15_32_59-N1

VI.　Birds

230227_1-11_27_26-N1		
230227_1-11_14_01-N2	230227_2-16_17_30-N2	230227_1-10_39_17-N1
230227_1-10_24_05-N2	230227_1-10_56_44-N1	
230227_1-10_56_46-N1		

230227_1-10_56_46-N1	230227_1-11_12_22-N2	230227_1-12_11_59-N1

230227_2-15_44_11-N1		

230227_2-16_14_12-N1	230227_2-16_14_23-N1	230227_2-16_17_30-N2

APPENDIX B   **ESTIMATION OF THE CASPIAN SEAL POPULATION BY A GROUP EXTRAPOLATION METHOD**

The Caspian seal was recorded during three aerial survey flights performed on February 21, 23 and 24, 2022. Each survey was conducted at daylight hours of the same day on parallel transects of different lengths, but of the same width, since the altitude in these flights was maintained in a constant mode. The interval between tacks was the same. This made it possible to combine transects and make calculations using the Kingsley method [Kingsley et al, 1985], described below.

The abundance of adult seals and pups for the i-th aerial survey was calculated separately per formula:

$$\hat{N}_i = K_i \sum_{j=1}^{J_i} x_i \qquad (5.1)$$

where, J_i –number of transects in the i-th aerial survey;

   K_i – a weighting factor for the i-th survey, defined as the ratio of the interval between tacks to the width of the transects;

   x_j – number of seals on the j-th transect.

The variance estimate was based on a series of differences between transects and calculated per formula:

$$V_i = \frac{k_i(k_i-1)J_i}{2(J_i-1)} \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2 \qquad (5.2)$$

When changing the distance between transects within the surveyed area, the following formulas are used:

$$\hat{N}_i = k_i \left[x_{i1}/2 + \sum_{j=2}^{J_i-1} x_{ij} + x_{iJi}/2 \right] \qquad (5.3)$$

$$V_i = \frac{k_i(k_i-1)}{2} \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2 \qquad (5.4)$$

where, J_i – number of transects in the i-th group of transects;

   x_{ij} – number of seals on the j-th transect in the i-th group.

The total number of adult seals and pups was estimated using the following formula:

$$\hat{N} = \Sigma_{i=1}^{I} N_i \qquad (5.5)$$

where, I – number of shots.

The total estimate variance was calculated per formula:

$$\hat{V} = \Sigma_{i=1}^{I} V_i \qquad (5.6)$$

Table B.1   Extrapolating Estimation of Adult Seals Abundance

Tack, No.	Tack code	Tack length	Flight altitude	Accounting transect width,	Accounting band area	Seals detected numbers	Observed population density	Sector width	Sector area	Extrapolating numbers in the sector	Statistical extrapolation error
		km	m	m	sq. km	specimens	specimens / sq. km	km	sq. km	specimens	
1	1_25	52,92	158	177	9,4	36	3,8	4	212	801,6	240
2	2_25	40,75	151	170	6,9	15	2,1	4	163	349,7	291
3	3_25	42,33	167	188	8	44	5,5	4	169	925,4	304
4	4_25	42,59	170	191	8,1	58	7,1	4	170	1216,3	539
5	5_25	41,22	158	178	7,3	6	0,8	4	165	135,2	1681
6	6_25	41,54	168	189	7,9	163	20,8	4	166	3453,5	1905
7	7_25	47,59	156	175	8,3	68	8,1	4	190	1543,3	3664
8	8_25	60,02	146	165	9,9	440	44,4	4	240	10671	4653
9	1_27-1	45,95	174	196	9	253	28,2	4	184	5176,8	1499
10	2_27-1	44,22	167	188	8,3	250	30	4	177	5302,6	296
11	3_27-1	56,38	162	183	10,3	338	32,9	4	226	7409	939
12	4_27-1	57,3	168	188	10,8	439	40,7	4	229	9322,7	7237
13	5_27-1	55,9	135	152	8,5	905	106,3	4	224	23779	10429
14	6_27-1	55,54	169	190	10,6	397	37,5	4	222	8336,4	7282
15	7_27-1	53,06	180	203	10,8	338	31,4	4	212	6661,7	931
16	8_27-1	58,01	178	200	11,6	288	24,8	4	232	5757,3	770
17	1_27-2	48,9	168	189	9,2	217	23,5	4	196	4599,4	173
18	2_27-2	46,57	170	191	8,9	221	24,8	4	186	4615,2	1685
19	3_27-2	51,66	155	174	9	56	6,2	4	207	1286,2	2304
20	4_27-2	58,44	156	175	10,2	202	19,7	4	234	4604,2	3842
21	5_27-2	57,14	161	182	10,4	519	50,1	4	229	11447,1	6268
22	6_27-2	64,07	154	173	11,1	35	3,2	4	256	810,9	5895
23	7_27-2	56,72	162	183	10,4	67	6,4	4	227	1455,8	648
24	8_27-2	44,56	153	172	7,7	11	1,4	4	178	255,9	478
25	9_27-2	25,41	149	168	4,3	8	1,9	4	102	190,4	210
26	10_27-2	17,25	170	192	3,3	22	6,6	4	69	457,2	194
27	11_27-2	20,31	151	169	3,4	12	3,5	4	81	283,5	134
28	12_27-2	22,84	146	164	3,8	8	2,1	4	91	194,9	86
Total:		1309,19			237	5416			5237	121042,2	18938
Extrapolating estimation of the seal abundance and its relative statistical error:										121042	0,156
Confidence (95%) interval for estimating seal abundance:										88168	162203

Number of parallel tacks: **29**

Area of the region (sq. km): **5237**   Mean interval between tacks (km): **4,00**

Table B.2   Extrapolating Estimation of Caspian Seal Pups Abundance

Tack, No.	Tack code	Tack length	Flight altitude	Accounting transect width,	Accounting band area	Seals detected numbers	Observed population density	Sector width	Sector area	Extrapolating numbers in the sector	Statistical extrapolation error
		km	m	m	sq. km	specimens	specimens / sq. km	km	sq. km	specimens	
1	1_25	52,92	158	177	9,4	6	0,7	4	212	145,7	56
2	2_25	40,75	151	170	6,9	2	0,3	4	163	50	36
3	3_25	42,33	167	188	8	1	0,1	4	169	10,6	49
4	4_25	42,59	170	191	8,1	5	0,6	4	170	101,4	52
5	5_25	41,22	158	178	7,3	2	0,3	4	165	45,1	73
6	6_25	41,54	168	189	7,9	9	1,1	4	166	186,7	89
7	7_25	47,59	156	175	8,3	3	0,4	4	190	79,8	161
8	8_25	60,02	146	165	9,9	19	2	4	240	470,8	401
9	1_27-1	45,95	174	196	9	45	5	4	184	916,2	334
10	2_27-1	44,22	167	188	8,3	59	7,1	4	177	1259,1	585
11	3_27-1	56,38	162	183	10,3	139	13,4	4	226	3032	935
12	4_27-1	57,3	168	188	10,8	207	19,1	4	229	4387,1	2910
13	5_27-1	55,9	135	152	8,5	384	45,1	4	224	10078,1	3600
14	6_27-1	55,54	169	190	10,6	264	25	4	222	5547,9	2284
15	7_27-1	53,06	180	203	10,8	186	17,3	4	212	3667,4	788
16	8_27-1	58,01	178	200	11,6	195	16,7	4	232	3885,5	590
17	1_27-2	48,9	168	189	9,2	106	11,5	4	196	2241,9	602
18	2_27-2	46,57	170	191	8,9	73	8,2	4	186	1528,4	699
19	3_27-2	51,66	155	174	9	11	1,2	4	207	251	1098
20	4_27-2	58,44	156	175	10,2	97	9,5	4	234	2217,9	3403
21	5_27-2	57,14	161	182	10,4	391	37,7	4	229	8606	5185
22	6_27-2	64,07	154	173	11,1	10	0,9	4	256	227	4610
23	7_27-2	56,72	162	183	10,4	20	2	4	227	447,9	244
24	8_27-2	44,56	153	172	7,7	0	0	4	178	0	189
25	9_27-2	25,41	149	168	4,3	0	0	4	102	0	81
26	10_27-2	17,25	170	192	3,3	6	1,8	4	69	127	88
27	11_27-2	20,31	151	169	3,4	0	0	4	81	0	72
28	12_27-2	22,84	146	164	3,8	0	0	4	91	0	0
Total:		1309,19			237,4	5237	49511			5237	49511
Extrapolating estimation of the seal abundance and its relative statistical error:										49511	0,193
Confidence (95%) interval for estimating seal abundance:										33437	70686

Number of parallel tacks: **28**		
Area of the region (sq. km): **5237**	Mean interval between tacks (km): **4,00**	

APPENDIX C   CASPIAN SEAL AT KSCS SAND BARS, 2023
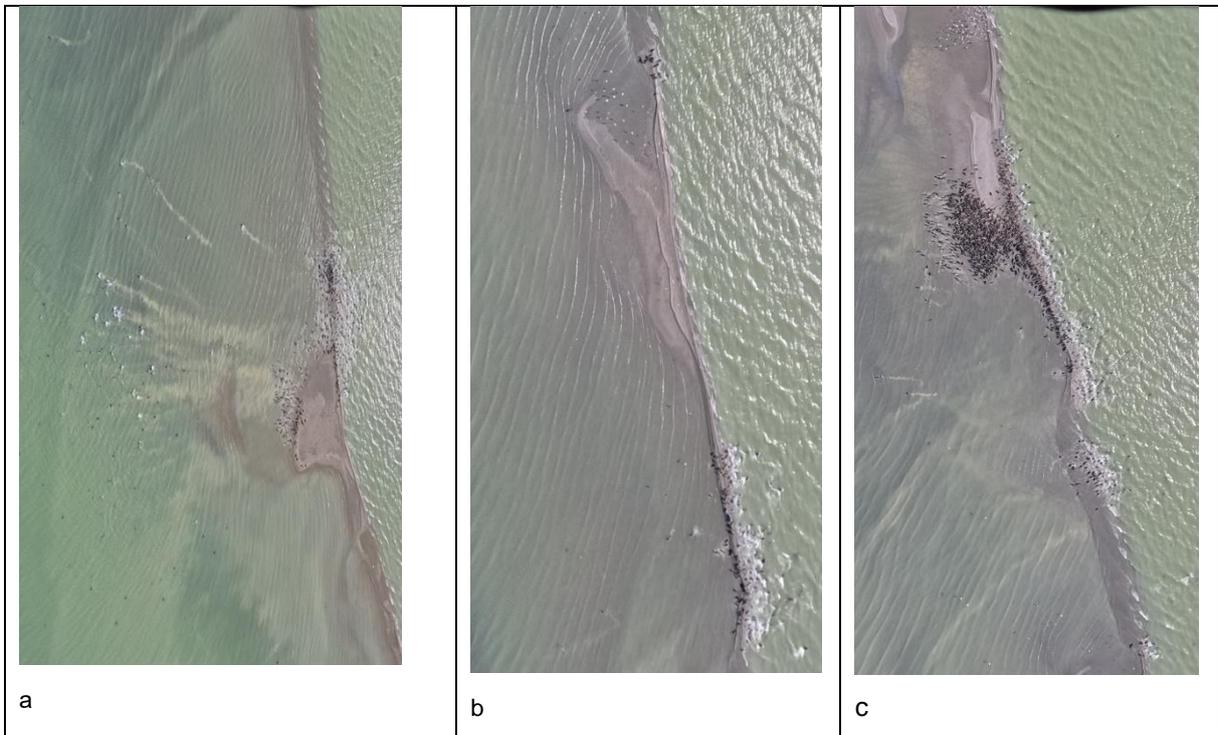

No. 1 Elongated Sand Bar

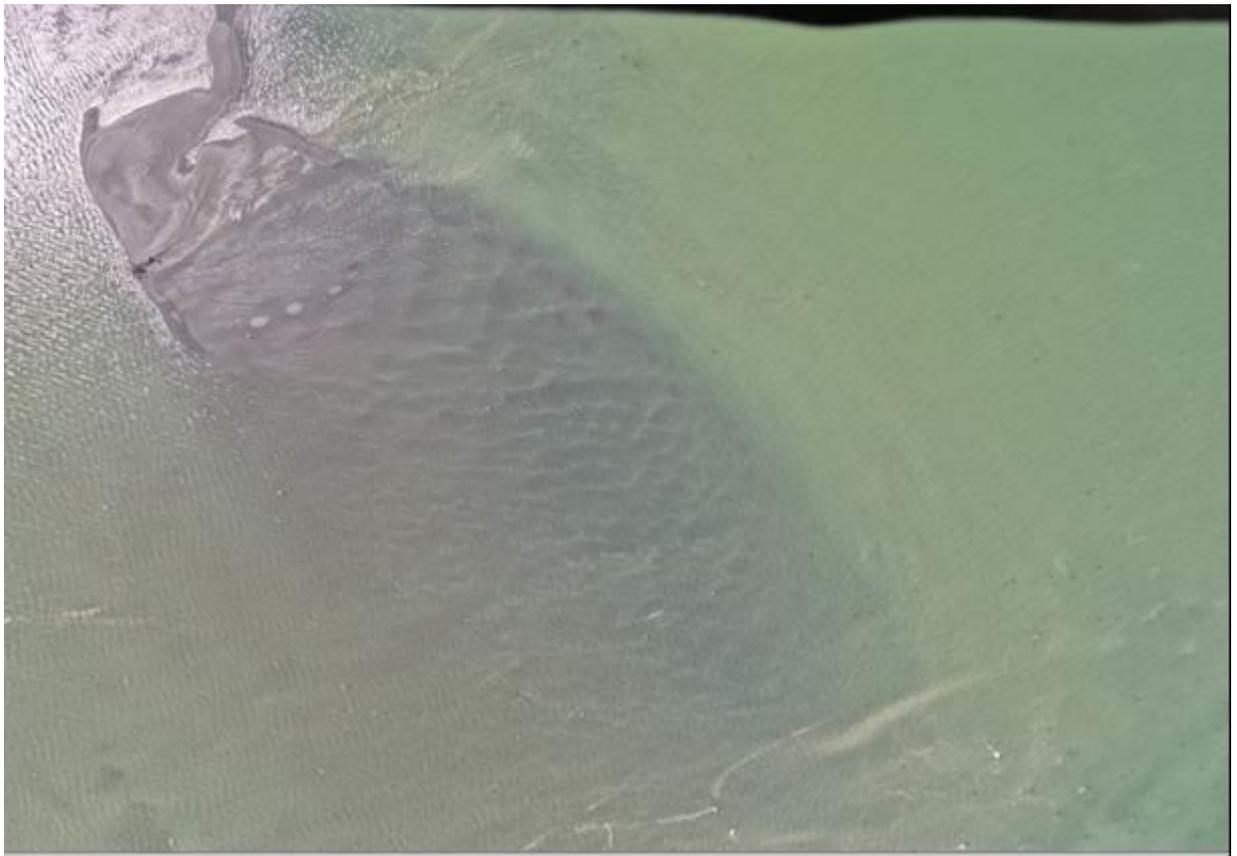No. 2 Diamond-Shaped Sand Bar

No. 3 Elongated sand bar

No.4 Elongated submerged sand bar (divided into 3 parts, a,b,c)

No.5 Elongated sand bar

No.6 Oval sand bar

No.7 Elongated sand bar

No.8 Elongated sand bar

No.9 Elongated sand bar (two clusters on the same sand bar)

No.10 Elongated Submerged Sand bar
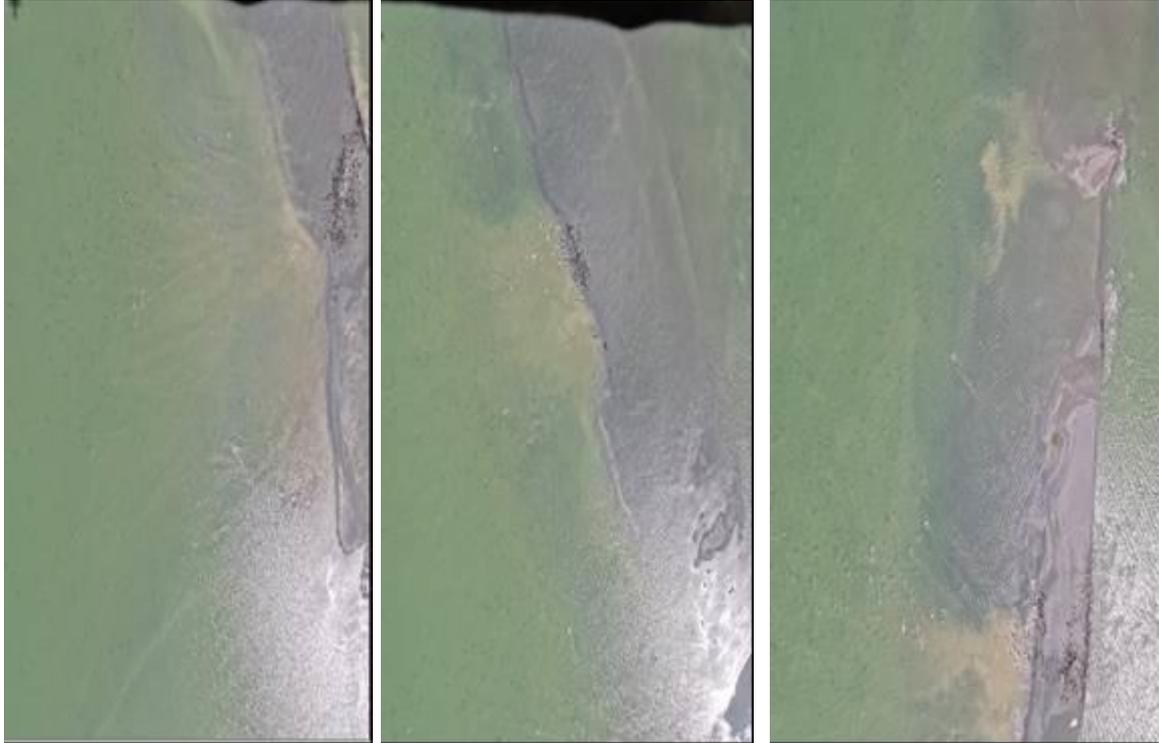
No.21 Elongated Sand Bar

No.12 Submerged elongated sand bar with a rectangular shoal

No.13 Oval Sand Bar

No.14 Submerged elongated sand bar

No.15 Chain of Submerged Sand Bars

No.16 Elongated Sand Bar

No.17 Narrow elongated sand bar with a round shoal

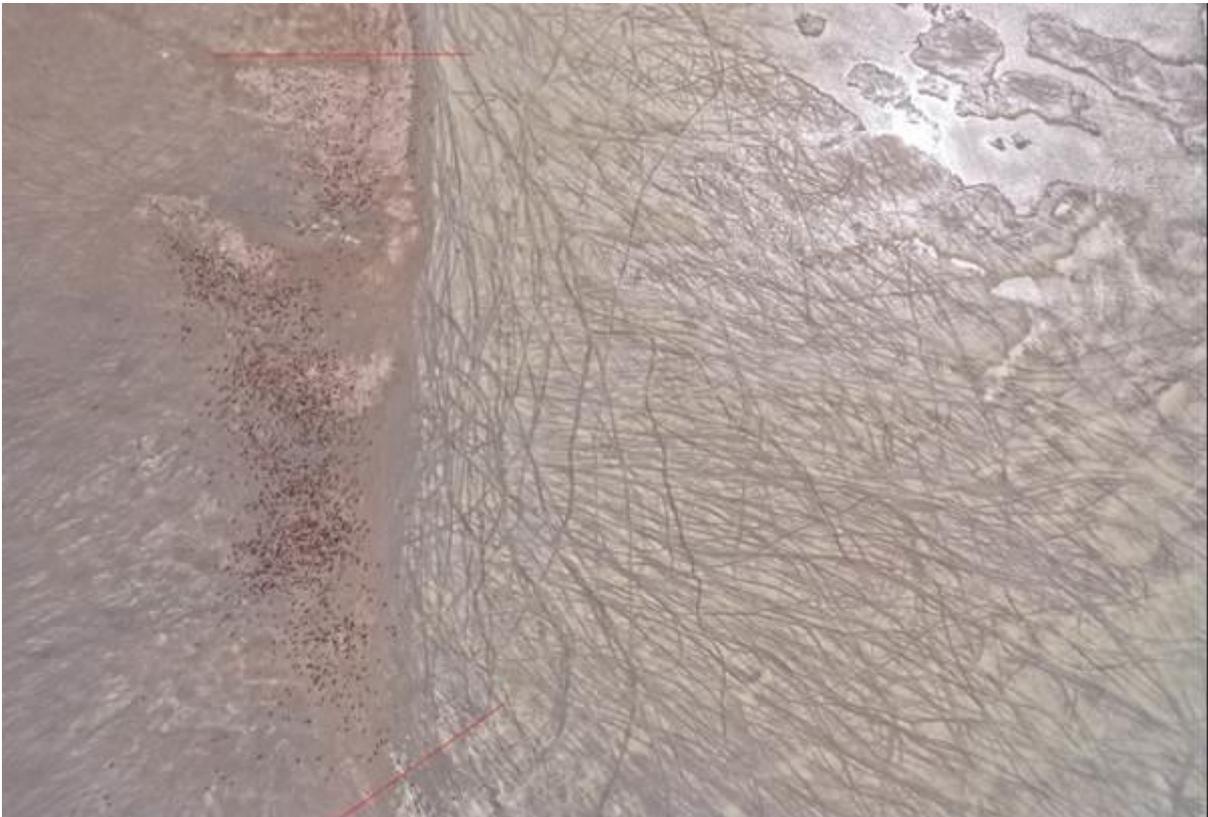No.18 Submerged elongated sand bar

No.19 Oval Sand Bar

No.20 Elongated sand bar

No.21 Elongated Sand Bar

No.22 Elongated sand bar

No.23 Elongated submerged narrow sand bar

No.24 Oval Sand Bar

No.25 C-shaped sand bar

No.26 Complex shaped sand bar

No.27 Narrow small sand bar

Nos.28-29 Two parallel curved sand bars

No.30 Narrow small sand bar

No.31 U-shaped sand bar

No.32 C-shaped narrow sand bar

APPENDIX D   **INTERNATIONAL SURVEY PROGRAM**

AGREED WITH	**AGREED WITH**
Federal Agency for Fisheries of the Russian Federation	Committee of Forestry and Wildlife of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan
Deputy Manager	Deputy Chairman
_____ P.S. Savchuk	_____ N.T. Zhunussov
_____ 2020	_____ 2020

DEVELOPED BY	**DEVELOPED BY**
Federal State Budget Scientific Institution - Russian Federal Research Institute of Fisheries and Oceanography (FSBSI RFRIFO)	Kazakhstan Agency of Applied Ecology LLC (KAPE LLC)
Director	General Director
_____ K.V. Kolonchin	_____ V.A. Skolskiy
_____ 2020	_____ 2020

WORK PROGRAMME

on "Assessment of abundance, distribution and natural reproduction of Caspian seal in the Kazakhstan and Russian waters of the North Caspian

in 2020-2024"

2020

CONTENTS

WORK PROGRAMME ON

ASSESSMENT OF ABUNDANCE, DISTRIBUTION AND NATURAL REPRODUCTION OF CASPIAN SEAL IN THE KAZAKHSTAN AND RUSSIAN WATERS OF THE NORTH CASPIAN IN 2020-2024

JUSTIFICATION

Caspian seal *(Phoca (Pusa) caspica)* is an endemic and the only marine mammal in the fauna of the Caspian Sea. Its distribution area covers the entire Caspian Sea, as well as the lower reaches of the major rivers flowing into it: Volga and Ural rivers. During the breeding and moulting season (January-February), the bulk of the seal population congregates on drift ice in the northern part of the Caspian Sea - in the Kazakh and Russian zones – where seals form extensive scattered rookeries. Females give birth to calves (usually one) in late January/early February. Immediately after the birth a short mating period begins, lasting from mid-February to early March. With the onset of spring ice melt in March-April, the seals leave the ice and spread out over the sea. In April and May they form dense concentrations on sand bars and spits on the north-eastern and north-western shores of the Caspian Sea, where the animals complete their moulting. During the summer months, the Caspian seal is distributed throughout the sea: some animals remain in the North Caspian, but most migrate to the areas of the Middle and South Caspian. During the autumn migrations, the seals return north and during this period they form concentrations on the sand bars and shell islands of the Middle and Northern Caspian. In autumn, seals sometimes enter the estuaries of Volga and Ural, moving sometimes up to 200 km upstream. As the breeding season approaches, seals migrate again to the north-eastern and north-western parts of the Caspian Sea.

At the beginning of the 20th century, the Caspian seal population was around 1 million, but by the 1980s it had declined to 400,000. The current state of its population is of great concern due to intensive anthropogenic activities in the Northern Caspian and the almost complete absence of new reliable information on the current number, fertility and other parameters of the Caspian seal population. The main threats to the seal population in the Caspian Sea are considered to be climate change, marine pollution and habitat changes caused by human activities.

In the USSR, the number of Caspian seals was counted in winter, during ice drifts, by aerial counts that covered the entire water area of the Northern Caspian. In the post-Soviet period, seal counts were carried out infrequently, irregularly, using different methods and, most importantly, separately in the national zones of Russia and Kazakhstan. These surveys gave contradictory results, making it difficult to make an objective and reliable assessment of the state of the Caspian seal population.

For example, visual aerial counts carried out by Kazakh and British specialists in the Northern Caspian at the beginning of the 21st century gave an estimate of the number of seals at less than 100,000 specimens, with a tendency for an annual decrease of 3-4%. Based on these data, the International Union for the Conservation of Nature (IUCN) included the Caspian seal in 1996 in the Red List as a "vulnerable species" and in 2008 this category was changed to "endangered species".

However, multispectral aerial counts of the seal in the Russian North Caspian alone, conducted by FSFRI KaspNIRKh in 2012 using a laboratory aircraft equipped with a thermal imaging camera, photo and video equipment, gave a different estimate of the number: about 270,000 specimens. Taking into account the seals breeding in the Kazakh part of the North

Caspian Sea, the total population of Caspian seals should be even higher. Thus, the current discrepancies in the assessment of the Caspian seal stock do not allow a reasonable estimate of the number and condition of the Caspian seal population to be made.

In order to develop an action plan for the conservation of the Caspian seal population and to create conditions conducive to the stabilization and recovery of the Caspian seal population, a step-by-step solution to the existing problems is needed with monitoring of the seal stock, studying the status of the seal population and the impact of changing environmental factors on it.

Thus, the main objective of this programme is to carry out joint studies, based on common methodologies, of the number, distribution and natural reproduction of the Caspian seal in the Kazakhstan and Russian waters of the Northern Caspian in order to develop a system for monitoring the Caspian seal population and assess its current state under conditions of changing climate and increasing anthropogenic impact.

1. CURRENT RESEARCH ISSUES FOR THE CASPIAN SEAL POPULATION

Study of the reaction of seals to habitat changes: The annual survival rate of the Caspian seal depends on various natural and anthropogenic factors. Weather and climatic conditions, which determine the ice cover status in the North Caspian, are paramount in the breeding and moulting season.

In severe winters, seal breeding and moulting grounds are located on a relatively small area spreading mainly along the Ural Furrow. During mild winters, when the North Caspian does not form a single ice field, numerous, small, seal rookeries are located mostly along the shoreline on landfast ice, making them much more difficult to locate and count.

Inadequacy of the quantitative survey methodology used.

The method used in recent years in the territory of the Republic of Kazakhstan for counting the number of Caspian seal has been developed on the basis of the methodology used for many years in the study of ringed seals in the Baltic Sea (Harkonen, 1990, 1992). However, this method, while relatively simple and inexpensive, has significant drawbacks. Record flights are carried out without preliminary operational reconnaissance of ice conditions, but on the basis of previously made satellite images (maps). The area of ice suitable for habitat is not fully covered by counts (extrapolation of data to the Russian ice zone). Animals that are in water at the time of the survey are not included in the counts. Animals entering the "dead" zone inaccessible to observers and instruments under the fuselage of the aircraft (200 m wide) are not counted. Visual detection and hand-held photographing of animals is conducted from a height (90 m), at high speed of the aircraft (up to 250 km/h) and at a considerable distance (in a strip of 100 to 500 m) from the observers. In such conditions, in the absence of a thermal imager and synchronous photography, errors are inevitable. As a result, there are significant differences in the final results of surveys, e.g. in 2009, when total estimated numbers were 55,000 and evaluative numbers were 111,000.
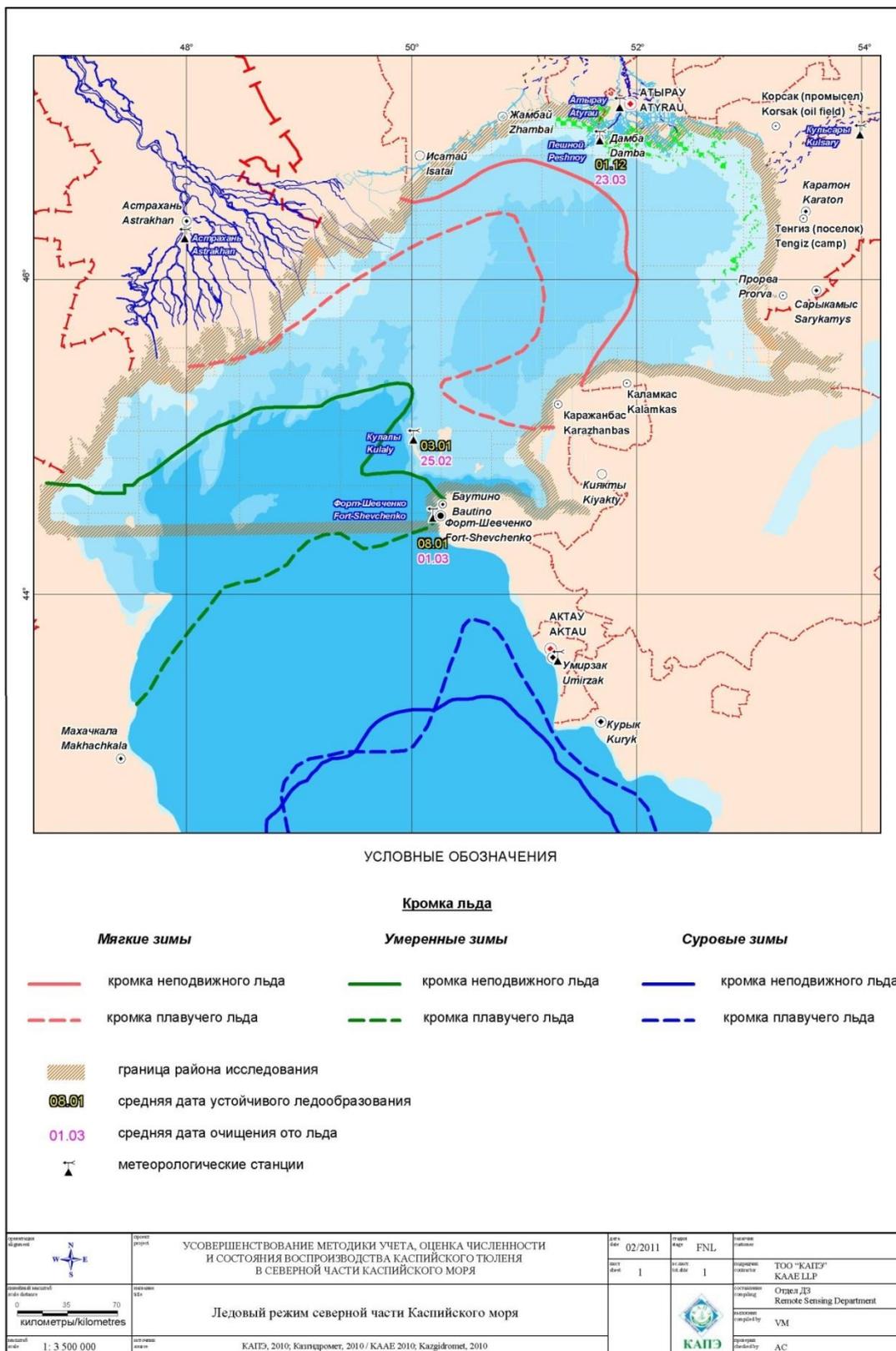
Figure 1   Ice regime in the northern Caspian Sea

2. SOLUTIONS

Most of the techniques used in modern global pinniped research practice involve the use of instrumental sounding techniques. These include multispectral aerial survey of marine mammals developed by Russian specialists using multichannel equipment, photo-, video-, infrared- and ultraviolet-spectrum surveys. The aerial survey error for this method does not exceed 10%.

Automated (computer-assisted) counting of animals surveyed allows for faster processing of aerial survey results. This method has proven to be a good method of counting white whales in water and Pacific walrus (joint Russian-US counts in the Bering and Chukchee Seas). However, it was most effective in counting harp seals on the ice of the White Sea, where it was possible to estimate long-term changes in the number of newborn calves. This data cannot be obtained using aerial counts, the error of which, according to experts, reaches much higher values (30-40%).

3. PROJECT DISCUSSION

This programme provides for studies on abundance, distribution and natural reproduction of Caspian seal in the Kazakhstan and Russian sectors of the Northern Caspian Sea. The research under this programme is carried out on the Russian side by FSFRI RFRIFO as part of the established state task in accordance with the legislation of the Russian Federation; on the Kazakh side - by the Kazakhstan Agency of Applied Ecology.

The research will be based on the methodology currently used by Russian experts in aerial surveys of seals, including those in the Caspian Sea. In the course of the programme this methodology will be refined and adapted to the Caspian seal study and subsequently introduced into the practice of continuous Russian-Kazakh monitoring of the Caspian seal population. Based on the results of the survey, this methodology will be approved in Russia and Kazakhstan as Methodological Guidelines for monitoring the status of the Caspian seal population, carried out jointly by the two countries.

Aerial counting methods are widely used to estimate the abundance of seals living on ice in the Sea of Okhotsk (Boltnev, Chernook, Stus, 2002), and pupping and moulting grounds of harp seals in the White Sea and Barents Sea (Chernook, Kuznetsov et al., 2002). Surveys of spotted seal in the coastal waters of Hokkaido, Japan (Mizuno 2002) and ringed seals in the Baltic Sea and Lake Ladoga (Tormossov & Filatov 2002) are conducted periodically.

The technology used to monitor the White Sea harp seal population using simultaneous thermal and photographic surveys has shown the practicality of the method used. Since 1998, counting of harp seals on the White Sea has been repeatedly carried out (Chernook et al., 2005). The method of multispectral survey of harp seals has been approved by international working groups 1CE5 (International Committee on Exploitation of Marine Bioresources).

In 2018-2019 RFRIFO specialists conducted aerial surveys of seals in the White Sea and Baikal, using UAVs, multi-spectral video and photography and modern video and photo information processing software. In the course of these works the methodological base of aerial surveys was significantly improved: both in terms of planning and conducting aerial surveys, and in terms of subsequent processing of the obtained materials. The high methodological level of conducting aerial surveys of seals achieved by Russian specialists creates a technical and methodological basis for conducting similar surveys in the Caspian Sea.

3.1.   Goal and Objectives of the Survey

Project Purpose: Estimating the abundance and distribution of Caspian Seals in the Kazakhstan and Russian sectors of the North Caspian in 2020-2024.

Tasks:

- Multispectral aerial survey to record the abundance of breeding stock and pups;
- Determination of the pattern and density of ice rookeries distribution;
- Determination of the nature and density of the distribution of pupping and moulting grounds in the spring on islands and sand bars;
- Determination of the females and pups ratio.
- Development of proposals for the population conservation.

In order to achieve the goal and objectives of the research this Programme will be financed by NCOC N.V. Company from the Kazakh side.

Research in the Russian sector of the Northern Caspian Sea will be financed by the Russian side within the framework of the state assignment of FSFRI RFRIFO.

3.2.   Area and period of the survey

Kazakhstan and Russian waters of the North Caspian Sea.

Quantitative surveys of the Caspian seal are conducted during the breeding season, when the bulk of the population inhabits the ice of the North Caspian. The ice cover of the sea depends on weather and climatic conditions of the year and has a major influence on the distribution of the wintering rookeries of Caspian seals. The population of seals will be counted annually in February - April 2020-2024 in the areas of their concentrations on the ice field and in the period of pupping and moulting on islands and sand bars.

3.3.   Legal and regulatory framework for project implementation

The legal framework for wildlife monitoring is the Law of the Republic of Kazakhstan on Protection, Reproduction and Use of Wildlife.

RoK Environmental Code

Federal Law "On Environmental Protection" of the Russian Federation of 10.01.2002, No. 7-FZ.

Federal Law "On Fishing and Conservation of Aquatic Biological Resources" of the Russian Federation of 20.12.2004 No. 166-FZ.

The Pentalateral Intergovernmental Commission (Russia, Kazakhstan, Azerbaijan, Iran, Turkmenistan) on Conservation, Rational Use of Aquatic Biological Resources and Management of their Shared Stocks, including the Caspian Seal was established on the basis of the Agreement on Conservation and Rational Use of Aquatic Biological Resources of the Caspian Sea (29 September 2014, Astrakhan).

3.4.   Methods and contents of work

The work is based on a multispectral survey of sea mammals ice rookeries: synchronous aerial survey in infrared and visible spectrum ranges of the Caspian seal pupping rookeries. Multispectral aerial survey of pupping gatherings is performed using unified methodological and technical support in optimal timeframe. Application of three-level

surveys (satellite - aircraft - reference data) allows increasing reliability of the aerial survey results and optimizing survey routes.

The flights are carried out in two stages: aerial reconnaissance and aerial surveys.

During the air reconnaissance flight the contours of seal rookeries, seal density and ice cover characteristics are identified. The flight is performed at an altitude of 200-300 m, depending on the resolution of photo-equipment, on regular transects at a speed of 220-260 km/hour. Number of required transects in reconnaissance flights is 30-40 (number of transects depends on ice cover area). The distance between exploration transects is 10 km. Orientation of transects is north-south. The length of transects depends on the ice cover area. These transects cover the entire ice cover area of the North Caspian Sea. An approximate layout of the exploration transects is shown in Figure 2. Visual observations are important during reconnaissance. The visual observation swath of seals from both sides of the aircraft reaches 4 km at an altitude of 200 m. The main objective of the visual observations is to locate accumulations of Caspian seals on the ice and determine the boundaries of detected haul outs. During the exploratory flights instrumental survey technology is fine-tuned and IR and photographic images of seal concentrations are taken.
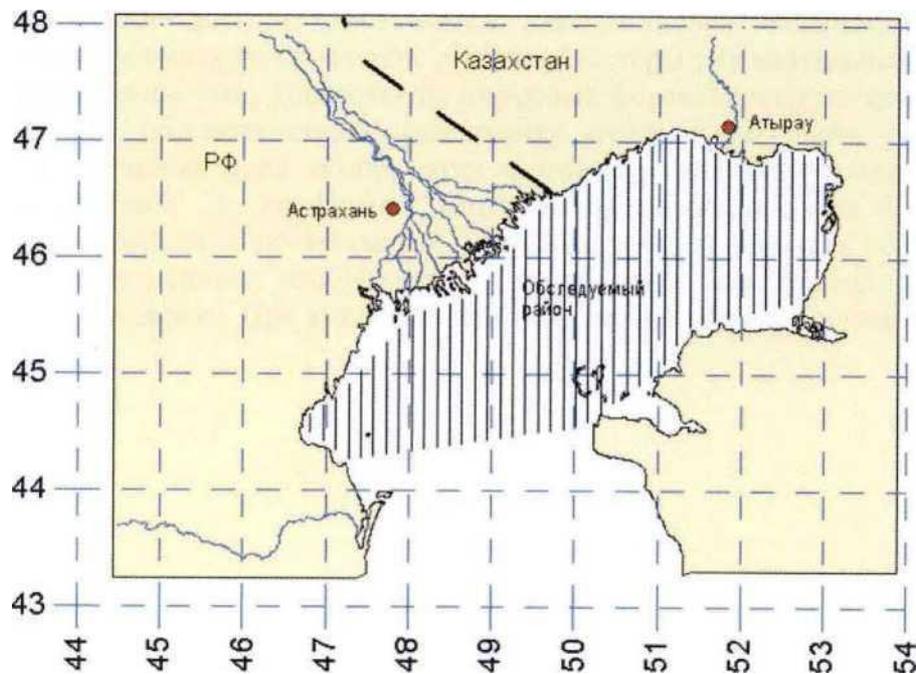

Figure 2. Tacking scheme in the winter seal survey flights.

After conducting reconnaissance flights and identifying the locations of seal pupping grounds and their boundaries, instrumental aerial surveys are conducted. An aerial survey on a frequent transect grid is conducted in areas where seal concentrations are identified based on aerial reconnaissance data. The distance between transects is 3.5 km and the length of transects can vary from 40 to 120 km. The scanning bandwidth of a thermal imager for a flight altitude of 150-300 m will be 450 m. The flight speed of the aerial survey will be 220-250 km/hour.

The aircraft used for aerial counts shall be equipped with the following aerial survey equipment: thermal imaging camera (with a matrix of at least 640x512 and sensitivity of at least 0.1 °C, cameras with a matrix of at least 50 megapixels and a 35-50 mm lens with

synchronized electronic shutter release, GoPro video cameras, on-board automated system for recording and accumulating instrumental, photo and video information.

Instrumental-visual aerial line transects allow documentation of detected animals, identification of seals, increased accuracy of parameters such as number of animals in a group, determination of animal behaviour and other biological parameters (Chernook et al. 1999). Instrumental aerial counting is based on synchronous shooting with a thermal imager and photo camera. A 'local' survey method is used, i.e. the survey is only taken at the moments when the seal is observed. Simultaneous multi-channel imaging of nursery areas in several spectral ranges: visible (cameras) and infrared (thermal imaging camera) improves reliability of seal identification (adult-child) when processing images together. Seal calves with white camouflage colouration are clearly visible on thermal imagery.

3.5. Logistical support, instruments and equipment

Surveys are to be conducted from an aircraft (laboratory aircraft or UAV), capable of flying at least 1,000 km (up to 5 hours flight time) without refuelling. If a laboratory aircraft is used, the aircraft shall have space for a thermal imager, video and photographic equipment, on-board computers and blisters for visual observations. Digital cameras with the characteristics specified above should be installed on board to ensure that the central part of the thermal imager's line of sight is photographed. The total viewing angle of these cameras shall be at least 110 degrees (Figure 3). Photography shall be controlled by the thermal imaging camera operator on the commands of the onboard observers or when seals are detected by the thermal imaging camera. All cameras shall be triggered simultaneously. At a flight altitude of 150m, the thermal imaging instrument has a swath of 450m.
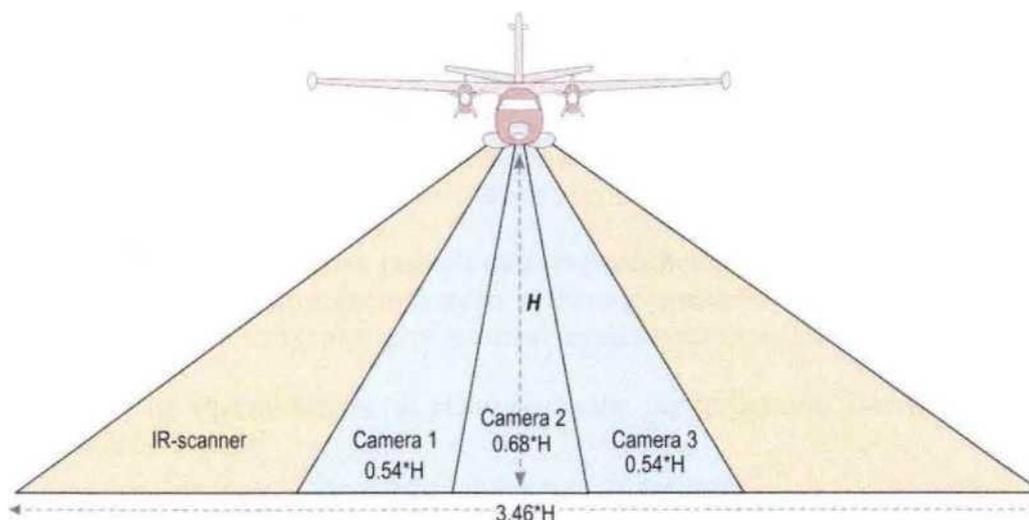

Figure 3. Camera and thermal imaging camera viewbands

For large-scale seal surveys a 4th camera with a 200 mm long-focal-length lens is used. This camera is manually pointed at the subject by the operator.

3.6. Performed by:

Kazakhstan Agency of Applied Ecology LLC, FSFRI RF Research Institute for Fisheries and Oceanography "RFRIFO".

3.7. Transfer of materials

Taking into account the peculiarities of regulation of activities of FSFRI RFRIFO, which is subordinate to the Federal Agency for Fishery of the Russian Federation (Rosrybolovstvo), materials and results of research conducted within this program of FSFRI RFRIFO are transferred to Kazakhstan Party after agreement with Rosrybolovstvo based on the order of Federal Agency for Fishery No. 230 of July 20, 2006, "On the order of transfer of biological and genetic materials, samples, fragments, parts obtained from aquatic biological resources and related information, as well as unpublished scientific and statistical materials related to the assessment of the status of aquatic biological resources and the prospects of their fishery, from organisations subordinate to Rosrybolovstvo to Russian and foreign individuals and legal entities".

4. EXPECTED RESULTS

1. With participation of Kazakh and Russian specialists, joint research on the seal population during the winter-spring season will be carried out. An improved unified methodology for quantitative counts of Caspian seals in the Northern Caspian Sea during the breeding and moulting periods has been developed and tested.

2. The number of offspring and adult seals on ice, pupping and moulting rookeries on islands and sand bars has been assessed. Seals distribution maps of the Northern Caspian Sea were drawn. A scientific report has been prepared.

3. An international (Kazakh-Russian) programme of long-term systematic monitoring of the Caspian seal using modern methods and means of instrumental and telemetric research has been developed.

4. Proposals and recommendations for the study of the Caspian seal population have been prepared.

5. Suggestions and recommendations for conservation and restoration of the Caspian seal population will be developed.

APPENDIX

to the work programme on "Assessment of Caspian seal abundance, distribution and natural reproduction in the Kazakhstan and Russian waters of the Northern Caspian Sea in 2020-2024".

TIME SCHEDULE

Ref No:	Stages	Deadline
1	Preparation and approval of the Work Programme. Obtaining permits for aerial surveys in Kazakhstan and Russian waters of the North Caspian Sea.	December-January
2	Preparation and conduct of aerial counts to determine the abundance and distribution of Caspian seal on the ice of the northern Caspian Sea. Laboratory processing of results of the multispectral aerial count of number and distribution of seals in the ice field, and of pupping and moulting grounds on islands and sand bars.	February-April
3	Analysis of archival materials on the results of long-term Russian and Kazakh studies of the Caspian seal population status. Development and improvement of a comprehensive methodology of multispectral aerial counting of the Caspian seal using telemetry and remote sensing. Obtaining data on number and distribution of animals on the ice haul outs. Calculation of the proportion of animals on ice for analysis of aerial data. Report "Current status of the Caspian seal population: birth rate, abundance estimates and main features of biology". Development of a joint Kazakhstan-Russian "Long-term Caspian seal monitoring programme under conditions of increasing anthropogenic activity in the Caspian Sea" including annual studies (4 seasons), taking into account the breeding and moulting periods, foraging migrations and their distribution in the ice-free period along the coast and coastal waters of the Caspian Sea of Kazakhstan and the Russian Federation. Development of proposals for the Caspian seal population conservation. Recommendations for further research. Presentation of research results and recommendations to the client.	March-September