

  	<b>PROJECT NAME:</b> <b>Caspian Seal Research in the Water Area of the North Caspian Sea in 2024</b>	<b>DOCUMENT NUMBER:</b> <b>KG00-00-000-KA-H-RE-0014-000</b>
	<b>CONTRACTOR NAME:</b> <b>KAZAKHSTAN AGENCY OF APPLIED ECOLOGY (RoK)</b> <b>RUSSIAN FEDERAL RESEARCH INSTITUTE OF FISHERIES AND OCEANOGRAPHY (RF)</b>	<b>INFORMATION CLASSIFICATION:</b> <b>Internal</b>
	<b>CONTRACT NO:</b> <b>UI176768</b>	
	<b>CONTRACT DESCRIPTION:</b> <b>PROVISION OF WILDLIFE AND BIODIVERSITY MONITORING SERVICES IN ATYRAU AND MANGYSTAU REGIONS</b>	

DOCUMENT TITLE:

**Section 1: Assessment of the Abundance and Fertility of the Caspian Seal in the Water Area of the North Caspian Sea in 2024**

ABSTRACT

*Summary of Document Purpose and Scope*

This report presents the results of monitoring studies assessing the abundance and birth rate of the Caspian seal in the North Caspian Sea. A comparative analysis of the population size for 2012, 2020-2024 is included. The work was conducted under Contract UI176768. The report provides a comprehensive assessment of the Caspian seal population size based on aerial surveys of seal haul-outs and molting grounds in the KSCS during the winter-spring period of 2024 in the North Caspian Sea.

**Revision Record**

A01	August - 2024	Approved revision
<b>Rev.</b>	<b>Date</b>	<b>Description of Revision</b>

**Approvals**

Signatures are required in Approved Revisions.

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**Revision Tracking**

Specify significant changes from previous revisions of the document.

Rev.	Date	Description of Revision
P01	29.07.2024	Preliminary revision (For internal review)
A01		Approved revision

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## 1. INTRODUCTION

The Caspian seal (*Phoca (Pusa) caspica*) is the only aquatic mammal native to the Caspian Sea. This species belongs to the pagophilic (ice-loving) group of seals [Badamshin, 1966].

Historically, the Caspian seal has been extensively hunted, particularly during the ice-out periods in the North Caspian Sea. At the beginning of the twentieth century, the population size was estimated at about 1 million individuals. In the post-war period (1946-1947), its population size was estimated at 340,000 individuals. In the 1950s, according to Badamshin and Chapsky, the total number of Caspian seals was considered to be about 750,000, and by the mid-1960s, it had declined to 470,000-600,000 individuals [Badamshin, 1960, 1966; Chapsky, 1963]. In 1973, an aerial survey of breeding females in nursery areas (on ice) was conducted for the first time, allowing for a more accurate determination of the breeding stock, which was estimated at 90,000 individuals. Consequently, the total number of Caspian seals was estimated at 450,000 individuals [Krylov, 1976]. In the early 2000s (2000-2004), aerial surveys indicated that the seal population did not exceed 375,000 individuals [Report. Agip KCO/2005-0347, 2006].

Following the initiation of intensive hydrocarbon exploration and production in the Kazakhstan sector of the Caspian Sea, annual visual aerial surveys of Caspian seals were organized. In 2005-2006, a counting strip method adapted for Caspian conditions was used. This method was first employed in official ringed seal surveys in the Baltic Sea conducted by the Swedish government since 1990 [Härkönen and Heide-Jørgensen, 1990; Härkönen and Lunneryd, 1992]. The results of the 2005/2006 count showed that the birth rate amounted to 20,000 pups in the ice field of Kazakhstan. Consequently, taking into account the assumed level of reproduction, the Caspian seal population size, according to the aerial survey data, reached 111,000 individuals per ice field [CISS Report, 2006]. Long-term visual aerial surveys by an international group of researchers (within the framework of the CISS program) have shown wide variations in the results of counting and estimates of the Caspian seal birth rate. For instance, the Caspian seal birth rate was estimated at 21,000 (2005), 16,900 (2006), 5,700 (2007), 8,000 (2008), 15,000 (2009), and 7,000 (2010) individuals [Härkönen et al., 2010].

Since 2005, annual surveys have been conducted, and by 2013, the results indicated a fluctuating trend in seal reproduction. In October 2008, the International Union for Conservation of Nature (IUCN) changed the conservation status of the Caspian seal from "Vulnerable" to "Endangered" based on ongoing seal mortality due to fishing, bycatch in fishing gear, and habitat loss. In 2020, the Caspian seal was included in the Red Books of the Republic of Kazakhstan and the Russian Federation.

The Caspian seal belongs to the pagophilic (ice-loving) group of seals. In the North Caspian Sea, the following activities occur on the ice: pupping, nursing of pups, mating, and molting. Seals congregate along the edges of large plates of flat ice, near natural ice holes, gaps between moving plates of ice, or areas of open water. They also prefer drifting ice floes with hummocks, which are relatively stable, inaccessible to predators, and well protected from wind. Aerial surveys are, therefore, the only feasible method of obtaining accurate population size estimates, allowing large areas to be surveyed in a relatively short period. However, seal pups are difficult to see due to their light coloration, which camouflages them against the snow and ice cover. Additionally, observers may miss some adult seals during the flight. Subjective factors such as fatigue, decreased attention, and high animal density primarily influence the number of animals missed. Undercounting also depends on many other factors: weather conditions, ice conditions, and flight parameters.

As part of the continuous improvement of the methodology of marine mammal surveys, the problems of population studies are being solved. The experience of using instrumental-visual aerial counts of seals in the White, Okhotsk, Bering and other seas creates a good methodological and technical basis for similar 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 of recording have a number of advantages: the high thermal

contrast of animals of relatively cold underlying surface (from 5 to 150 C) allows reliable detection of animals on IR images. Due to the high contrast of animals, methods of automated recognition and counting of animals on IR images work well, the wide bandwidth of the IR scanner allows to increase the accounting bandwidth, the instrumental nature of aerial survey makes it possible to document all animal encounters. Instrumental methods of counting make it possible to detect and identify not only adults, but also seal pups with masking coloration.

In 2020-2024, within the framework of the joint Kazakh-Russian Program (2020-2024), scientists of FSBSI RFRIFO and KAPE carried out a survey of Caspian seals using multispectral video and photographic surveys. Modern software devices were used to process video and photo information.

The winter of 2019/2020 belonged to the type of relatively warm early winters. The survey flights were conducted under good weather conditions, with minimal ice cover (6.5-2.3%). Estimated lower and upper limits of the total population estimate using multispectral aerial survey data in 2020 ranged from 282.3 to 352.4 thousand seals.

The winter of 2020-2021 belonged to the type of moderate winters. The duration of ice breakup was 140 days. The maximum area of ice cover amounted to 80% of the total area of the north-eastern part of the Caspian Sea. The calculated lower and upper limits of the total population estimate using multispectral aerial survey data in 2021 ranged from 302.02 to 369.15 thousand Caspian seals.

The winter of 2021-2022 belonged to the winters with a mild character (Table 4.1-1). The sum of frost degree days at sea was about 250-260 and the duration of ice breakup was 82 days. The maximum area of ice cover amounted to 80% of the total area of the north-eastern part of the Caspian Sea. Estimated lower and upper limits of the total population estimate using multispectral aerial survey data in 2022 were from 311.4 to 431.4 thousand Caspian seals. High mortality in spring and fall-winter 2022 from influenza and morbillivirus pathogens resulted in the death of more than 30,000 Caspian seals of different ages. Discharges of dead seal carcasses were observed on the coasts of all Caspian littoral states.

The winter of 2022-2023 was moderate in character. The ice breakup lasted for a significantly longer period of 112 days, compared to 82 days in the winter of 2021-2022. Most of the time, the ice cover in 2022-2023 was static due to the absence of strong winds and low air temperatures.

The winter of 2023-2024 was classified as temperate. The duration of the ice breakup was 111 days, and the maximum ice cover during the study period reached 86% of the total area of the northeastern part of the Caspian Sea.

In 2024, work continued under the joint Kazakh-Russian Program (2020-2024) to count the number of Caspian seals. To obtain up-to-date data on the number of Caspian seals in the North Caspian Sea, the following activities were conducted: a multispectral survey of rookeries in winter and an aerial survey of rookeries and moults in spring 2024.

A comparative analysis of changes in the Caspian seal population showed that various factors - natural mortality, diseases (such as canine distemper and pneumonia), deaths in fishing nets, and other poorly studied factors-influence the preservation of their numbers. During the entire research period from 2020 to 2024, Caspian seal reproduction took place on the ice field. Due to the formation of the main ice field within the borders of the Republic of Kazakhstan, the breeding grounds were largely located in the KSCS. The number of seals within the borders of the Russian Federation did not exceed 5-7% of those registered in the current year. Observing the changes in population size, it can be noted that there has been a gradual increase from 2012 to 2024, with the total number increasing by 3% and the number of pups by 12.8%.

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## 1.1. PURPOSE OF THE SURVEY

*Research objective:* Estimation of the number, distribution of the Caspian seal population in the North Caspian Sea area in 2024.

*Survey objectives:*

- Conducting a multispectral aerial survey of the breeding stock and litter using infrared, video, and photo surveys from airplane, in accordance with the international Work Program "Assessment of the Number, Distribution, and Natural Reproduction of Caspian Seals in the Kazakhstan and Russian Waters of the North Caspian Sea in 2020-2024," approved by the authorized state authorities of the Republic of Kazakhstan and the Russian Federation;
- Determining the nature and density of animal ice haul-outs;
- Determining the ratio of females to cubs;
- Conducting an aerial survey of seal haul-outs and moults in spring;
- Performing primary desktop processing of aerial survey materials, verification of materials, arrangement, and preparation for estimating Caspian seal abundance;
- Mapping seal concentration sites;
- Developing proposals for the conservation of the population.

## 1.2. DISTRIBUTION AND INTENDED AUDIENCE

Unless otherwise authorized by NCOC N.V., the distribution of this document is confined to NCOC N.V. and representatives of state environmental authorities.

## 1.3. DEFINITIONS, ACRONYMS AND ABBREVIATIONS

### 1.3.1. General Definitions

The **RoK** is the Republic of Kazakhstan.

**Company** means North Caspian Operating Company N.V.

**Contractor** means the party providing services to the Company during the term of the Contract on a Task Order basis, including project management and preparatory work, field survey work, analytical studies and reporting.

**Supplier** means the party manufacturing or supplying equipment and services as specified by the Contractor.

The word **shall** is used to indicate that a provision is mandatory.

The word **should** is used to indicate that a provision is not mandatory, but recommended as good practice.

**1.3.2. Specific Terms, Definitions, Acronyms and Abbreviations**

Term / Acronym / Abbreviation	Explanation / Definition
IUCN	International Union for Conservation of Nature
NCOC N.V.	North Caspian Operating Company N.V.
RK	Republic of Kazakhstan
RF	Russian Federation
KAPE	Kazakhstan Agency for Applied Ecology LLC
ATC	Aviation Training Center LLP
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	Infrared camera (FLIR A325, Optris pi 450)

**1.4. REFERENCE DOCUMENTS AND LINKS**

If there is no reference to specific deadlines, the latest edition of each publication, including any changes/additions/edits, should be used.

Ref.	Document Number / Link	Title / Description
(1)	RK CODEX No. 400-VI dated 02.01.2021. Chapter 16, Article 245, 256; Chapter 19, Article 269, 274.	Environmental Code of the Republic of Kazakhstan
(2)	No. 593-II of July 09, 2004	Law of the Republic of Kazakhstan On Protection, Reproduction and Use of Wildlife
(3)	Federal Law of the Russian Federation of December 20, 2004 N 166-FZ	On fishing and conservation of aquatic biological resources
(4)	Federal Law of the Russian Federation from 24.04.1995 N 52-FZ	About the animal world
(5)	FAF of the Russian Federation, CF&W of the Ministry of EG&NR of the Republic of Kazakhstan, FSBSI RFRIFO, KAPE	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”
(6)	Are approved by the order Ministry of Agriculture of the Republic of Kazakhstan of 04.04.2014 No. 104-Ө	Rules for preparing a biological justification for the use of wildlife (as amended by Order of the Minister of EG&NR of the Republic of Kazakhstan dated 18.10.2022 No. 662)
(7)	01-H34-MA-01394-000	Guidelines “Environmental baseline surveys, compliance environmental monitoring and wildlife surveys: fieldwork”. NCOC N.V. January 26, 2023. Revision A01”
(8)	KAPE, FSBSI RFRIFO, 2022	Report. Counting of Caspian seal in the North Caspian Sea in winter and spring periods of 2022
(9)	KAPE, FSBSI RFRIFO, 2023	Report. Counting of Caspian seal in the North Caspian Sea in winter and spring periods of 2023
(10)	-	Scope of work. Caspian Seal Research in the Water Area of the North Caspian Sea in the Winter and Spring Periods of 2024

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Gladkikh Alexander	Director of GIS AI Department, desk work, data analysis	KAPE	Almaty
Chernov Alexander	Head of GIS Department, desk work, data analysis, work with cartographic material	KAPE	Almaty
Victoria Morozova	Deputy Head of GIS Department, desk work, data analysis, map construction	KAPE	Almaty
Viktor Razvaliaev	Chief specialist of GIS department, desk work, data analysis, database	KAPE	Almaty
<b>Piper PA-34 airplane (winter)</b>			
Evgeny Zhukov	Pilot	AUTZ LLP	Karaganda
Unzhakov Sergey	Pilot	AUTZ LLP	Karaganda

**RUSSIA:**

Personnel	Position / Role	Institute/Company where he/she works	Location
<b>Scientific staff</b>			
Vyacheslav Bizikov	Deputy Director for Science / Scientific Supervisor, Ph.D in Biology	RFRIFO	Moscow
Lev Sidorov	Head of the Laboratory of Marine Mammals / Responsible Executive Officer, Ph. in Biology	RFRIFO	Moscow
Vasily Kuznetsov	Senior Researcher	RFRIFO, Volga-Caspian Branch (CaspNIRKh)	Astrakhan
Ivan Belokobylski	Senior Researcher	RFRIFO	Moscow
Chernook Vladimir	Chief Researcher / Responsible Executive Officer, Dr. Sci.	RFRIFO, SIT LTD.	St. Petersburg
Alexander Vasiliev	Chief Specialist / Responsible Executive Officer, Ph,D	RFRIFO, SIT LTD.	St. Petersburg
Chernook Ilya	Director General	SIT LTD.	St. Petersburg
Ivan Matveev	Lead Engineer	SIT LTD.	St. Petersburg
Chernook Nadezhda	Lead Engineer	SIT LTD.	St. Petersburg
Sabirov Marat	Programmer	SIT LTD.	St. Petersburg
Vyacheslav Bizikov	Senior Engineer	SIT LTD.	St. Petersburg
Lev Sidorov	Engineer	SIT LTD.	St. Petersburg

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### 3. FIELD PROGRAM

#### 3.1. SURVEY PLAN

The survey consisted of two phases: winter and spring 2024.

**Winter Period** of 2024: The first stage of the survey was a winter aerial survey of the seal population, conducted over 12 days from February 18 to March 1. Due to difficult weather conditions (fog, strong wind), flights were conducted on February 24, 25, 27, 28, and March 1, 2024. The total length of the survey routes was more than 6,874 km, with a survey strip width of 800 meters. The aerial surveys were carried out in a single synoptic period to exclude the influence of ice drift.

Within the territorial boundaries of Russia, above the ice field where aggregations were observed, Caspian seal abundance was calculated by extrapolation [Kingsley et al., 1985], taking into account their location in the adjacent territory of the Republic of Kazakhstan.

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

**In the spring period** of 2024, the second stage of research was carried out, namely, aerial survey of haul-outs and molts of seals in April. The aerial survey of Caspian seals was carried out by a selective method, in which the coastal strip, sandy shoals and islands suitable for molt rookeries of seals in the North-Eastern Caspian Sea were surveyed. The duration of aerial surveys was 5 days - from April 8 to April 12, 2024. The total length of aerial survey routes was more than 2635 km. The width of the observation band is 1200 m.

#### 3.2. METHODOLOGY OF FIELD RESEARCH

##### 3.2.1. Multispectral aerial survey (winter period)

In preparation for the survey, daily monitoring of ice and meteorological conditions in the Caspian Sea was carried out from the beginning of February. NCOC specialists provided daily available information on ice conditions in the Caspian Sea based on passive microwave sounding data from the SSMI/DMSP satellite system, RADARSAT and Aqua/Terra satellites. Implementation of satellite mapping of sea ice extent, seasonal displacement of the ice edge and variability of its position allows predicting the distribution of animals during the pupping period [Chernook and Melentiev, 2002]. Ice maps obtained from NCOC using satellite imagery data, in combination with available materials from Internet resources and previous aerial surveys, were used in predicting the location of harbor seals and planning flight routes.

Aerial surveys of Caspian seals were carried out using a selective method, whereby the ice cover is partially surveyed rather than covered by a continuous survey. An acceptable proportion of the area covered may be from 8 to 10% of the area of all ice in the North Caspian suitable for harbor seals. It can be smaller if the grid of survey routes is optimized depending on the seal population density in different parts of the water area. In order to increase the efficiency of aerial surveys, more efforts are directed towards surveying areas with high and medium seal density, without ignoring areas with low density.

The planning of flight routes was carried out taking into account long-term data on the location of seal haul-outs, information from scientific teams accompanying icebreaker routes, and information obtained during preliminary survey flights. Ice and weather conditions were also taken into account. The flights were made on days with good low-wind weather during daylight hours. Aerial survey was carried out in good visibility, both in clear and cloudy weather in the absence of fog and precipitation. Medium-term weather forecasts were used for planning the work, as well as operational tracking of changes in ice and meteorological conditions using satellite images.

To count seals, a regular pattern of transects parallel to each other in a north-south or west-east direction with a fixed spacing between them (4-8 km) was used. If necessary, an optimized grid of parallel transects with variable spacing may be used. The total number of routes is limited by the planned flight time limit for aerial survey work. The minimum required flight time for the instrumental aerial survey of Caspian seal broodstock in the North Caspian Sea corresponds to 52 flight hours for a laboratory airplane. The increase in the total length of air survey routes makes it possible to obtain more accurate estimates of seal abundance, reduce statistical error, and obtain more reliable information on the spatial distribution of seal density.

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

The duration of the aerial survey should not exceed 10 days and should be carried out during a single synoptic period in order to exclude the influence of drift of haul-outs on the ice.

The location of survey transects is optimized beforehand in order to conduct the Caspian seal survey in the most efficient way. This takes into account the density of seals according to previous observations, physiographic, ice and other natural characteristics of the survey areas, remoteness of the survey areas from the base airports, technical characteristics of the airplane and other criteria.

Aerial photography is performed at a fixed, pre-selected flight altitude (in accordance with the Rules for the preparation of biological justification for the use of wildlife as amended by the order of the Minister of EG&NR of the Republic of Kazakhstan dated 18.10.2022 No. 662), which is chosen so that:

- provide high resolution of thermal images (not worse than 0.3 m) and photos (not worse than 0.03 m);
- ensure a wide survey swath (at least 300 m) for greater coverage of the surveyed water area;
- not to scare the seals away with the noise of a low-flying airplane.

The flight altitude shall be kept strictly constant on each transect, ensuring a fixed swath width. If necessary (change of weather conditions and other circumstances), the flight altitude may be changed only between survey transects - during or after a turn to the next transect.

Based on previous work experience, the basic flight altitude can be 200 m. This altitude provides the necessary contrast of thermal marks to detect seals on thermal images of the ice surface and high resolution for reliable identification of adult seals and pups on photographs. The width of the central strip is determined by the angle of view of the camera and the flight height and is about one flight height, i.e. 200 m (at H=200 m) at the angle of view of 55 deg. The total swath width is determined by the "effective" swath width of the thermal imager and is about three flight heights according to experimental data.

The method of multispectral aerial survey consists in surveying seal haul-outs synchronously in infrared and visible spectral regions. In this case, continuous infrared imaging of the underlying surface is continuously performed at the operating altitude of the flight. Seals on the ice are registered by the thermal imager as bright marks on the dark background of the snow and ice cover. The onboard operator of the airborne surveying complex monitors the quality of infrared images and photos on the computer screen, and also controls the adjustment of the equipment at the beginning of each transect to improve the quality of the seals' display (clear separation of seals on the ice background, reduction of the effect of warmed seal rookeries and open water areas). The equipment settings shall not be changed until the end of the transect.

To identify marks on thermal images, regular and selective nadir photography is performed using digital cameras. The choice of time interval depends on the density or frequency of seal sightings and the technical capabilities of the equipment. The photography interval can be different depending on the purpose and objectives of the survey. If continuous (regular) photography is interrupted for one reason or another, this is recorded in the flight report.

In order to collect more statistics in areas where seals are denser, the animals are photographed more frequently. In case of dense seal aggregations, the lower cameras take photos in 1 second intervals and the photos are taken with a small overlap (about 10%). At the same time the photo shooting is controlled automatically under the control of the flight operator who observes the image of the underlying surface on the screen of the thermal imager monitor. The thermal imager camera is installed in such a way that its field of view is slightly ahead (about 10 degrees) of the field of view of the camera installed in the nadir. For this reason, when seal marks appear on the thermal imager screen, the flight operator has time to analyze the IR and signal the lower camera unit to switch on in the continuous shooting mode with 1 sec interval.

In parallel with the instrumental survey, visual observations of the airplane's side are carried out. Visual observations are conducted continuously in a wide angle of view through portholes located on the sides of the airplane. The observers review the situation at the seal haul-outs, periodically comment on ice and weather conditions during the flight, as well as provide other useful information (animal behavior, predators, pollution, etc.). Observers' messages and comments are recorded in audio files for subsequent transcription in ground conditions and use then for interpretation of the survey results.

Time, coordinates, heading, altitude, roll, airplane speed and other necessary parameters are automatically recorded synchronously in the flight record. Synchronization of all types of operations is performed with high time accuracy, not worse than 1.0 sec. In addition, the beginning and end of transects, moments of switching on and off the equipment, pauses in observations and other significant events are recorded, and a map of the flight is built on the display. During the flight, all images and audio messages of observers containing information on detected animals, as well as ice, weather and other conditions of surveying are digitally recorded.

The result of the flights is the collected survey materials, including digitally recorded thermal images and photographs, audio recordings of visual observers and other flight participants, a flight protocol table, observation diaries, and compiled flight maps. All the material collected during the expedition serves as the basis for subsequent ground processing.

### **3.2.2. Aerial Survey of Seal Haul-outs (Spring Period)**

The aerial survey of Caspian seals is conducted selectively, targeting coastal strips, sandy shoals, and islands suitable for molting seals in the North-Eastern Caspian Sea.

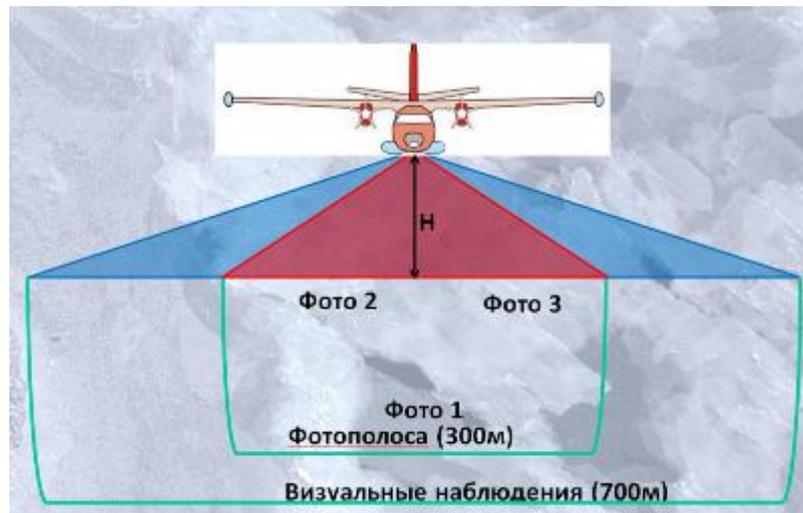
Flight routes are planned using long-term data on seal haul-out locations and taking weather conditions into account. Surveys are conducted on days with low wind and good visibility during daylight hours. Both clear and cloudy weather are suitable, provided there is no fog or precipitation. Medium-term weather forecasts and real-time meteorological data from Atyrau airport are used for planning.

Flight planning is carried out in advance to ensure the survey is efficient. Factors considered include previous seal density observations, the physical and geographical characteristics of survey areas, the distance from base airports, and the technical specifications of the airplane.

Aerial photography is performed at a fixed, pre-selected flight altitude to:

- Ensure high-resolution photos (at least 0.03 m);
- Cover a wide survey swath (at least 300 m);
- Avoid disturbing the seals with airplane noise.

The flight altitude is maintained constantly along the route to ensure a fixed width of the survey strip. Based on previous experience, the typical flight altitude is 200 m, which provides high-resolution images for reliable identification of adult seals and pups. The width of the central strip is determined by the camera's angle of view and flight height, approximately equal to one flight height (200 m at H=200 m with a 45-degree angle of view). The total width of the swath is about 300 m, (see Figure 3.2.1).



**Figure 3.2.1 Schematic diagram of the aerial survey**

During aerial counts, regular and selective photography is performed using digital cameras. The choice of time interval depends on the density or frequency of seal sightings and the technical capabilities of the equipment. The photography interval can vary depending on the purpose and objectives of the survey. If continuous (regular) photography is interrupted for any reason, this is recorded in the flight report.

To collect more data in areas with higher seal densities, the animals are photographed more frequently. In the case of dense seal aggregations, the lower cameras take photos at 1-second intervals with a small overlap (about 30%). Photography is controlled automatically under the supervision of the flight operator.

In parallel with the instrumental survey, visual observations are made from each side of the airplane. Visual observations are conducted continuously with a wide-angle view through portholes located on the sides of the airplane. The observers review the situation at the seal haul-outs, periodically comment on weather conditions during the flight, and provide other useful information (animal behavior, presence of predators, pollution, etc.).

Time, coordinates, heading, altitude, roll, airplane speed, and other necessary parameters are automatically recorded synchronously in the flight log. Synchronization of all operations is performed with high time accuracy, no less than 1.0 second. Additionally, the beginning and end of the flight, moments of switching the equipment on and off, pauses in observations, and other significant events are recorded, and a flight map is plotted on the display.

The results of the flights include digitally recorded photos, data in the field diary, and compiled flight maps. All the material collected during the expedition serves as the basis for subsequent ground processing.

### **3.2.3. Hardware and Software**

Instruments used in the surveys provided the necessary characteristics of the Caspian seal haulouts. To compare quantitative data obtained using a camera and a personal navigator, as well as information gathered by observers from different sides of the airplane, all instruments involved in the survey were synchronized in time.

The equipment used in the studies is presented in Tables 3.2-1 through 3.2-2.

**Table 3.2-1 Equipment List**

Equipment	Description, parameters	Function
<b>Multispectral imaging (winter)</b>		
GPS navigator	Garmin Oregon 550, Garmin GPS Map 64	Positioning
Satellite phone	Turaya SG-2520	Mobile communication
Digital camera	Nikon D850, Nikon D850	Photographic documentation of seals and their tracks
Video camera	GoPro 11 (2 pcs). DJI OSMO Action 3	Flight video
Infrared camera	FLIR A325, Optris PI450	IR image fixation
Binoculars	Olympus 10X50 DPS I, Canon 12x36 IS III	Seal sightings
High-precision lidar	Lidar	Determining the height of the flights with an accuracy of 1 cm
Laptop	Lenovo G770, Lenovo G770	Recording, processing and storage of information
Battery set	«Varta» AA	For GPS navigation and voice recorder
Charger	Garmin	For charging rechargeable batteries
<b>Aerial photography (spring)</b>		
GPS navigator	Garmin GPSMAP 64 (2 pcs)	Positioning
Satellite phone	Thuraya SG-2520	Mobile communication
Digital camera	Canon EOS 800D, Nikon D850 (2 pcs)	Photographic documentation of seals and their tracks
Video camera	GoPro 11 (2 pcs). DJI OSMO Action 3	Flight video
Binoculars	Bushnell PowerView 10X50 binoculars (2 pcs)	Seal sightings
High-precision lidar	Lidar	Determination of flight altitude
Laptop	HP 470 G3 Laptop, Lenovo IdeaPad 3 17ITL6 Notebook	Recording, processing and storage of information
Battery pack	Varta AA 2100mah	For GPS navigation and voice recorder
Charger	Varta 57677	For charging rechargeable batteries

**Table 3.2-2 Characteristics of airborne survey equipment for multispectral imaging**

Aerial camera	Resolution, matrices	Focal lens distance	Field of View	Tilt from vertical to right/left
Nikon D850 camera to the left	46 MP	50 mm	38°x25°	19° to the left
Nikon D850 camera to the right	46 MP	50 mm	38°x25°	19° to the right
Thermal imaging camera - Flir A325 to the left	320 x240	18 mm	25°x19°	14° to the left
Thermal imaging camera- Optris PI450 to the right	382 x288	17 mm	28°x23°	15° to the right
HERO GoPro 11 Review Camera	27 megapixels	-	110°x74°	0°
DJI Osmo Action 3 Review Camera	12 megapixels	-	155°	19° to the left

A set of computer programs was used to ensure aerial survey and processing of the obtained materials. The name of programs and their purpose are given in Table 3.2-3.

**Table 3.2-3 Software programs**

Description	Program function
"Arctica."	Receiving and recording navigation data. Receiving information and recording from sensors of environmental parameters. Visualization of the flight route.
"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.

Note: \* programs specifically designed for aerial photography.

GIS applications were used as a tool for analysis and data preparation at all stages of aerial survey data processing. MapViewer 7 and Google Earth served as the software environment for GIS applications.

The use of GIS allowed for the following:

- Mapping the routes of aerial surveys;
- Spatializing thermal and photographic images;
- Spatial georeferencing of SSMI, Terra, and RADARSAT satellite ice maps;
- Constructing maps of seal abundance distributions.

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#### 4. RESULTS OF OBSERVATIONS

##### 4.1. ICE CONDITIONS IN THE NORTH CASPIAN SEA

The formation of Caspian seal haul-outs and the conduct of aerial surveys are heavily influenced by the ice cover in the North Caspian Sea. Ice conditions here vary annually, significantly changing with the severity of winter (severe, moderate, or mild).

The winter season in the North Caspian extends from south to north, lasting 140-150 days. Frosty days average 90 days, with air temperatures reaching -29 to -30°C. The start of ice formation depends on atmospheric processes before winter. In years with early ice formation (late October - early November), there are significant cold Arctic air incursions. Typically, ice formation begins in early November during average pre-winter conditions, and in early December during warm pre-winter periods. In exceptionally warm pre-winter periods, ice forms along the entire shallow northern coast only in mid-December to early January ["Seas" Project, 1992].

The ice formation in the North Caspian progresses from shallow coastal areas to deeper central areas. In November, the ice boundary is close to the coast in moderate winters or extends to the 2-meter isobath in severe winters. Complete freeze-up in the shallow northeastern region typically occurs by early December. extremely cold pre-winter the shallow coastline is covered with stationary ice in the first half of November and by the third decade of November there is complete freezing of the water area with depths up to 3-5 m. In extremely warm winters, the freezing process in the North Caspian is delayed by 20-25 days. In such winters, only unstable ice from shallow waters is observed in the open sea areas with depths of more than 3-5 m.

Ice thickness in the Caspian Sea varies significantly across the ice-covered area and throughout the winter. Ice evolves through stages: nilas, gray, gray-white, and white ice. The frequency distribution of occurrence of floating ice age species indicates a certain regularity of their development during the ice season and depends on landfast ice thickness. At the beginning of the pre-winter period, thin nilas ice is formed in the form of ice rind (windless weather) or pancake formations (in windy conditions). By the middle of November, due to the growth of ice rind, it passes to the stage of gray (up to 15 cm) and gray-white (15-30 cm thick) ice. Floating white ice (thicker than 30 cm) forms mainly from landfast ice breakup or thermal factors, persisting through winter as coarse ice and ice fields.

During the initial period of ice cover development, a rapid displacement of the young ice boundary and an increase of landfast ice area and thickness are noted. In the second half of the ice season, the influence of dynamic factors on the ice cover increases, causing landfast ice breakup, ice compression and thinning, as well as the processes of layering and hummock formation. In the open part of the North Caspian Sea, ice breakup and ice movement are observed under winds of different directions. The most intensive breakup of landfast ice and retreat of its southern boundary to the north is observed in warm winters with a high frequency of southerly winds and weak frosts.

It is believed that in milder winters the edge of mobile ice moves significantly to the northeast and ice movement on the Ural Borozdin occurs constantly as in the west.

In severe winters, when frequent cold northeastern winds blow, the ice edge drops to Cape Urdyuk (Mangyshlak Peninsula) in the east and to Makhachkala in the west. In such winters, ice movement occurs, as a rule, only in the western part of the North Caspian Sea, and no ice movement is observed on the Ural Borozdin in severe winters. Currents in the area of the probable location of seal haul-outs are very weak, and ice movement is driven solely by winds (Figure 4.1.1).

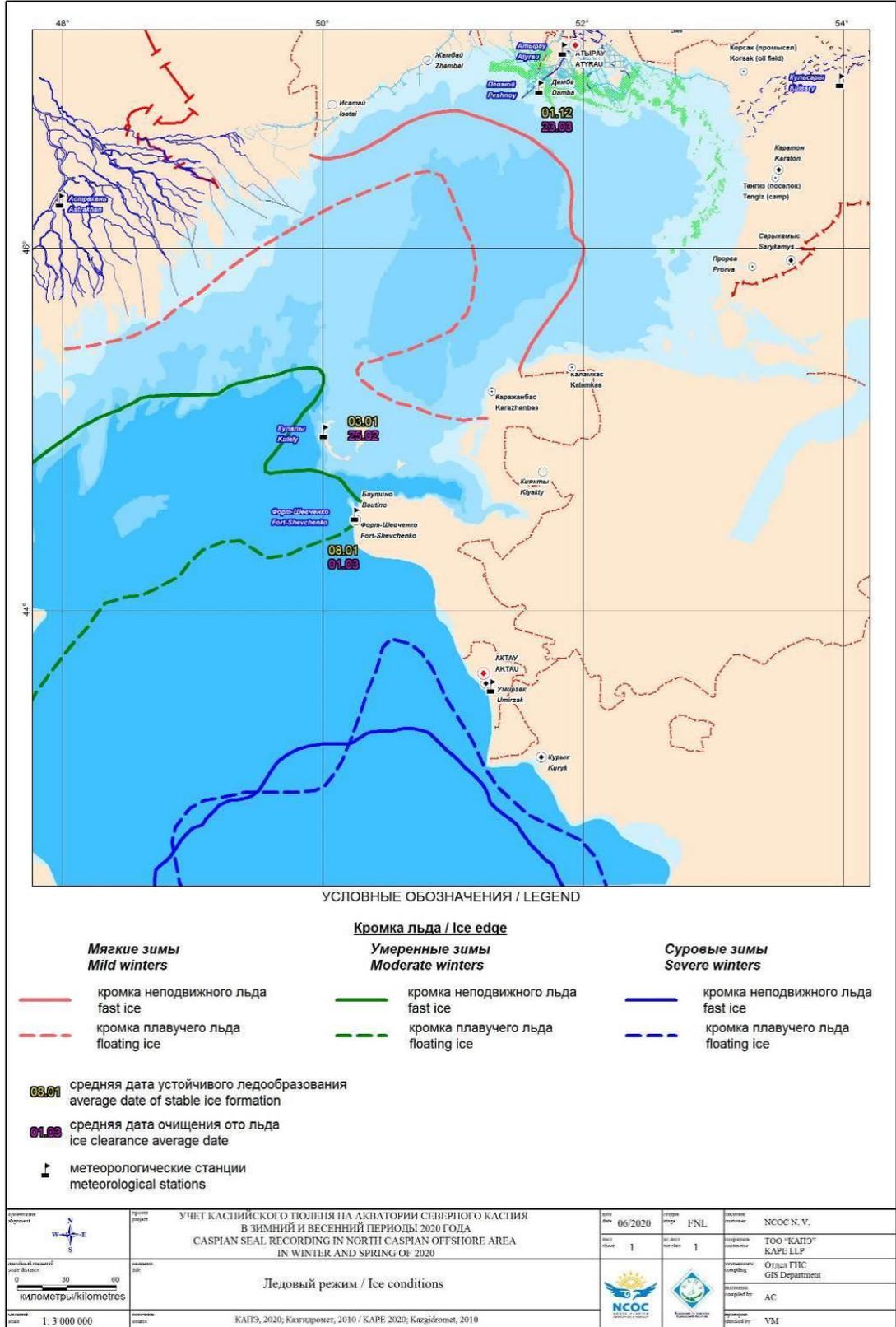


Figure 4.1.1 Ice distribution in the Caspian Sea in winters of varying severity

Seal haul-out distribution in the Caspian Sea largely depends on ice and weather conditions. The location of the landfast ice edge and the boundaries of drifting ice are important. Seals prefer relatively old, solid ice for pupping, penetrating deep into the ice mass if through holes and cracks. During warm winters, breeding occurs in the eastern part of the North Caspian Sea with 10-30% ice cover. In moderate winters (40-80% ice cover), denning occurs throughout the entire ice area of the eastern North Caspian. In cold winters (80-100% ice cover), denning areas are compactly located along the ice edge from east to west.

Females typically give birth to one pup each and nurse it with milk. Breeding and lactation on the ice of the North Caspian Sea extend from late January to mid-February, with the peak of births in early February. By this time, ice extent, thickness, and hummockiness reach their maximum values. Initial dense accumulations of seals become more sparse over time due to wind and currents, with haul-outs on drifting ice more susceptible to "spreading." Haul-outs formed on landfast ice are preserved longer. In the conditions of moving weak ice there is formation of haul-outs scattered over a large area. Males, yawed females and immature individuals form separate haul-outs of "shoal" animals (**Appendix A. I. Adult seals**). Unlike shoaled females, they keep along the ice margins or along cracks and crevices [Ivanov, Sokolsky, 2000]. During the nursery period, adult seals spend a considerable part of their time on the ice, but at the same time females keep themselves separate and a pup can often be seen near a female (**Appendix A. II. Females with pups**).

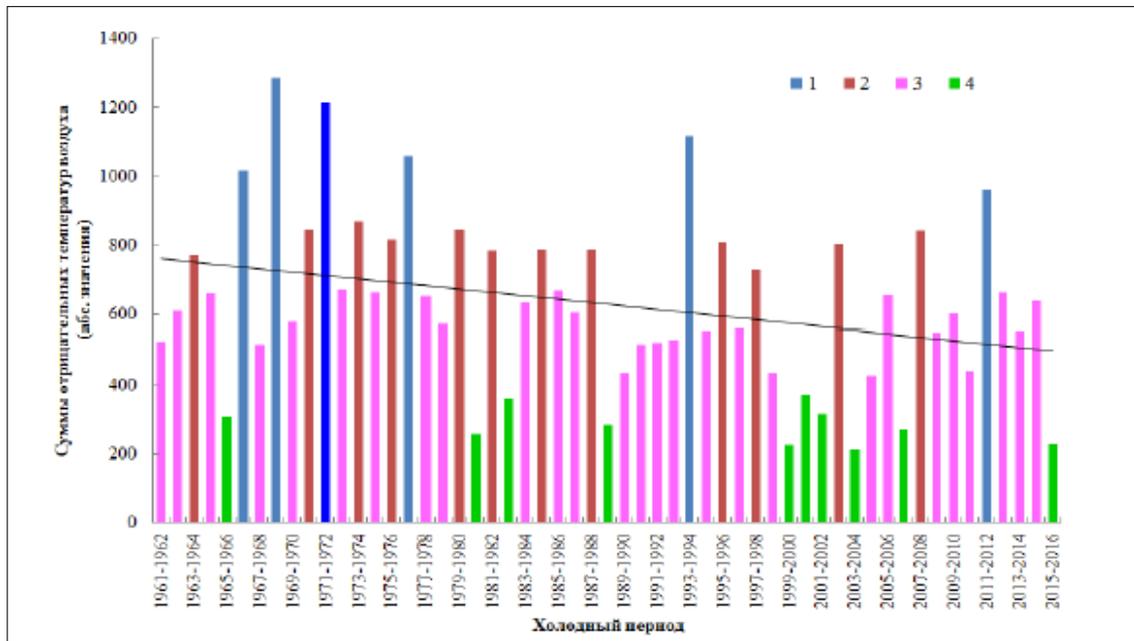
A newborn Caspian seal is covered with white hair with a greenish-yellow tint and is called a "greenling" on the first day. After 2-3 days its cover turns white, and the pup turns into a "squirrel", which at first avoids water (**Appendix A. III. Squirrels**). In two weeks the hair of the seal begins to molt, and the fur begins to slip off in shreds (**Appendix A. IV. Seal pups at different stages of molting**). When this occurs, the pup is called a "tulupka." After molting at the age of 3-4 weeks, the pup acquires gray colored hair and is called "sivar". The sivar stays mostly on the ice for some time, then gradually goes into the water and starts to feed on its own. Lactation in the female lasts 3-4 weeks, after its completion the calf weighs about 12-16 kg and starts to feed independently [Khuraskin, 1989].

Mass mating occurs in the second half of February, followed by adult molting in March-April. The area and density of seal haul-outs vary with ice conditions. As ice cover disappears, seals move to shallow waters and small sandy islands until molting is complete.

In recent years, the Caspian Sea has seen shorter ice cover durations and milder winters. The most objective and accessible, in terms of obtaining operational information, is the classification of P.I. Bukharitsin (Table 4.1-1), [Ivkina et al., 2015]. Using the classification of P.I. Bukharitsin, where the sum of frost degree days is used as 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 (Figure 4.1.2) was plotted based on the obtained calculations. The analysis revealed that for the period under consideration (1961-2016), the recurrence of very severe winters is decreasing, the last decades are marked by an increase in the recurrence of mild and moderate winters. 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 Classification of the degree of winter severity by P.I. Bukharitsin**

Very severe winter	Severe winter	Moderate winter	Mild winter	Very mild winter
> 900	900...700	700...400	400...100	< 100



1 - very severe winter, 2 - severe winter, 3 - moderate winter, 4 - mild winter

**Figure 4.1.2 Total negative temperatures in winter seasons from 1961 to 2016 [Ivkina et al., 2017]**

In Kazakhstan, the winter of 2023-2024 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 - -14°C at night and to -4 - -13°C during the day. January was relatively warm, with temperatures dropping to -15 - -18°C at night in the sea area. In February, the temperature ranged from -10 to +2.

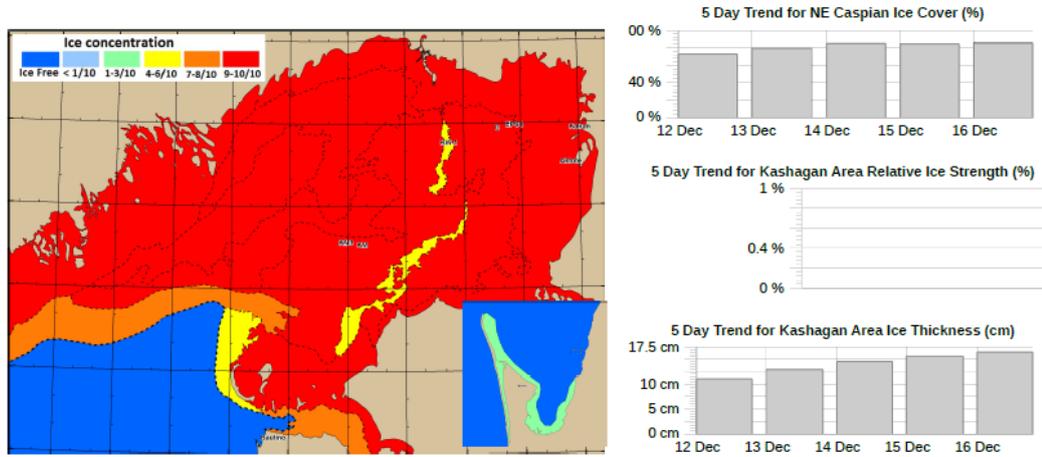
Comparing satellite information with the existing classification of winter severity in the Caspian region, the winter season 2022-2023 can be classified as a moderate winter (Table 4.1-1). The sum of frost degree days at sea amounted to about 250-260, and the duration of ice breakup was 111 days. Under the moderate winter conditions, 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, and in the second ten-day period of December, the ice cover area was about 80%. The maximum ice cover area of 86% was recorded on December 16 (Figure 4.1.3).

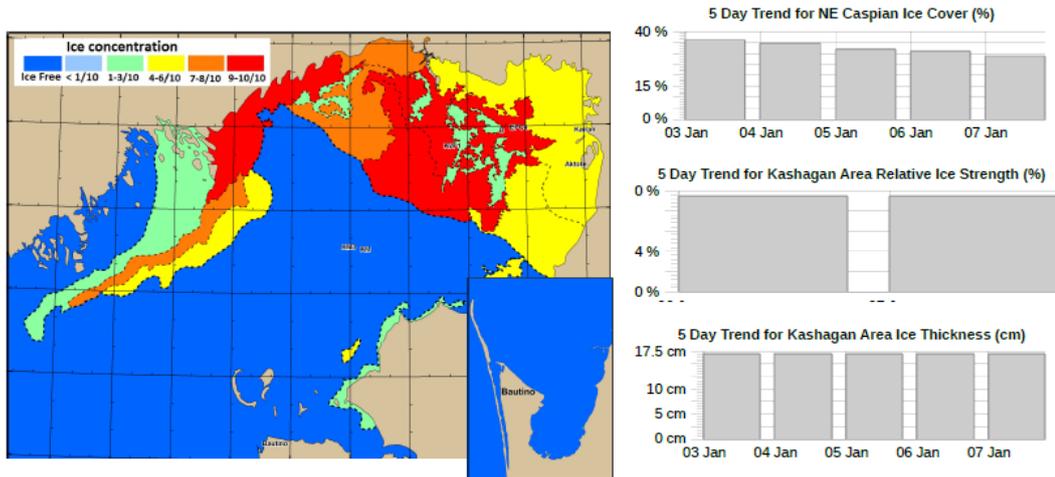
Under the influence of warm atmospheric fronts by the beginning of January the ice cover area decreased to 45% (January 7), ice thickness in the Kashagan area reached 17 cm (Figure 4.1.4). The maximum ice cover area was formed by January 26 and amounted to 96% of the total area of the north-eastern part of the Caspian Sea with the maximum ice thickness in the Kashagan field area of 27 cm (Figure 4.1.5).

In February, weather conditions were unstable. At the beginning of the month the ice field was 92% and by February 15 it decreased to 80% of the area of the North Caspian Sea (Figure 4.1.6). The sea temperature fluctuated from minus at night to positive during the day. In mid-March, the ice field was 24%, and the ice melted completely by March 26, 2024. Individual stamukhs melted by April 7, 2024. The scheme of ice cover distribution in the winter period 2023-2024 is presented in Figure 4.1.7.

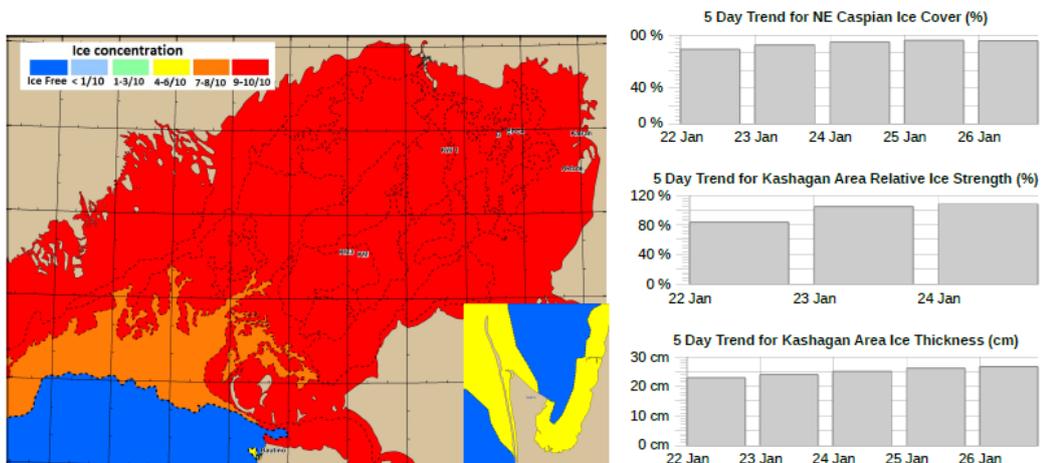
During the aerial reconnaissance flights on February 24,25,27,28 and March 1, ice cover ranged from 83% on February 24 to 79% on March 1.



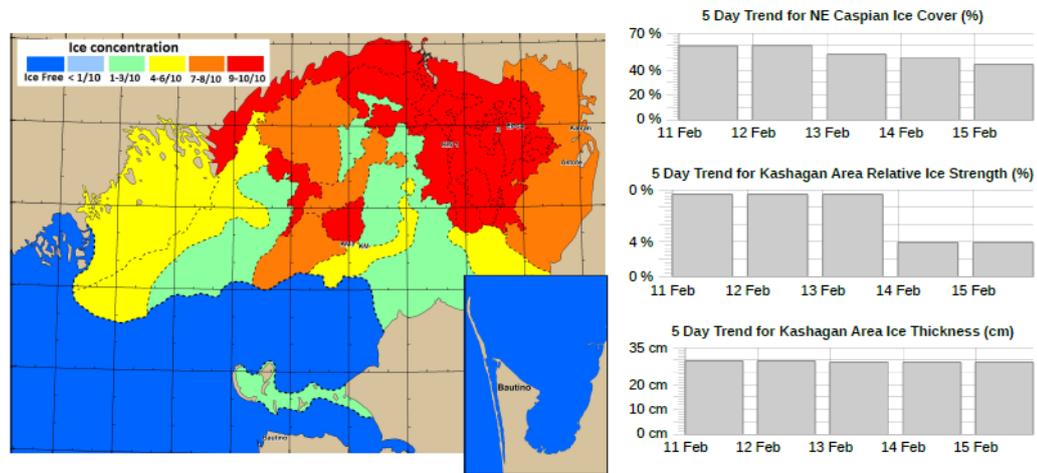
**Figure 4.1.3 Ice distribution in the North Caspian Sea on December 16, 2023**



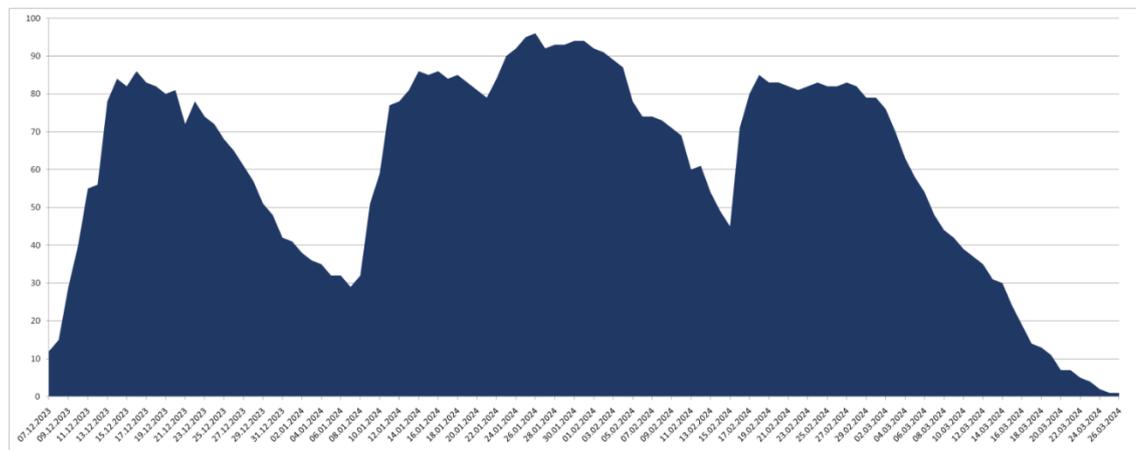
**Figure 4.1.4 Ice distribution in the North Caspian Sea on January 7, 2024**



**Figure 4.1.5 Ice distribution in the North Caspian Sea on January 26, 2024**



**Figure 4.1.6 Ice distribution in the North Caspian Sea on February 15, 2024**



**Figure 4.1.7 Ice distribution in the North Caspian Sea in 2023-2024**

**4.2. MULTISPECTRAL AERIAL SURVEY OF CASPIAN SEAL ICE HAUL-OUTS**

**4.2.1. Equipping the "Piper PA-34" Airplane for Aerial Surveys**

A Piper PA-34 (tail number UP-P4302) was used for aerial surveys of Caspian seal ice haul-outs (Figure 4.2.1).

The airplane was outfitted with various survey instruments, including thermal imagers, cameras, and flight computers (Figure 4.2.2). After installation in the hangar, the equipment was tested using ground power sources to ensure functionality. Flight tests conducted on February 24 confirmed that the imaging system worked properly and did not interfere with the airplane's standard equipment. Due to unstable weather, the first survey flight was carried out on February 18, 2024, to determine the boundaries of seal haul-outs. From February 24 to March 1, flights were conducted to collect data on Caspian seal populations in Kazakhstan, consistent with studies from 2020-2023.



**Figure 4.2.1 Piper PA-34 airplane**

The survey team included Klimov F.V. and Loskutov E. from KAPE LLC (Kazakhstan), and Chernook V.I. and Vasiliev A.N. from FSBSI RFRIFO (Russia). The pilots were Zhukov E.G. and Unzhakov S.Yu. (Figure 4.2.2).



Research team (left) and scientific equipment (right)

**Figure 4.2.2 Survey Execution During Flights**

#### **Technical Specifications of Piper PA-34:**

- Practical flight range: 1300 km;
- Flight speed during aerial surveys: 200-240 km/h;
- Cruising speed: 240 km/h;
- Maximum flight duration: 6 hours;
- Main survey altitude: 170 m.

#### **Survey Equipment:**

- On-board automated system (OAS) with two computers;
- Satellite navigation equipment;
- Two thermal imaging cameras: Optris PI450 and Flir A325;
- Two high-resolution Nikon D850 cameras;
- Two GoPro 11 cameras;
- Laser altimeter, lidar SF 30/D.

Figure 4.2.3 shows a block diagram of the Piper PA-34 survey complex, illustrating the functional relationships between instruments.

All flight parameters (time, coordinates, heading, altitude, speed, etc.) were recorded every second using GPS and linked to survey materials (infrared images, photographs, etc.). The

beginning and end of survey transects, equipment operation times, weather, and other conditions were documented. Transect width was calculated based on flight altitude and lens angle for each type of equipment.

The primary survey was conducted using two thermal imagers (Flir A325 and Optris PI450) and three cameras (two Nikon D850s and a GoPro 11) mounted on the lower fuselage of the airplane. The viewing swaths of the survey cameras are shown in Figure 4.2.4.

Seal counting on the ice was performed with two Nikon D850 cameras, with a 20° angle of view to the right and left of nadir. The cameras continuously captured images at 2.5-second intervals (approximately every 140 meters at 190 km/h). This interval ensured no overlap between successive photos.

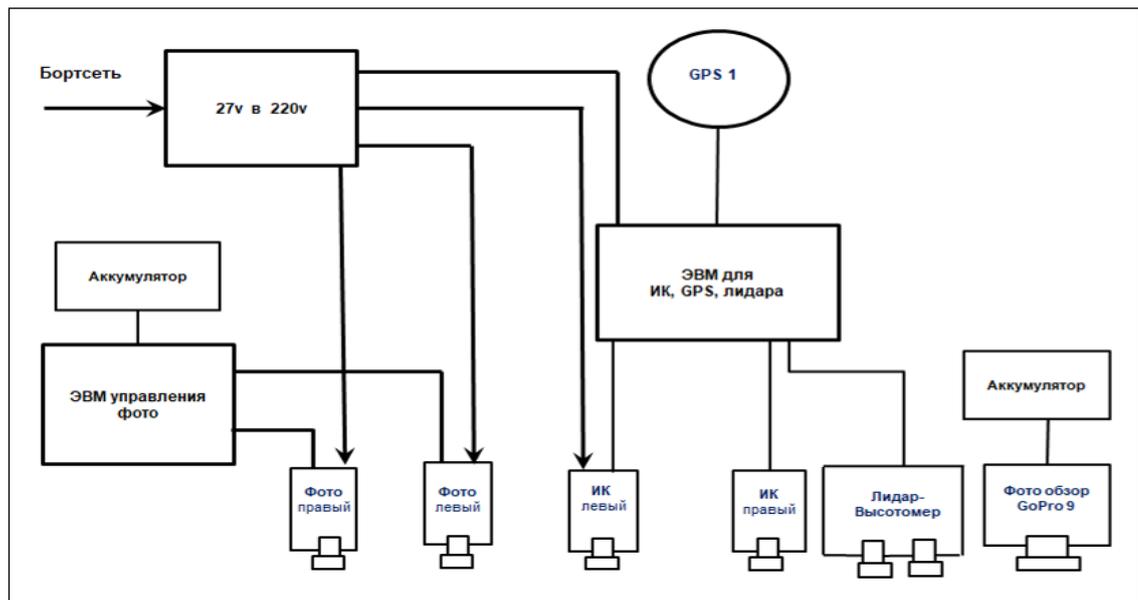


Figure 4.2.3 Block diagram of the aerial survey complex of the Piper PA-34 airplane

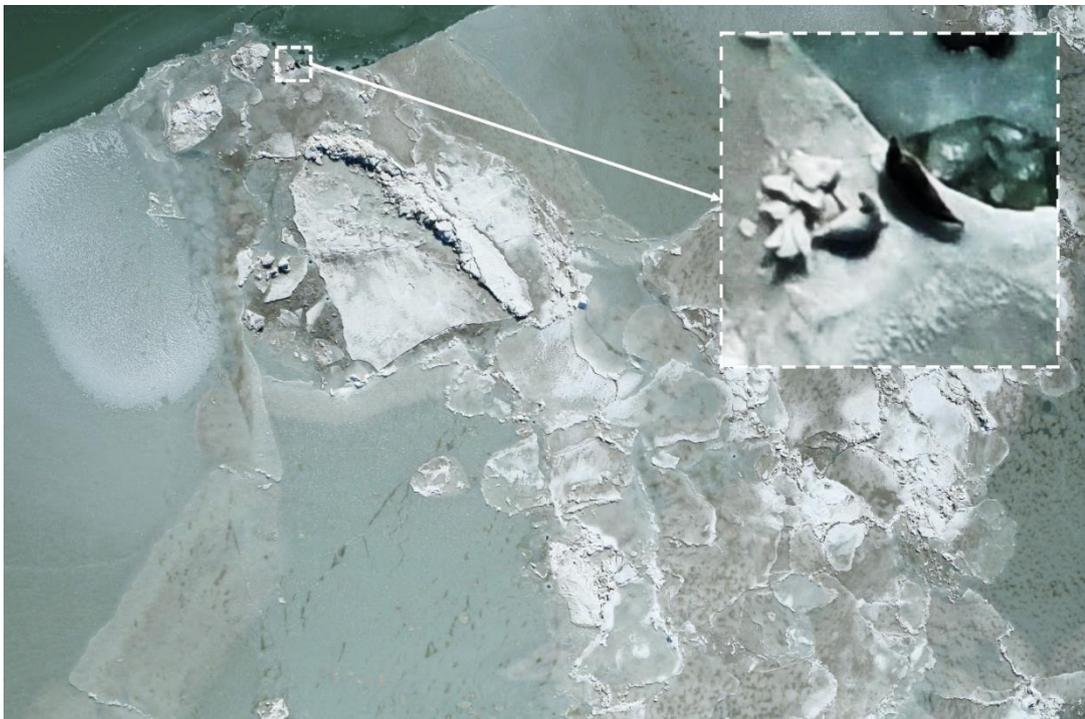


Figure 4.2.4 Aerial photography swaths

Nikon D850 cameras, with a 46 MP full-frame sensor and 50mm lens, provided high-quality images with a spatial resolution of 2-3 cm at an altitude of 180 meters, allowing for reliable identification of adult and baby seals, as well as determining pup stages (belek, tulupka, sivar) (Figure 4.2.5).

During the survey period (February 24 to March 1, 2024), air temperatures ranged from -11°C to +2°C, with winds from 4 to 8 m/sec. The ice was predominantly finely broken and gray-white, making seal detection challenging. However, the quality of the photographic materials allowed for clear identification of seals and signs of their presence on the ice (Figure 4.2.6).

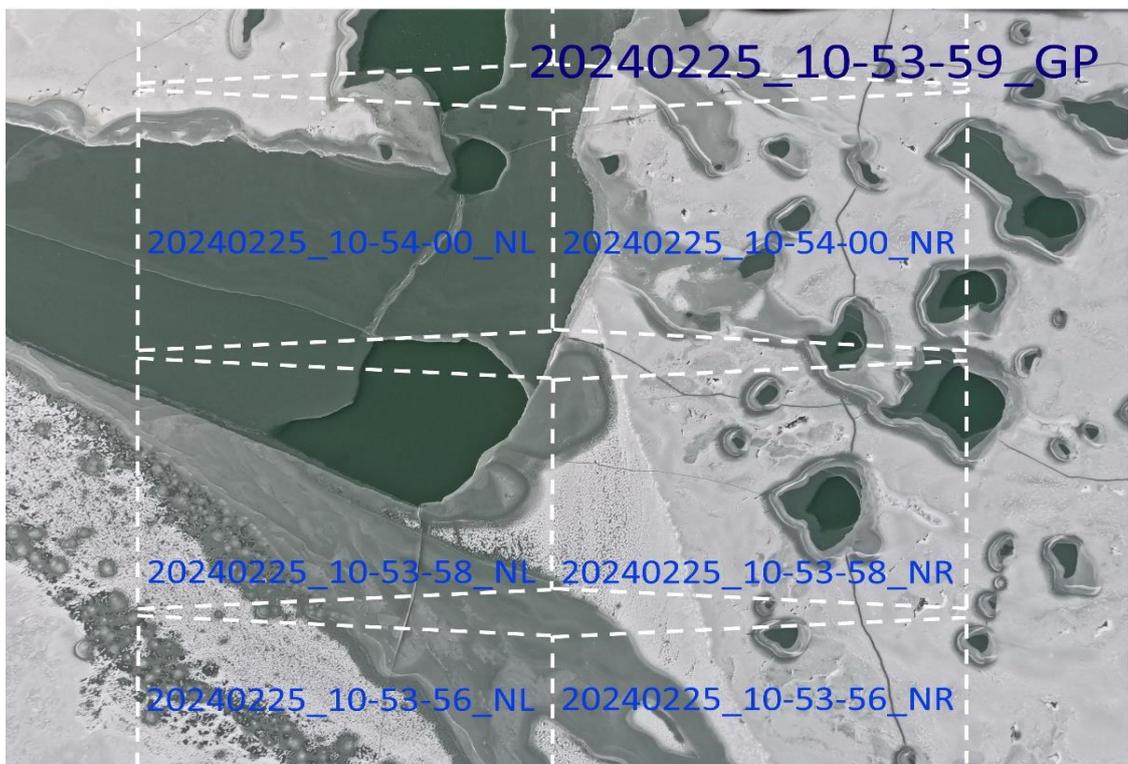
Two Nikon D850 cameras provided central strip photography with a total viewing angle of 78 degrees. These 2 cameras were triggered simultaneously. GoPro 11 cameras captured panoramic images, Appendix A, Figures A1-A4.



**Figure 4.2.5** Photographic image of the ice surface with enlarged fragment (Caspian Sea, February 24, 2024, 13:53:00, Nikon D850, Piper PA-34)

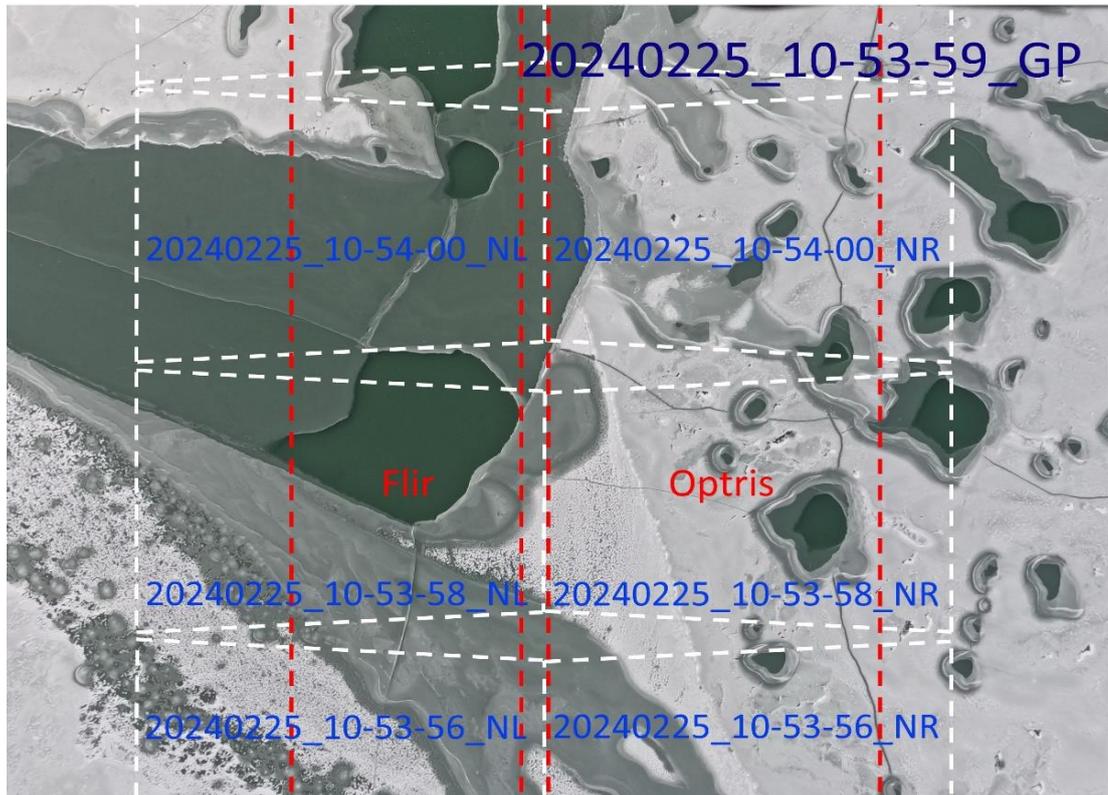


**Figure 4.2.6** Fragment of a photograph of seals on the ice of the Caspian Sea



**Figure 4.2.7** Area ratio of GoPro, left and right Nikon D850 camera photos (Caspian Sea, February 25, 2024, 10:53:59, Piper PA-34)

Thermal imaging with Optris PI450 and Flir A325 cameras recorded infrared images of the surface. The combined swaths of the thermal imaging videos covered 1.12 times the flight altitude (Figure 4.2.8).



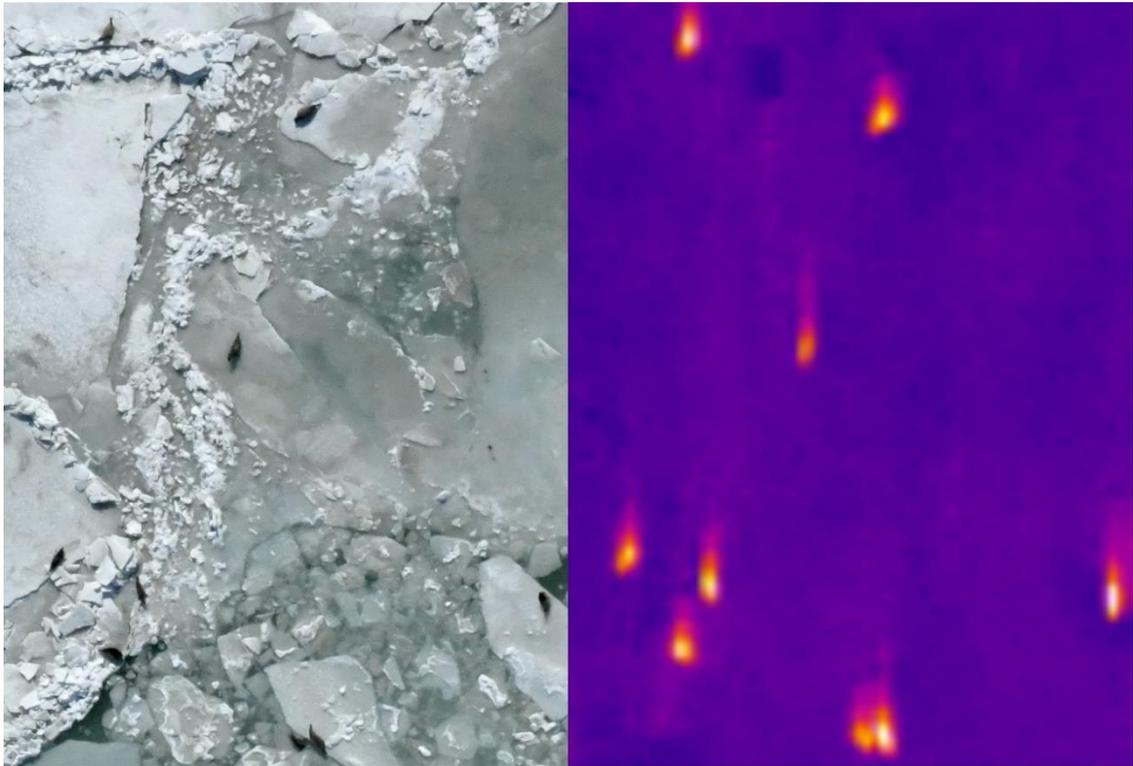
**Figure 4.2.8** Correlation of swaths of GoPro still images, left and right Nikon D850 and Flir and Optris thermal imager videos (Caspian Sea, February 25, 2024, 10:53:59, Piper PA-34)

Thermal imagers, with a sensitivity better than 0.1°C and a dynamic range of 14 bits, had a maximum resolution of 1.5 mrad, corresponding to a spatial resolution of 30 cm at 170 meters.

Thermal imaging was particularly effective in detecting seals due to the temperature contrast between warm-blooded seals and the ice/snow cover, and proved useful even in thick fog (Figure 4.2.9).

During the 2024 survey, the temperature contrast of Caspian seals with the surrounding ice ranged from 2°C to 8°C, depending on the time of day and weather conditions.

The survey collected 0.572TB of photo, video, and thermal imaging data, including 371.7GB (21,980 images) from Nikon D850 cameras, 166.93GB from thermal imagers, and 27.8GB from GoPro cameras.



**Figure 4.2.9** Photo and thermal image of seals on ice (Caspian Sea, February 24, 2024, 13:52:38, Flir A325 thermal imager, left side of Piper PA-34 airplane)

#### 4.2.2. Conducting Aerial Survey Flights in February 2024

The survey period lasted 12 days, from February 18 to March 1, 2024. Due to difficult weather conditions (fog, strong wind), flights were conducted on February 24, 25, 27, 28, and March 1, 2024.

On February 18, KAPE specialists conducted a reconnaissance flight to determine the distribution of Caspian seals along the route of marine vessels (Figure 4.2.10). They observed a total of 225 adult seals and 75 pups. The main groups of seals were found in areas of old thick ice bordering open water breaks, 50-70 km north and northeast of Kulaly Island. To the northeast, on solid ice, seals were recorded in small numbers near small polynyas. Most juveniles were in stages 2 and 3.

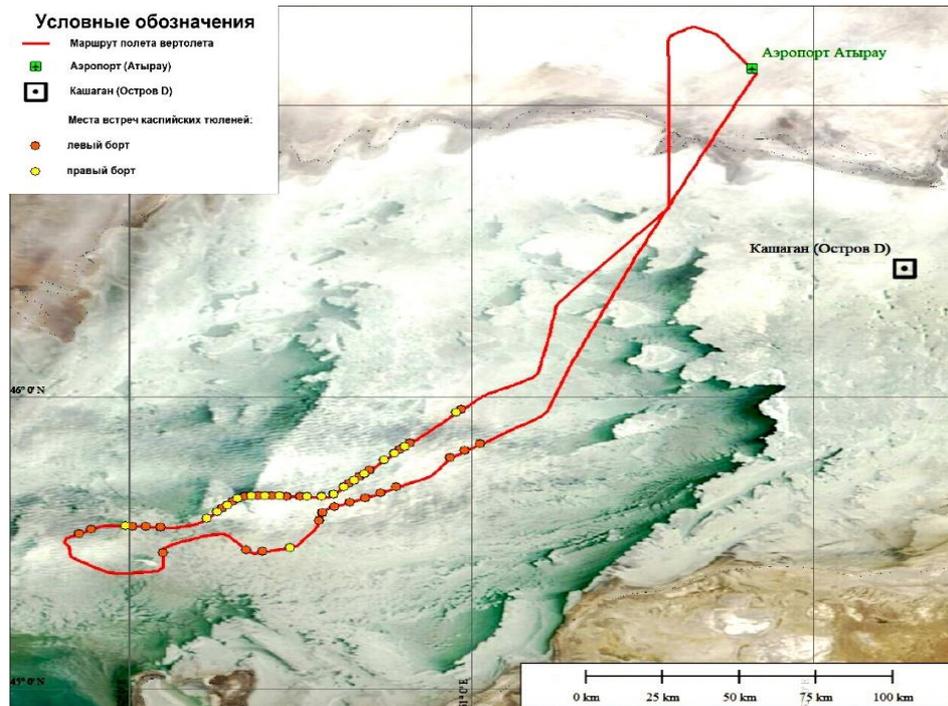
Nine sites with the highest density of Caspian seals were identified during the survey (Table 4.2-1).

**Table 4.2-1** Sites with Maximum Seal Density on the Aerial Survey Route on 18.02.2024

Coordinates of Seal Haul-out Sites		Number of Individuals in Haul-out		
Latitude	Longitude	Adults	Pups	Total
N45° 39.658'	E50° 22.610'	25	6	31
N45° 39.396'	E50° 34.939'	11	6	17
N45° 39.496'	E50° 30.005'	11	5	16
N45° 39.437'	E50° 32.471'	10	4	14
N45° 39.685'	E50° 21.389'	11	2	13
N45° 39.606'	E50° 25.075'	9	3	12
N45° 40.742'	E50° 36.769'	11	1	12
N45° 34.444'	E50° 33.276'	8	3	11

Coordinates of Seal Haul-out Sites		Number of Individuals in Haul-out		
Latitude	Longitude	Adults	Pups	Total
N45° 42.833'	E50° 39.442'	4	6	10

This information was used to plan routes for aerial survey flights using a Piper PA-34 airplane.



**Figure 4.2.10 Exploration flight route on February 18, 2024**

On February 19, the Piper RA-34 airplane arrived in Atyrau, and the aerial survey equipment was installed. Permits for air registration flights from specialized state bodies were obtained in advance (from the Main Center of the Internal Affairs Directorate of the Air Defense Forces of the Armed Forces of the Republic of Kazakhstan - January 8, from the Border Service of the National Security Committee of the Republic of Kazakhstan - January 15, from the Commander of the Air Defense Forces of the Air Defense Forces of the Armed Forces of the Republic of Kazakhstan - January 18). From February 19 to 23, 2024, due to difficult weather conditions over the North Caspian Sea, flights were prohibited by the Atyrau Airport aviation service. The first survey flight took place on February 24, 2024.

From February 24 to March 1, 2024, research was conducted to obtain reliable data on the distribution of Caspian seals, their abundance, and the number of offspring. The scientific team, consisting of Klimov F.V., Loskutov E.A., Chernook V.I., and Vasiliev A.N., successfully carried out the research. Figure 4.2.11 shows the team working during a survey flight.



**Figure 4.2.11** Operators working on board the airplane, with cameras and thermal imagers mounted under the table

#### **Aerial Survey on 02.24.2024:**

Satellite information on ice conditions was thoroughly analyzed before the flight. A flight route was developed based on satellite images of ice distribution, focusing on the western part of the ice cover. Transects were laid at 8 km intervals in the meridional direction (north-south).

The reconnaissance started from the west, near the border of Kazakhstan with the Russian Federation, moving east along the transects.

In the morning, there was low cloudiness, fog, and wind at 4-6 m/s. The airplane took off at 11:00 and landed at 15:52 Atyrau time, with a flight duration of 4 hours and 52 minutes. The flight altitude on the transects was about 180 m, with an average speed of 200-220 km/h, covering a total route length of 1977 km.

After the flight, the collected data was carefully analyzed, and adjustments were made to the aerial cameras' configuration and the software operation.

Figure 4.2.12 shows the ice distribution on 20.02.2024 and the route of the flight conducted on February 24-25, 2024. The main seal aggregations were at the ice edge, consisting of shoal haul-outs. An example of a haul-out is shown in Figure 4.2.13.

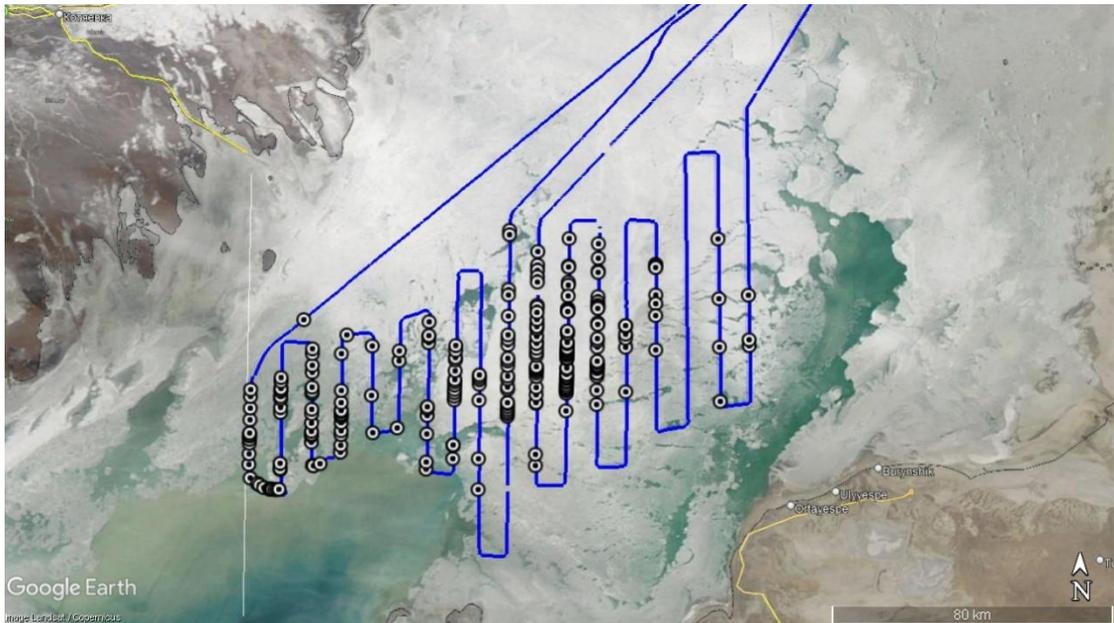
Seals were observed on all 10 transects, with many pups on the ice. Rare blood spots from pup births were observed, fewer than 10.

#### **Aerial Survey on 02.25.2024:**

On February 25, the plane took off at 11:00 and finished the flight at 15:05 in Atyrau, with a duration of 4 hours and 35 minutes. Flight altitude was maintained at 160-180 m, with a speed of 200-220 km/h, covering a total route length of 1918 km. Weather conditions included temperatures from -4°C to -12°C, with a south wind at 4-8 m/s.

Transects continued from the February 24 flight (from the 10th transect of February 24 to the east), oriented in the north-south direction with an 8 km distance between transects (Figure 4.2.12).

The flight allowed to clarify the distribution of seals in the eastern part of the ice cover. The flight was carried out on 8 transects, which allowed us to determine the main area of seal haul-outs.



**Figure 4.2.12** Route of the exploration flight on February 24-25, 2024 shown on the satellite map of ice distribution (MODIS, 22.02.2024)



**Figure 4.2.13** Perspective photo of a seal haul-out at the ice edge

**Aerial Survey on 02.26.2024:**

On February 26, due to bad weather, fog, and strong winds up to 15 m/s, the airport meteorological service did not give permission for the flight. Primary analysis of multispectral imagery data from February 24 was carried out.

**Aerial Survey on 02.27.2024:**

On February 27, the plane took off at 11:29 and finished its flight at 14:32 in Atyrau, with a duration of 3 hours and 03 minutes. Flight altitude was maintained at 160-180 m, with a speed of 180-240 km/h. Weather conditions included faint fog, temperatures from -6°C to 0°C, and a south wind at 6-11 m/s. The flight was stopped due to increased cloudiness, and the plane returned to Atyrau airport, covering a total route length of 991 km.

**Aerial Survey on 02.28.2024:**

The flight route was developed based on the results of the previous flights and satellite images of ice distribution. The flight lasted 3 hours and 20 minutes, with an altitude of 170-190 m and a speed of 200-230 km/h, covering a total route length of 876 km. Due to heavy cloudiness, the flight was terminated, and the plane returned to Atyrau airport.

Weather conditions included temperatures from -8°C to 0°C, southwest wind at 6-10 m/s, and heavy cloudiness in places.

**Aerial Survey on 02.29.2024:**

On February 29, at the request of the military of Kazakhstan, flights over the North Caspian Sea area were prohibited. The day was used to analyze and process flight materials from February 25.

**Aerial Survey on 01.03.2024:**

The flight route was developed based on the results of the previous flights and satellite images of ice distribution. The flight lasted 5 hours and 04 minutes, with an altitude of 170-190 m and a speed of 200-230 km/h, covering a total route length of 1112 km. Weather conditions included temperatures from +2°C to +4°C, with a southwest wind at 3-6 m/s.

From February 24 to March 1, almost all areas with seal haul-outs in the North Caspian Sea within Kazakhstan's zone were surveyed using a grid of transects spaced 4 km apart, covering 54 transects. Some transects in the central part of the ice cover were repeated due to ice field displacement.

**Visual Count Data for 24.02.2024 - 01.03.2024**

According to visual counts from the starboard side of the plane within a 400 m strip, 7098 adult Caspian seals were counted. Counting of pups was not conducted due to significant error, as some pups had light coloration and merged with the ice surface (Table 4.2-1).

**Table 4.2-2 Visual Aerial Count of Adults from the Starboard Side of the Airplane, individual/traverse**

Traverse No.	24.02.2024	Traverse No.	25.02.2024	Traverse No.	27.02.2024	Traverse No.	28.02.2024	Traverse No.	01.03.2024	TOTAL
1	394	1	336	1	128	1	24	1	186	1068
2	221	2	184	2	264	2	88	2	273	1030
3	193	3	47	3	206	3	93	3	305	844
4	301	4	7	4	199	4	118	4	126	751
5	52	5	16	5	145	5	38	5	75	326
6	184	6	0	6	96	6	65	6	138	483
7	75	7	3	7	144	7	117	7	223	562
8	126	8	0	8	70	8	213	8	266	675
9	105			9	266	9	118	9	188	677
10	246			10	164	10	74	10	101	585
11						11	0	11	0	0
12						12	29	12	68	97
<b>Total</b>	<b>1897</b>		<b>593</b>		<b>1682</b>		<b>977</b>		<b>1949</b>	<b>7098</b>

#### 4.3. AERIAL SURVEY OF CASPIAN SEAL HAUL-OUTS AND MOLTS, APRIL 2024

In spring 2024, the second stage of research involved aerial surveys of seal haul-outs and molts in April. The surveys were performed on a Piper UP-P3402 airplane (Figure 4.3.1) using video and photo recording, at an altitude of 200 m.

The specialists from KAPE LLC - Klimov F.V., Mulyaev A.N., and Boyko V.V. participated, with pilots Unzhakov S. and Zhukov E. (Figure 4.3.1).

Photo documentation was carried out using two Nikon D850 cameras with full-frame 46 MP sensors and F=50mm lenses in infinite focus mode, providing photography of the central part of the transect. The combined angle of view of these cameras was 78 degrees, with simultaneous triggering. GoPro 11 and DJI Osmo Action 3 large format video cameras were also used. Visual observations were made from both sides of the airplane.

Flight parameters (time, coordinates, heading, altitude, speed, etc.) were recorded every second using the Garmin GPS satellite navigation system. Coordinates were obtained in degree format with decimal fractions (45.36158, 52.25318). All cameras and GPS were synchronized to within 1 second. Equipment was calibrated and tested on the ground before the flights.

A catalog of files was created for each flight, with coordinates defined for each image. Files were synchronized to identify overlapping areas between the two cameras to avoid duplication of seal counts in different photos.



**Research Airplane UP - P3402**

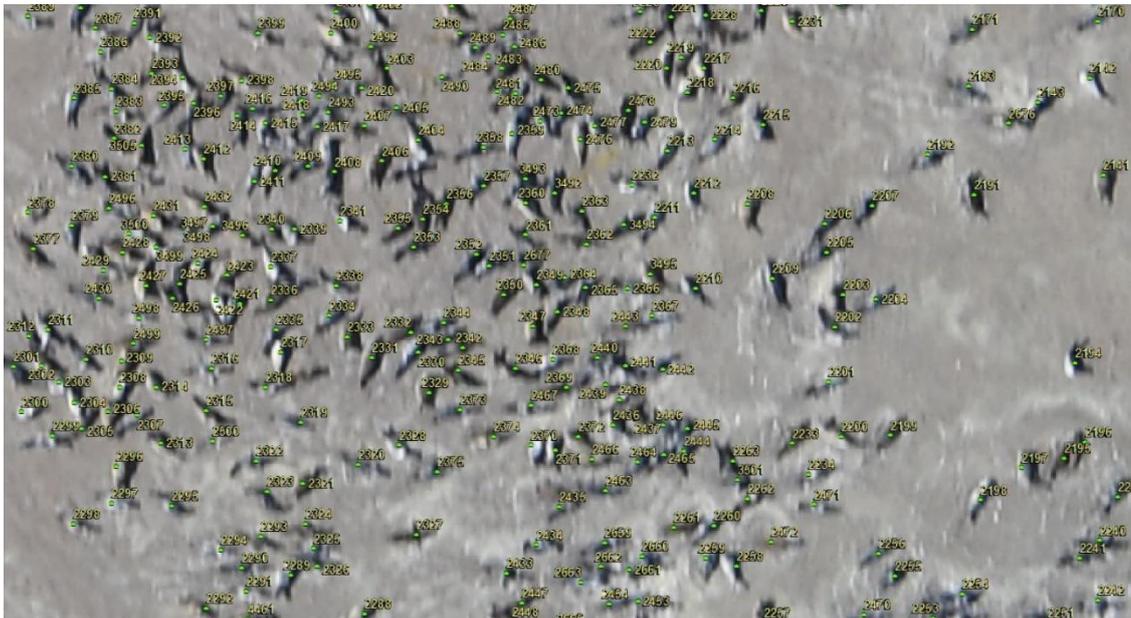


**Field Team**

**Figure 4.3.1 Field surveys in spring 2024**

The total length of the route was over 2635 km. During the aerial survey, 9,838 photos and 70 video clips (totaling 539.4 GB) were taken along the entire route. Visual observations were also made from both sides of the airplane. According to photo, video, and visual observations, seal aggregations were observed on 23 out of 61 surveyed islands/sand islands in the North-Eastern Caspian Sea.

The first stage involved browsing files to identify Caspian seal images. In the second stage, these images were processed with a graphic program with a counting function (Figure 4.3.2). Parts of sand islands in different photos were "stitched" in Adobe Photoshop CC 2019 to avoid duplicate counts. The final stage involved creating an MS Excel 2010 spreadsheet with photo names, capture times, GPS coordinates, and the number of individuals. Map construction was carried out in QGIS 3.10.0 Geographic Information System.



**Figure 4.3.2 Counting seals on the sand island**

#### 4.3.1. Aerial Survey Flights, April 2024

The aerial surveys were conducted over six days, from April 8 to April 12, 2024, covering more than 2,635 km.

##### **April 8, 2024 aerial survey:**

Mobilization of personnel, installation of equipment on Piper UP-P3402, check of equipment operation, adjustment, quality control. Meeting with customer representatives, briefing on safe work conduct, discussion of the scope of work.

##### **April 9, 2024 aerial survey:**

**Plan:** Count Caspian seals on islands, shoals, and sandbanks in the north-eastern Caspian Sea, within the Kazakhstan sector (Kashagan area, Aktoty, Kairan, Prorva, Durneva Islands).

**Actual:** An aerial survey was conducted to count the number of Caspian seals on islands shoals and sand island of the north-eastern Caspian Sea within the boundaries of the Kazakhstan sector of the Caspian Sea (Kashagan area, Aktoty, Kairan, Prorva, Durneva islands, repair shoals). Several significant groups of seals were observed (repair shoals 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 amounted to 845 km. The flight route is shown in Figure 4.3.3.

##### **April 10, 2024 aerial survey:**

**Plan:** Survey of sea shoals south of the North Caspian Sea Canal, new Durnev Island, sea shoals north of Buzachi settlement in the direction to Morskoy Island.

**Actual:** A survey of sea shoals south of the North Caspian, new Durnev Islands, repair shoals along the coast of Buzachi Peninsula - in the direction to Morskoy Island was carried out. The total length of the route was 893 km. The flight route is shown in Figure 4.3.3.

16 00 -20 00: Primary analysis of photo and video materials from the survey conducted between 16:00 and 20:00.

**April 11, 2024 aerial survey:**

**Plan:** Count Caspian seals on Seal Islands, along the coast of Buzachi and Tupkaragan.

**Actual:** An aerial survey was carried out to count the number of Caspian seals on Seal Islands, sand islands west of the Kashagan field, along the coast of Buzachi and Tupkaragan semi peninsula and west of the Kashagan field.

Several significant groups of seals were observed in the new sand islands located south of the Kashagan field, with a total of about 1000 different-aged Caspian seals. The total length of the routes amounted to 897 km. The flight route is shown in Figure 4.3.3.

**April 12-13, 2024 aerial survey:**

**Plan:** Desk work, transfer of photo and video materials to NCOC, demobilization of specialists, equipment and crew.

**Desk work:** work with photo and video materials of the Caspian seal survey in the north-east of the Caspian Sea within the boundaries of the North Caspian Sea. Transfer of primary data and results of photo and video survey carried out in April 9-11, 2024 to NCOC.

April 12-13, 2024: demobilization of specialists, equipment and airplane to the places of permanent deployment.

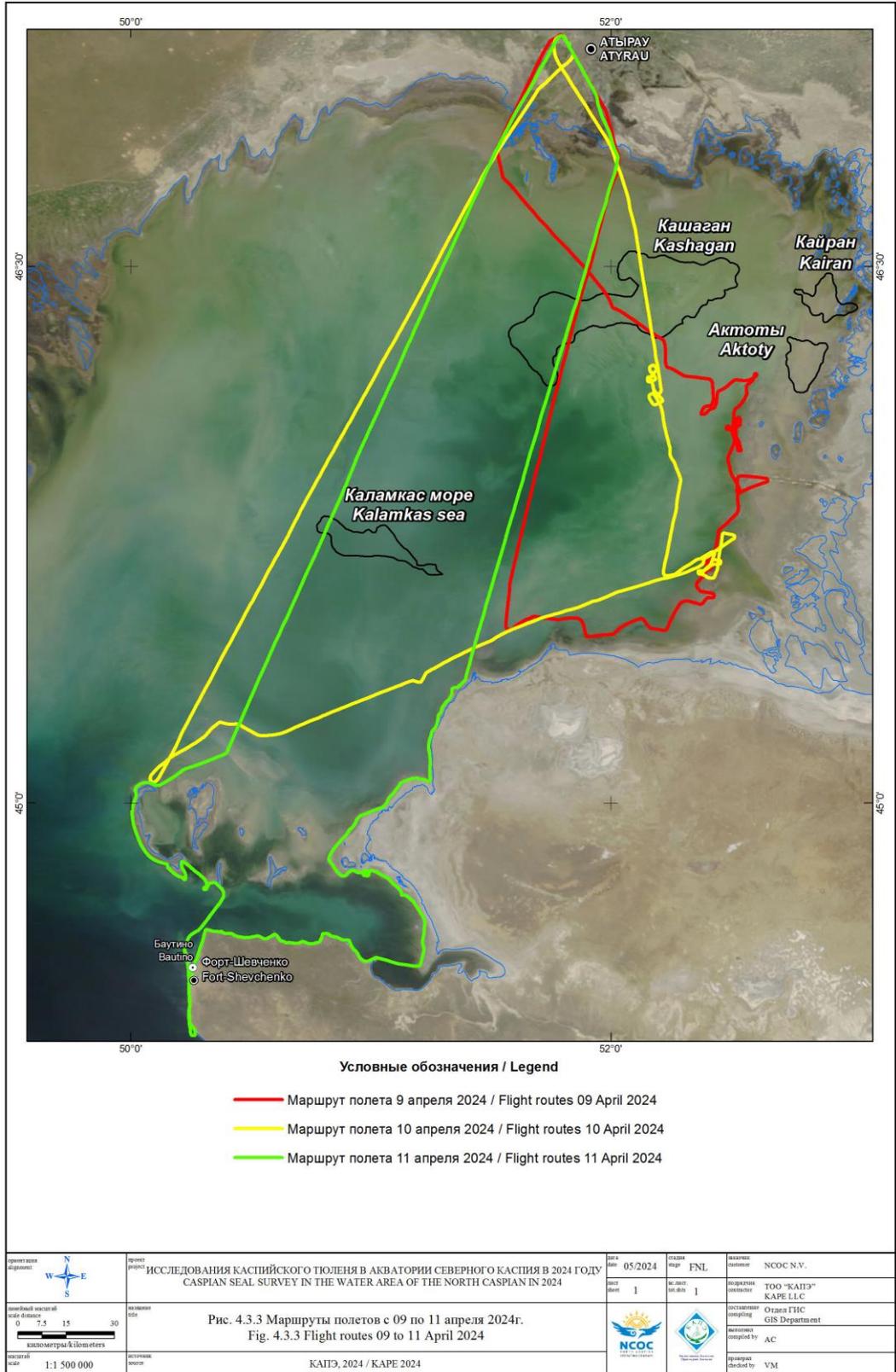
According to the results of flights from April 8 to 12, 2024 in the water area of the north-eastern Caspian Sea including Seal Islands and the Buzachi and Tyupkaragan coast, the area of 2635 km<sup>2</sup> was surveyed, 23 sea shoals were identified (Figure 5.6), where molting of Caspian seal took place in April 2024 (Table 4.3-1).

**Table 4.3-1 Caspian Seal Abundance on Islands and Shoals in the North-East Caspian, 2024**

No.	Object	North latitude	East longitude	Number of seals, individuals
1	Submerged longnose sand island	N46° 07' 56.3"	E52° 25' 35.4"	867
2	Long, elongated sand island	N46° 07' 24.3"	E52° 25' 27.1"	7675
3	Submerged elongated sand island	N46° 05' 52.4"	E52° 22' 45.8"	906
4	Long submerged sand island.	N46° 08' 11.5"	E52° 26' 27.4"	2176
5	Sand island in the shape of a frying pan	N46° 10' 51.7"	E52° 33' 12.5"	59
6	Small submerged sand island	N46° 07' 28.9"	E52° 33' 01.4"	780
7	Oval submerged shisha	N46° 06' 28.5"	E52° 31' 42.7"	72
8	Elongated long sand island, broken by a strait	N46° 02' 55.1"	E52° 30' 27.8"	4408
9	Elongated long sand island	N45° 59' 36.3"	E52° 31' 34.1"	286
10	Long oval sand island	N46° 03' 00.3"	E52° 31' 13.8"	5428
11	Knife-shaped sand island	N46° 03' 56.5"	E52° 31' 20.3"	8721
12	Long submerged sand island.	N45° 55' 59.3"	E52° 29' 44.4"	1154
13	Narrow, elongated sand island	N45° 39' 47.9"	E52° 24' 45.3"	9472
14	Long submerged sand island.	N45° 39' 17.5"	E52° 24' 08.1"	784
15	Long submerged sand island.	N45° 39' 12.9"	E52° 24' 18.2"	453
16	Narrow, elongated sand island	N45° 39' 48.4"	E52° 25' 10.0"	19
17	Seal-shaped sand island	N46° 09' 35.5"	E52° 10' 32.8"	6
18	Chain of small submerged sand islands	N46° 10' 08.9"	E52° 10' 24.2"	374
19	Submerged shoal with two islands	N46° 10' 30.9"	E52° 10' 14.5"	115
20	Chain of small submerged sand islands	N46° 11' 56.3"	E52° 10' 24.3"	114
21	Small elongated submerged sand island	N46° 09' 40.0"	E52° 10' 33.7"	34
22	Elongated submerged sand island	N46° 06' 55.4"	E52° 11' 19.9"	30
23	Elongated submerged sand island	N46° 07' 50.0"	E52° 11' 27.4"	60
	<b>Total:</b>			<b>43 993</b>

Desk work on data processing to estimate the number of Caspian seals on the islands and shoals was conducted in the research laboratory of KAPE LLC. The analysis showed a total of **43,993** seals, with numbers ranging from **6 to 9,472** per location.

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**Figure 4.3.3 Flight routes, April 9-11, 2024**

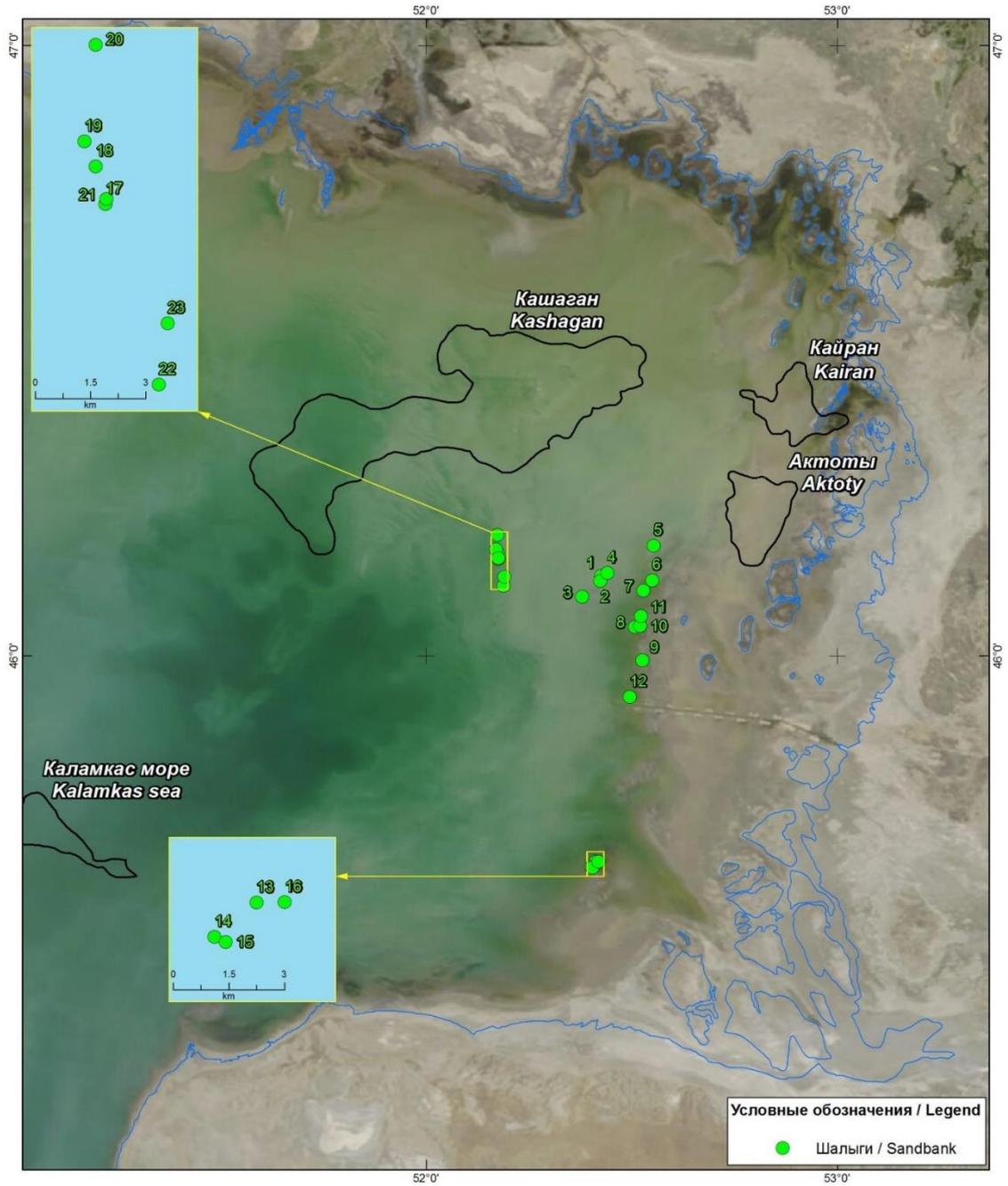


Figure 4.3.4 Location of seal haul-outs in the North-East Caspian Sea, April 2024

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#### 4.4. DISCUSSION

Comparing satellite data with the classification of winter severity in the Caspian region indicates that the 2023-2024 winter was mild. The sum of frost degree days at sea was about 250-260, and ice breakup lasted 111 days, with ice cohesion ranging from 1-9 points and thickness from 5-45 cm.

In the winter of 2024 (February), the first stage of research was carried out - multispectral aerial survey of the Caspian seal haul-outs. The aerial survey of the seal haul-outs on ice was carried out from a Piper PA-34 airplane. The survey flights were made under good weather conditions. The main instrumental aerial survey of seals was carried out using two Optris PI450 and Flir A325 thermal imagers and cameras (Nikon D850 and GoPro11) fixed in the lower part of the airplane's fuselage.

During the period of the aerial survey, all ice was in the northeastern and northwestern part of the North Caspian Sea. The main seal haul-outs on the ice were found in the Kazakhstan sector. During the flights from February 24 to March 1, practically all areas with seals in the North Caspian within the borders of the Republic of Kazakhstan were surveyed using a regular grid of transects with a distance of 4 km. Some transects in the central part of the ice cover were repeated on different dates of flights. As a result of the aerial survey, a large amount of data on the distribution and abundance of seals in the winter of 2024 was obtained. According to the aerial survey data, no dead seals were found on the ice field.

The second research stage in April 2024 involved aerial surveys of rookeries and molts of Caspian seals, using a Piper PA-34 airplane with video and photo equipment (Nikon D850, DJI Osmo Action, GoPro 11).

The coast of the North Caspian Sea, North Caspian Sea Canal (artificial islands), sea shaligas, Seal Archipelago islands, Durneva Island, coast of Buzachi Peninsula, Tyupkaragan, Mangyshlak from Bautino settlement to Saury settlement were surveyed.

According to the results of flights from April 9 to 11, 23 sea shoals were identified, where the Caspian seal molting took place in April 2024. The number of Caspian seal on sea shoals, islands, including shallow waters, in areas of seal haul-outs amounted to 43993 different-aged individuals and varied from 6 to 9472 individuals per shoal.

In the spring of 2024, 64 seal carcasses were found on Kulaly Island and Tyupkaragan Spit, possibly due to an epidemic. No seal haul-outs were observed along the Buzachi and Tyupkaragan coasts, but mass aggregations of flamingos, pelicans, swans and other seabirds were observed. seabirds were noted.

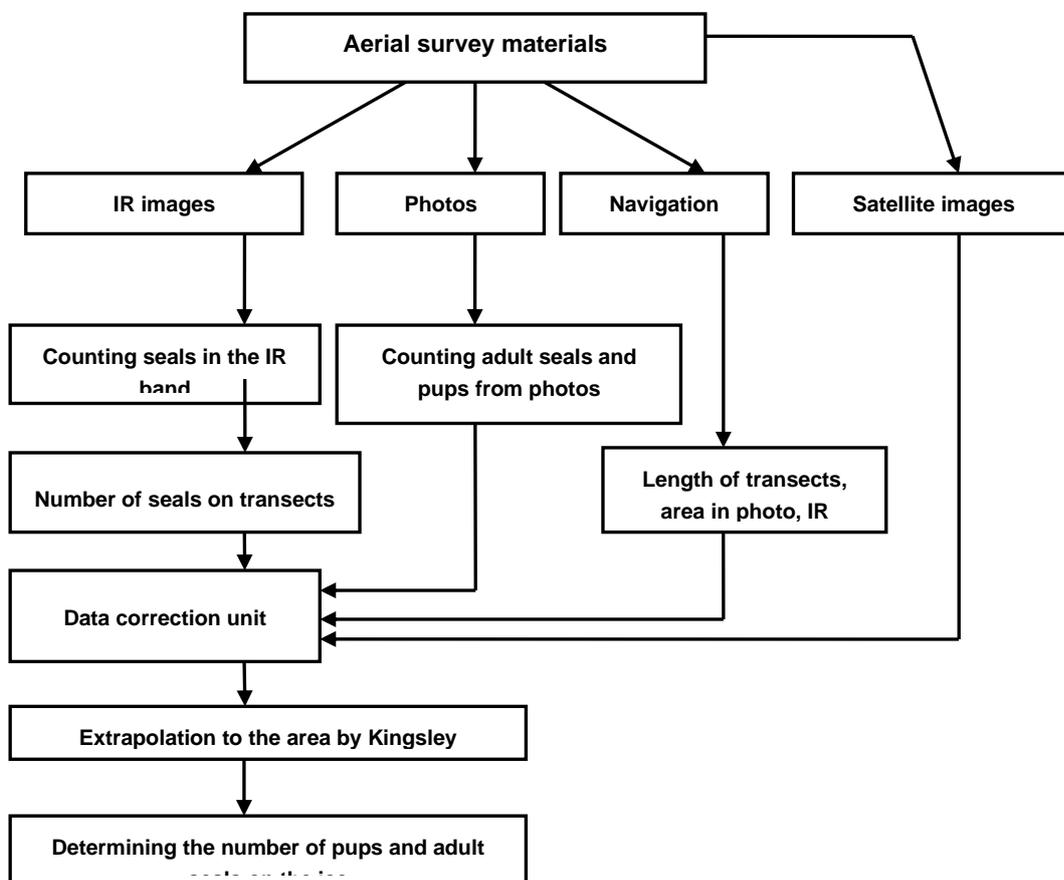
**5. PROCESSING OF AERIAL SURVEY MATERIALS**

**5.1. MULTISPECTRAL AERIAL SURVEY OF CASPIAN SEAL ICE HAUL-OUTS**

**5.1.1. Initial processing of air logging materials**

After the aerial survey of the Caspian seal was carried out, the primary processing of aerial survey materials was carried out, which consisted of several stages. The most labor-intensive is the stage of counting seals on infrared and photographic images, the volumes of which are constantly increasing with increasing resolution of aerial survey equipment. Instrumental aerial survey is carried out simultaneously in the visible and infrared ranges.

The block diagram of the technology of processing of aerial survey materials is shown in Figure 5.1.1.



**Figure 5.1.1 Block diagram of seal aerial survey data processing technology**

At the preparatory stage of desktop processing, primary analysis is performed, including review, sorting and selection of materials, and cataloging of all collected material is performed. The dates of aerial surveys are determined, based on the materials of which 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 IR file is determined, and taking this into account, all photos are renamed by a specially developed program. The photos are assigned names of the following kind: Year\_month\_day hour-min-sec\_camera code.jpg (L - left, R - right).

Analysis of complex aerial survey materials is performed:

- promptly during the period of aerial survey work on the materials of each survey flight - in order to assess the quality of survey materials, to map the distribution of seals and to optimally plan the routes of subsequent survey flights;
- in laboratory conditions - a long stage of complex ground processing, starting with viewing and systematization of all accumulated material, selection of high-quality images of different spectral ranges suitable for analysis, cataloguing of all collected material. After preliminary separate processing of images of different spectral ranges, they are analyzed together with interpretation of the survey objects - adult seals and pups.

### 5.1.2. Co-processing of photographic and IR materials

The previously developed technology of complex processing of instrumental survey materials was applied to the materials of aerial survey of the Caspian seals' breeding grounds.

Stage 1: All infrared images are reviewed. The flights are selected, in which all possible locations of Caspian seal haul-outs were covered by aerial survey in a short time - February 24 to March 1, 2024. During the flights the main area of distribution of dense haul-outs was covered by survey transects, the boundaries of seal haul-outs were clearly fixed. A high-quality synchronous photo and thermal imaging survey of seal aggregations was carried out.

Step 2: The hot spot thermal images and their corresponding digital photographs are jointly analyzed for marine mammal detection.

Data processing is performed on thermal images and photographs of Caspian seals. Counting of seals on thermal images and photographs was performed by two operators independently of each other. Beforehand, each operator underwent a training phase. Operator training began with training to detect heat-spotted seals on thermal images and to separate them into adults and pups using appropriate photographs. For the purpose of training, the operators independently reviewed selectively the photographic and thermal imagery materials, highlighting characteristic features of ice conditions and seal location, and made interpretation of adults and pups.

Application of both infrared and photographic surveys allows to increase reliability and accuracy of seal abundance determination, but at the same time complicates the procedure of materials processing. It is necessary to process the materials of each spectral channel and, in addition, their mutual analysis and correction in the presence of various factors complicating the processing: change of scale of the underlying surface image from the center to the edges of the survey strip both on photographic and infrared images, different degree of distinction of animals in different spectral channels under different weather conditions, etc.

Materials of visible and infrared ranges (Figure 5.1.2) complement each other, considerably facilitating the detection of animals on the ice. IR images allow quick detection of seals, while photographs allow identification of adults and pups, filtering out various interferences in the IR image (spots of heated ice at the place of animals that have gone into the water or changed their haul-out place just before the moment of photographing, holes, sun glare from mirror-smooth ice floes, etc.). All suspicious IR spots were examined in detail on photographs, after which identification was made - whether it was a seal or not.

The use of infrared imagery is particularly effective when searching for baby seals. Even an experienced researcher is not always able to see a baby seal on a photo image, because baby seals have white camouflage coloration and, besides, they often hide from the wind in hummocks. Joint analysis of infrared and photographic images due to better detection of pups increases reliability and validity of counting animals on the ice.

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

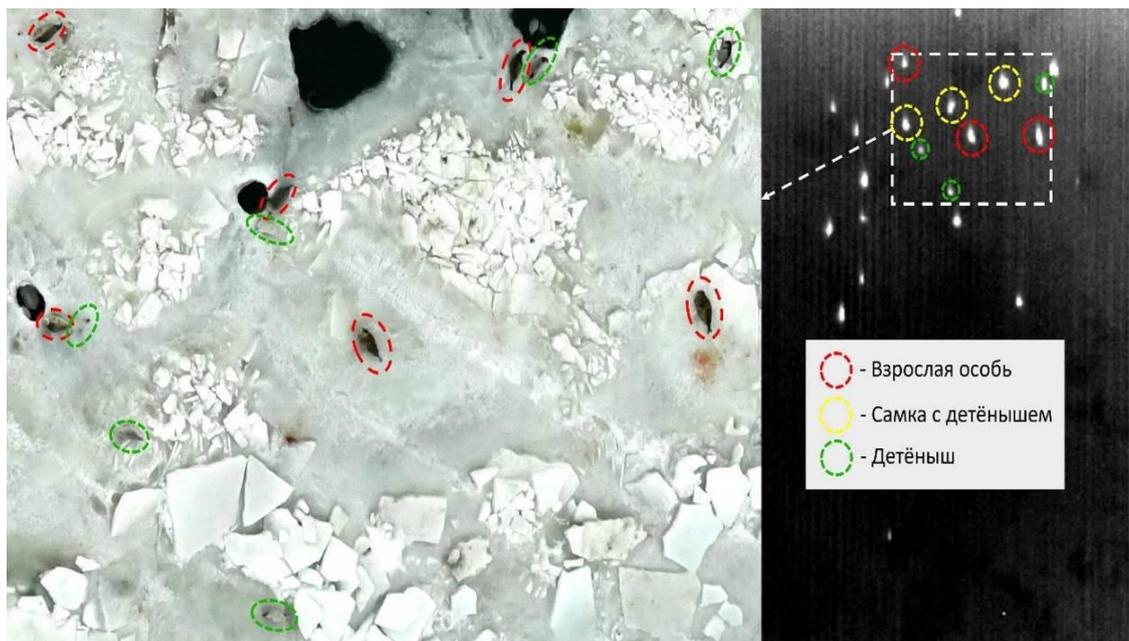
- a) Linking to the thermal image of an arbitrarily selected photograph of one of the cameras (we orient ourselves by the time of photographing, time on the thermal image, by the

configuration of characteristic ice floes, as well as by the location of animals on the ice - Fig. 4.2.9).

- b) Selection of photos with animals (we focus on IR images in the selection).
- c) The operator, comparing the images on photo and IR, based on the characteristic features of the ice and the location of seals on it, determines the position of the camera and thermal imaging camera bands relative to each other.
- d) Identification and tagging of animals in photographs is performed on two computers using three high-resolution monitors. On one computer the operator finds thermal highlights on the thermal image, then on the second computer he identifies the animal (adult or white collar pup) from the reference photo and sets tags of different colors for each species on the photo image using a mouse. An example of a photo image with tags of adult seals (red color tags) and baby seals (green color tags) is shown in Figure 5.1.2.

A molted sivar pup is characterized by two parameters by which it is identified in photographs:

- silver-gray fur coloration, which is present in individuals only in the first year of life. With subsequent molting, the fur coloration acquires a structure similar to that of adults;
- Sivars range in length from 80 to 96cm (average length is 88cm) and yearlings have an average length of 123cm.



**Figure 5.1.2** Fragments of infrared image and photo of the seal haul-out on ice (24.02.2024, 11:59:21) The green ovals highlight the puppies, the red ones – the adults. In the fragment of the IR image, the yellow ovals highlight the “hot spots” from the females with the cubs lying nearby

The information about the placed marks is saved by the program "jpegproj" in the output text file, which allows to display the photo image with the marks of any operator displayed on it, as well as to place the marks on the map in GIS-programs. The "jpegproj" program provides a possibility to edit information about the marked objects and to add additional information, for example, about behavioral features of seals, ice characteristics, etc.

The "MapViewer 7" and "Google Earth" software products were used as GIS application software environment.

The use of GIS made it possible to map the routes of aerial surveys (see Figure 4.2.12), make spatial georeferencing of thermal and photographic images, make spatial georeferencing of graphical satellite ice maps using MODIS satellite system, and construct maps of seal abundance distribution.

### 5.1.3. Summary of instrumental survey results, winter 2024

During 5 flights carried out from February 24 to March 1, 2024 practically the entire ice cover with seal haul-outs was surveyed along 54 transects with a distance of 4 km.

To determine the number of seals on transects, counts were made using thermal images and high-resolution photographs from Nikon D850 cameras. Adult seals and pups were counted independently by four experienced personnel members. The final results of seal counts placed on the ice of the North Caspian Sea are summarized in Tables 5.1-1 and Table 5.1-2.

In the period from February 24 to March 1, 2024, the ice situation was relatively stabilized. Figure 4.2.11 showed the flight routes, the results of which were used to calculate the Caspian seal abundance, superimposed on two different satellite images made in February 24 and 25, 2024.

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

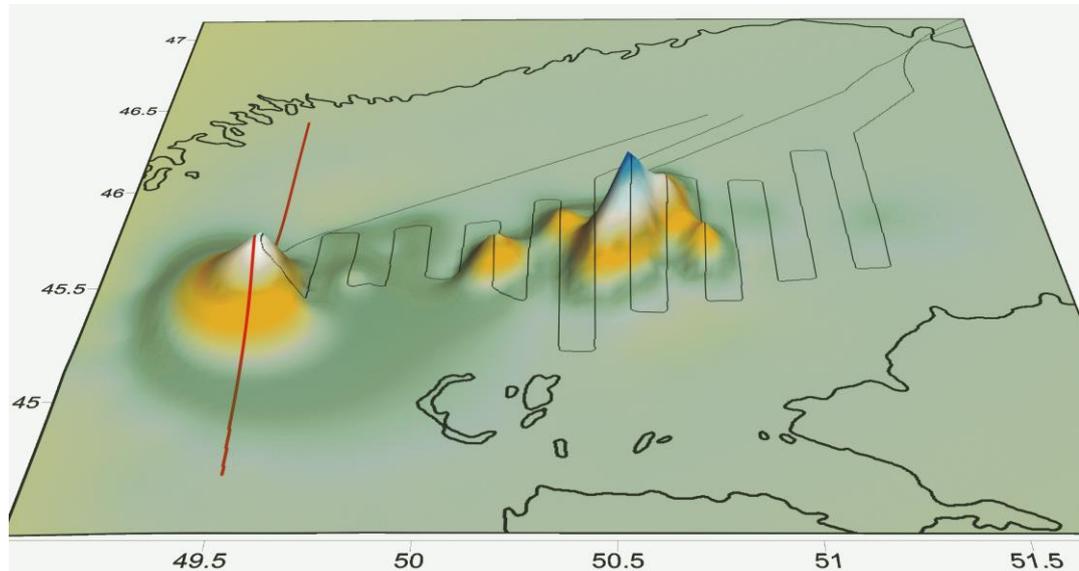
**Table 5.1-1 Ratio of adults and pups found on the ice of the Kazakhstan and Russian sectors of the Caspian Sea during February 24-25, 2024**

Area	Adults, individuals	White collars, individuals	Molting, individuals	Sivari, individuals	Total, individuals	Including pups, individuals	Proportion of pups, %
Kazakhstan sector	3409	162	661	527	4759	1350	28,15
Russian sector	1060	50	203	161	1474	414	28,09
<b>Total</b>	<b>4469</b>	<b>212</b>	<b>864</b>	<b>688</b>	<b>6233</b>	<b>1764</b>	<b>56,24</b>

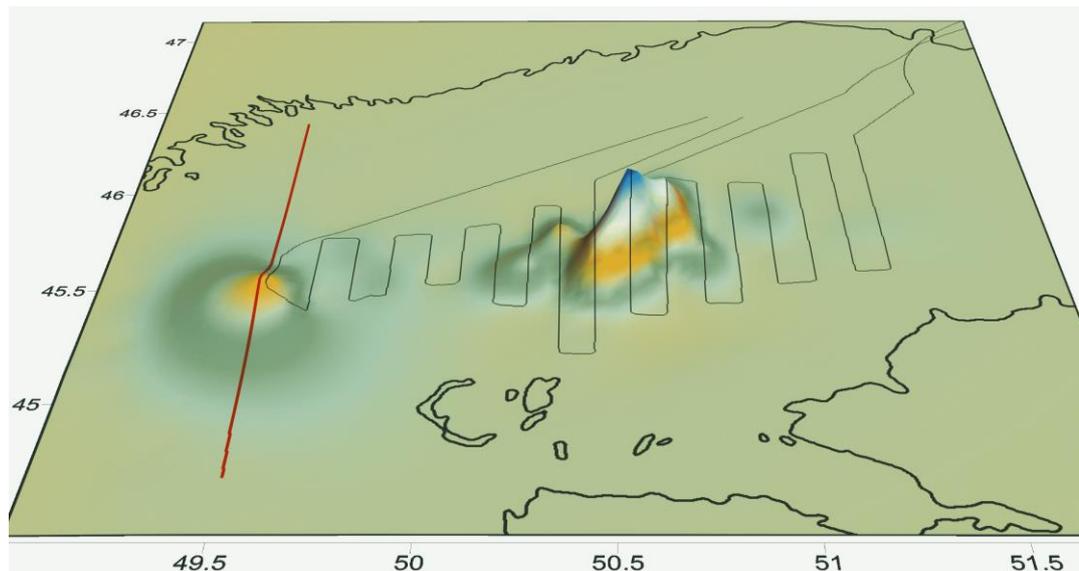
**Table 5.1-2 Ratio of adults and pups found on the ice of the Kazakhstan and Russian sectors of the Caspian Sea during February 24-25, 2024**

Date of flight	White collars, individuals	White collars proportion, %	Molting, individuals	Moulting seals proportion, %	Sivar, individuals	Sivars proportion, %	Total of pups
Kazakhstan sector	162	12	661	49	527	40	1350
Russian sector	50	12	203	48	161	39	414
<b>Total</b>	<b>212</b>	<b>12</b>	<b>864</b>	<b>49</b>	<b>688</b>	<b>39</b>	<b>1764</b>

Analyzing the distribution of Caspian seal pups in February 24 and 25 (see Figure 5.1.4), it can be noted that the main pup haul-outs of Caspian seals in the Kazakhstan sector 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 pups were found either. In the west, near the border with the Russian territory, aggregations of adults and pups were recorded, and the method of extrapolation of the data obtained on the adjacent transects within the RK boundaries to this territory was used to determine their numbers. There were practically no pups on the 3 eastern transects of the area. Single pups were recorded in the north-east of the area in ice leads at the ice edge.



**Figure 5.1.3** Density distribution of adult seals on the flight paths for February 24 and February 25 of 2024



**Figure 5.1.4** Density distribution of seal pups on the flight paths in February 24 and February 25 of 2024

#### 5.1.4. Calculation and estimation of Caspian seal abundance on the ice field

Surveys were made on parallel transects of different length but the same width, as the altitude was kept constant in each flight. The interval between transects was the same and equal to 4 km. This made it possible to extrapolate the results of counting adult seals and pups on transects to the entire surveyed water area with an estimate of the number of adult seals and pups according to the Kinsley method [Kingsley et al, 1985]. Calculation results for KSCS territory are given in Tables 5.1-3 - 5.1-4. By extrapolation method three transects were laid westward from the territory of the Republic of Kazakhstan, which allowed to calculate the estimated abundance in that area. The calculated data for the territory of the Russian sector are presented in Tables 5.1-5 - 5.1-6.

**Table 5.1-3 Calculation of the number of cubs on the Caspian Sea ice (based on flight data for February 24 and 25, 2024), Kazakhstan sector**

Trip number	Length of trip, km	Flight altitude, m	Width of the accounting strip, m	Counting strip area, sq. km	Number of cubs, individuals	Observed population density, individuals/sq. km	Sector width, km	Sector area, square kilometers.	Extrapolated number in the sector, individuals	Statistical error of extrapolation
24-1	28	173	187	5.2	576	109.8	8.00	224	24604.7	11939
24-2	40	178	192	7.8	261	33.6	8.00	323	10852.9	11952
24-3	33	174	188	6.3	223	35.5	8.00	268	9509.0	841
24-4	34	177	191	6.4	189	29.4	8.00	269	7901.6	3603
24-5	27	177	191	5.1	12	2.4	8.00	214	503.3	2937
24-6	30	177	192	5.8	42	7.2	8.00	244	1754.1	619
24-7	44	174	188	8.3	79	9.5	8.00	354	3359.7	411
24-8	56	179	193	10.9	93	8.5	8.00	452	3853.1	696
24-9	80	173	186	14.8	85	5.7	8.00	636	3647.4	1259
24-10	96	175	189	18.1	52	2.9	8.00	766	2201.7	21844
25-1	76	176	190	14.5	878	60.6	8.00	610	37015.3	18627
25-2	74	171	185	13.7	612	44.7	8.00	593	26494.6	9301
25-3	68	180	194	13.3	227	17.0	8.00	548	9339.7	8592
25-4	69	171	185	12.8	22	1.7	8.00	554	951.5	4263
25-5	59	185	200	11.7	28	2.4	8.00	469	1119.0	454
25-6	77	155	168	12.9	7	0.5	8.00	613	333.9	555
25-7	71	172	186	13.1	10	0.8	8.00	565	430.0	66
25-8	84	167	180	15.1	13	0.9	8.00	668	576.5	47
<b>Total:</b>	<b>1046.3</b>			<b>195.9</b>	<b>3409</b>	<b>17.3</b>	<b>144.00</b>	<b>8371</b>	<b>144448</b>	
<b>Extrapolation estimate of abundance and its relative statistical error</b>									<b>144448</b>	<b>0.251</b>
<b>Confidence (95%) interval for estimating the number of Caspian seal cubs on the Caspian Sea ice in the economic zone of the Republic of Kazakhstan</b>									<b>86325</b>	<b>227391</b>

**Table 5.1-4 Calculation of the number of cubs on the Caspian Sea ice (based on flight data for February 24 and 25, 2024), Kazakhstan sector**

Trip number	Length of trip, km	Flight altitude, m	Width of the accounting strip, m	Counting strip area, sq. km	Number of cubs, individuals	Observed population density, individuals/sq. km	Sector width, km	Sector area, square kilometers	Extrapolated number in the sector, individuals	Statistical error of extrapolation
24-1	28	173	187	5.2	233	44.5	8.00	224	9965.3	5110
24-2	40	178	192	7.8	92	11.8	8.00	323	3828.1	5128
24-3	33	174	188	6.3	89	14.1	8.00	268	3783.7	1279
24-4	34	177	191	6.4	29	4.5	8.00	269	1215.6	1403
24-5	27	177	191	5.1	3	0.6	8.00	214	137.3	420
24-6	30	177	192	5.8	7	1.3	8.00	244	309.5	274
24-7	44	174	188	8.3	28	3.3	8.00	354	1183.0	345
24-8	56	179	193	10.9	31	2.9	8.00	452	1300.4	321
24-9	80	173	186	14.8	24	1.6	8.00	636	1013.2	397
24-10	96	175	189	18.1	22	1.2	8.00	766	943.6	9808
25-1	76	176	190	14.5	394	27.2	8.00	610	16601.7	8278
25-2	74	171	185	13.7	294	21.5	8.00	593	12736.4	5008
25-3	68	180	194	13.3	70	5.2	8.00	548	2860.5	4607
25-4	69	171	185	12.8	8	0.6	8.00	554	337.6	1298
25-5	59	185	200	11.7	16	1.4	8.00	469	650.6	322
25-6	77	155	168	12.9	3	0.2	8.00	613	143.1	346
25-7	71	172	186	13.1	4	0.3	8.00	565	156.4	21
25-8	84	167	180	15.1	3	0.2	8.00	668	144.1	29
<b>Total:</b>	<b>1046.3</b>			<b>195.9</b>	<b>1350</b>	<b>6.8</b>	<b>144.00</b>	<b>8371</b>	<b>57310</b>	
<b>Extrapolation estimate of abundance and its relative statistical error</b>									<b>57310</b>	<b>0.286</b>
<b>Confidence (95%) interval for estimating the number of Caspian seal cubs on the Caspian Sea ice in the economic zone of the Republic of Kazakhstan</b>									<b>31771</b>	<b>95538</b>

**Table 5.1-5 Calculation of the number of cubs on the Caspian Sea ice (based on flight data for February 24 and 25, 2024), Russian sector**

Trip number	Length of trip, km	Flight altitude, m	Width of the accounting strip, m	Counting strip area, sq. km	Number of seals, individuals	Observed population density, individuals/sq. km	Sector width, km	Sector area, square kilometers.	Extrapolated number in the sector, individuals	Statistical error of extrapolation
1	40	178	192	7,8	261	33,6	8	323	10852,9	11952
2	33	174	188	6,3	223	35,5	8	268	9509	841
3	28	173	187	5,2	576	109,8	8	224	24604,7	11939
<b>Total:</b>	<b>101</b>			<b>19,3</b>	<b>1060</b>	<b>59,6</b>	<b>24</b>	<b>815</b>	<b>44966,6</b>	
<b>Extrapolation estimate of abundance and its relative statistical error</b>									<b>44966,6</b>	<b>0,251</b>
<b>Confidence (95%) interval for estimating the number of Caspian seal cubs on the Caspian Sea ice in the economic zone of Russia</b>									<b>11286,6</b>	<b>56253,2</b>

**Table 5.1-6 Calculation of the number of cubs on the Caspian Sea ice (based on flight data for February 24 and 25, 2024), Russian sector**

Trip number	Length of trip, km	Flight altitude, m	Width of the accounting strip, m	Counting strip area, sq. km	Number of cubs, individuals	Observed population density, individuals/sq. km	Sector width, km	Sector area, square kilometers.	Extrapolated number in the sector, individuals	Statistical error of extrapolation
1	40	178	192	7,8	92	11,8	8	323	3828,1	5128
2	33	174	188	6,3	89	14,1	8	268	3783,7	1279
3	28	173	187	5,2	233	44,5	8	224	9965,3	5110
<b>Total:</b>	<b>101</b>			<b>19,3</b>	<b>414</b>	<b>23,5</b>	<b>24</b>	<b>815</b>	<b>17577,1</b>	
<b>Extrapolation estimate of abundance and its relative statistical error</b>									<b>17577,1</b>	<b>0,286</b>
<b>Confidence (95%) interval for estimating the number of Caspian seal cubs on the Caspian Sea ice in the economic zone of Russia</b>									<b>5027,1</b>	<b>22604,2</b>

### 5.1.5. Results of the Caspian seal winter aerial survey in 2024

#### ***Kazakhstan sector of the North Caspian Sea water area:***

The ice cover area was large, which combined with good weather conditions allowed us to conduct an aerial survey in a short period - from February 24 to March 1 in 2024. Ice movement during this period was minimal.

Aerial counts were conducted during the optimal period when the pupping was mostly over (there were almost no blood spots on the ice). In the total number of pups, the share of white coat pups was 12%, the share of molting pups was 49%, and the share of over-molting pups (sivarians) was 31%.

The calculation was made for 18 transects with a distance between them of 4 km. The estimated number of seals on the ice is 144,448 individuals, with a statistical error of 25.1%. Of these, the number of pups is 57,310, with a statistical error of 28.6%.

The total estimated number of seals on ice within the Kazakhstan sector of the North Caspian Sea water area during the period February 24 - March 1, 2024 was 177,999, of which the number of pups was 57311.

#### ***Russian sector of the North Caspian Sea area:***

The area of the ice cover was not stable, the ice field with pup haul-outs was adjacent to the border of the Republic of Kazakhstan. In this area, the pup haul-outs started on the Russian territory and continued towards the Republic of Kazakhstan, forming several areas with increased concentration on the ice field (Figures 5.1.3 and 5.1.4).

The calculation was made by extrapolation of the data obtained in the Republic of Kazakhstan on 3 transects with a distance between them of 4 km. The estimated number of seals on the ice is 44,967 individuals, with a statistical error of 25%, of which the number of pups is 17,577 individuals, with a statistical error of 29%.

The total estimated number of seals on the ice within the Russian sector of the North Caspian Sea area on February 24, 2024 was 44,967 individuals.

Thus, the total estimated number of seals on the ice of the Kazakhstan and Russian sectors of the North Caspian Sea in the period of February 24-25, 2023 was 189.415 individuals, of which the number of pups was 74888 individuals.

### 5.2. AERIAL SURVEY OF CASPIAN SEAL SPRING MOULTED HAUL-OUTS

Fattening and molting of the seal brood is fast, during the short period of ice age in the North Caspian. Mass mating takes place in the second half of February, followed by molting of the adult stock on drifting ice and sea shoals in March-April. The area of ice patches and the density of seals on them varies depending on ice conditions. With the disappearance of the ice cover, the seals that have not molted move to shallow waters and small sandy islands, where they remain until molting is complete.

Spring population counts during the period of molt haul-outs in the KSCS were conducted from April 8 to 12, 2024. The survey covered the coast of the Kazakhstan sector of the North Caspian from the coast of the Buzachi, Tyupkaragan and Mangyshlak peninsulas, from the village of Bautino to the village of Saury, as well as the islands (Durneva Islands, Seal Islands, islands in the areas where the mouths of the Zhaiyk and Zhem rivers exit, sea sand islands, artificial islands in the North Caspian Sea Channel, and protective barriers at the Kashagan field). The total length of the routes of aerial surveys amounted to more than 2635 km. In the surveyed area of the North-Eastern Caspian Sea, according to the survey data, dead seals were found on the coast of Kulaly Island and Tupkaragan peninsula.

Based on the results of flights carried out at 61 surveyed islands and 23 sand islands (**Appendix C**), Caspian seal molting was taking place in April 2024 (Table 5.2-1).

Traces of seals that had recently been there were noted on empty sand island. It can be assumed that the molting period has passed and most of the seals have left the sand islands. The number of seals on the 23 sand islands where seals were recorded varied from 6 to over 9472 seals. The density of seals depended on the nature of a particular sand island and its location, water depth and availability of food resources. Both very dense and sparse haul-outs were recorded. Seals were very active. The total number of seals counted at the sand islands amounted to 43993 individuals.

**Table 5.2-1 Caspian seal abundance on KSCS sand islands in April 2024**

Item No.	Object	North latitude	East longitude	Number of seals, individuals
1	A submerged longnose sand island	N46° 07' 56.3"	E52° 25' 35.4"	867
2	A long, elongated sand island	N46° 07' 24.3"	E52° 25' 27.1"	7675
3	Submerged elongated sand island	N46° 05' 52.4"	E52° 22' 45.8"	906
4	A long submerged sand island.	N46° 08' 11.5"	E52° 26' 27.4"	2176
5	Sand island in the shape of a frying pan	N46° 10' 51.7"	E52° 33' 12.5"	59
6	A small submerged sand island	N46° 07' 28.9"	E52° 33' 01.4"	780
7	Oval submerged sand island	N46° 06' 28.5"	E52° 31' 42.7"	72
8	An elongated long sand island, broken by a strait	N46° 02' 55.1"	E52° 30' 27.8"	4408
9	An elongated long sand island	N45° 59' 36.3"	E52° 31' 34.1"	286
10	Long oval sand island	N46° 03' 00.3"	E52° 31' 13.8"	5428
11	A knife-shaped sand island	N46° 03' 56.5"	E52° 31' 20.3"	8721
12	A long submerged sand island.	N45° 55' 59.3"	E52° 29' 44.4"	1154
13	Narrow, elongated sand island	N45° 39' 47.9"	E52° 24' 45.3"	9472
14	A long submerged sand island.	N45° 39' 17.5"	E52° 24' 08.1"	784
15	A long submerged sand island.	N45° 39' 12.9"	E52° 24' 18.2"	453
16	Narrow, elongated sand island	N45° 39' 48.4"	E52° 25' 10.0"	19
17	A seal-shaped sand island	N46° 09' 35.5"	E52° 10' 32.8"	6
18	A chain of small submerged sand islands	N46° 10' 08.9"	E52° 10' 24.2"	374
19	A submerged sand island with two islands	N46° 10' 30.9"	E52° 10' 14.5"	115
20	A chain of small submerged sand islands	N46° 11' 56.3"	E52° 10' 24.3"	114
21	A small elongated submerged sand island	N46° 09' 40.0"	E52° 10' 33.7"	34
22	An elongated submerged sand island	N46° 06' 55.4"	E52° 11' 19.9"	30
23	An elongated submerged sand island	N46° 07' 50.0"	E52° 11' 27.4"	60
	<b>Total:</b>			<b>43993</b>

### 5.3. SUMMARY OF AERIAL SURVEY RESULTS IN FEBRUARY AND APRIL 2024

In the Kazakhstan and Russian sectors of the North Caspian Sea the number of Caspian seals on the ice field according to research data amounted to 189451 individuals in February 2024, in April (spring) 43993 individuals were recorded on sand islands. The decrease in the number of Caspian seals in the spring of 2024 may indicate the onset of feeding migrations. If we take into account that a significant number of seals have already migrated to the southern regions, then no more than 23.2% of those recorded in February 2024 remained on the surveyed sand islands.

According to visual observations, the young individuals had average fatness indicators. The high proportion of 74888 litters (39.5%) in the structure of seal haul-outs in winter 2024 indicated successful reproduction of seals in the eastern part of the North Caspian, as well as successful reproduction of Caspian seal.

Work in the water area of the Kazakhstan part of the North Caspian Sea was conducted in April, when a significant part of adults and their young migrated to the southern parts of the Caspian Sea. During the aerial survey from April 8 to 12, 2024, harbor seals were observed only in the offshore sand islands of the North-Eastern Caspian Sea (see Figure 4.3.4). According to the results of

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desktop processing the total number of registered seals on 23 sandy islands located north and south of the NCMC, sand islands north of the Seal Islands amounted to 43993 individuals, the occupancy of sand islands varied from 6 to 9472 seals.

In the winter period of 2024 no dead seals were registered on the ice field, in the spring period (April 8-12, 2024) carcasses of dead seals probably killed by the ongoing epidemic of plague of carnivores and influenza infection were recorded on the coast of Kulaly Island and the Tyupkaragan peninsula, totaling 64 individuals, during the study period.

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## 6. TOTAL CASPIAN SEAL ABUNDANCE, 2024

### 6.1. PECULIARITIES OF REPRODUCTION CONDITIONS WHEN ESTIMATING CASPIAN SEAL ABUNDANCE

The breeding areas of the Caspian seal are located in the ice area of the North Caspian Sea. Sexually mature mothers come to the ice in winter to breed and lactate. The lactation period in most cases is extended, beginning in the second half of January and ending at the end of February. The degree of severity of winters can influence the processes of lactation and its duration. Winters affecting the breeding processes and distribution of sexually mature mothers of the Caspian seal can be divided into 3 types: warm, moderate and cold.

In warm winters, Caspian seal breeding takes place in the eastern part of the North Caspian Sea when the ice area is 10 to 30% of the total area of the North Caspian Sea. In this case, the haul-outs are compactly located, which enables to determine the total number of adult specimens and broodstock (baby seal, sivar) most accurately during the period of the instrumental aerial surveys. During the cameral processing there is a difficulty in separating the brood at the stage of sivar from adult seals and shoaling animals (immature specimens of two and more years old), filmed at an altitude of 150-200 m. At minimum ice area, there is mixing of haul out rookeries with adults and juveniles.

In moderate winters, when the ice cover is between 40 and 80%, the distribution of haul-outs occurs throughout the entire ice area of the eastern part of the North Caspian Sea. During the period of instrumental aerial surveys, the large extent of haul-outs may increase the error in the results of seal abundance estimation.

In cold winters, haul-outs are compactly located along the ice edge from east to west. The ice cover of the North Caspian Sea during these winters can vary from 80 to 98%. Adults and shoaling animals stay at a great distance from rookeries and there is no mixing of animals. Such winters are the most optimal for the instrumental aerial surveys and enable to obtain the most objective data on the estimation of the number of seals, both adults and litter at different stages of development (baby seal, sivar). However, in these winters the haul-outs are located simultaneously in the areas of responsibility of the Russian Federation and the Republic of Kazakhstan, and the objective assessment is difficult due to internal political reasons of the two Caspian littoral states.

The winter of 2022-2023 can be attributed to cold winters with mild nature. The instrumental aerial surveys of Caspian seals in the KSCS was conducted on February 21-27, 2023, most of the litter at the sivar stage had size-weight indices similar to those of older age groups. With moderate ice coverage (approximately 76-98% of the North Caspian Sea area), mixing of some of the brood with shoaling animals occurred at the southern boundaries of the ice field in late February, making it difficult to identify the brood from the rest of the population.

The Caspian seal breeding in the winter of 2023/2024 was satisfactory. This can be evidenced by the length, fatness and coloration of pups (**Appendix A**). Many well-fed barrel-shaped seals (adults and pups) were observed in the photographs, which also indicates a good population status. In 2024, the number of Caspian seals (adults and pups) on the ice amounted to 189,451 thousand specimens, which is 2.2 times more than the number of seals on the ice in 2012 (88,6 thousand specimens), [Report.CISS-2012-001, 2013]. Relative to 2023 (170,553 thousand specimens), the number of seals increased, by 18,862 thousand specimens.

## 6.2. RETROSPECTIVE DATA ON ABUNDANCE AND BIOLOGICAL INDICES OF THE CASPIAN SEAL POPULATION

The basis for the calculation is the method of direct counting during aerial surveys of Caspian seal pups on the ice surface of the North Caspian Sea. A pup born during a calendar month cannot stay in the water for a long time and does not make long migrations. One producing mother in a litter brings one pup. According to this strict relationship, the number of litter is equal to the number of producing mothers.

The first estimates of the number of producing mothers of the Caspian seal and the litter can be attributed to the early 70s of the XX century. Until that time, fishery science during the state fishery in the ice period of its life was engaged in systematization of biology, behavioral peculiarities, collection of field material on age-sex structure, morphology, size-weight indices and nutrition.

The first aerial survey of seals was carried out from IL-14 airplane in 1973. Subsequent aerial surveys of seals (1976, 1980, 1986, 1989) were carried out at intervals of 3-6 years, photography was made by area or route methods, only adults were counted.

When calculating the Caspian seal abundance based on the results of aerial surveys in 1976, 1986 and 1989, a correction factor of 0.35 was used, calculated on the large actual material of aerial surveys in 1976. calculations of the Caspian seal abundance based on the results of aerial surveys in 1976, 1986 and 1989, a correction factor of 0.35 was used, which was calculated on the basis of the large actual material from the 1976 aerial surveys. When calculating the Caspian seal abundance based on the 1973 aerial surveys, a factor of 0.4 was used. According to the majority of specialists, the total number of Caspian seals in the period from 1973 to 1980 did not exceed 600 thousand specimens.

In 2012, as a result of calculated data, the relative share (%) of sexually mature mothers participating in reproduction or producing mothers in the Caspian seal population had an index equal to 21%. At a minimum level of malevolence, the Caspian seal population in the long-term dynamics in the modern period has a tendency to increase in the modern period (Table 6.2-1), [Melentiev 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 Results of aerial surveys for 1965-2024, thousand specimens**

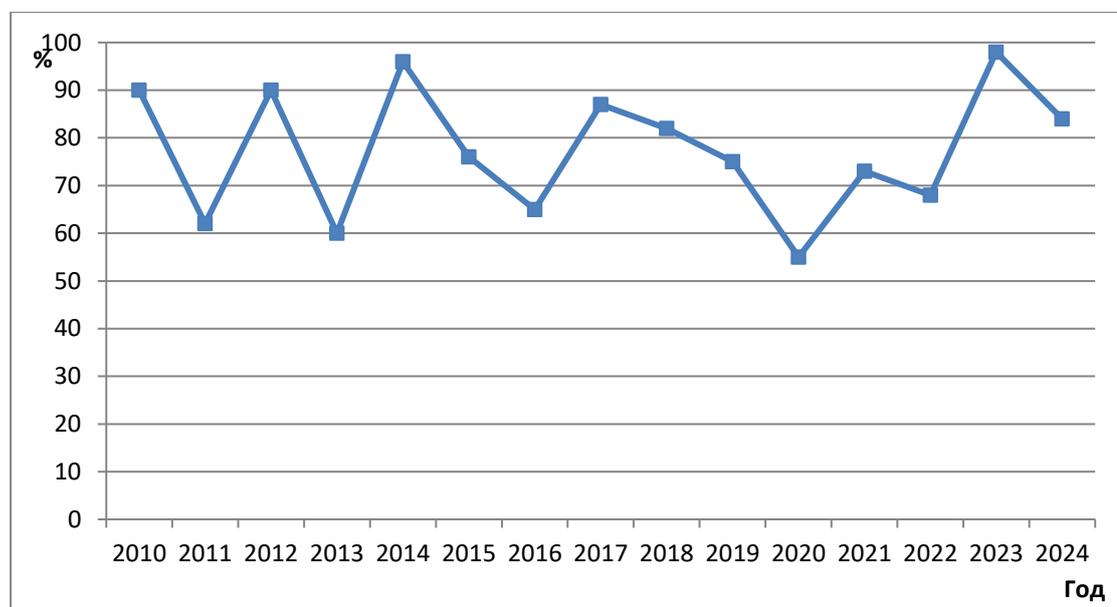
Parameters	Year											
	1965	1973	1976	1980	1986	1989	2012	2020	2021	2022	2023	2024
Number of producing mothers	82,4	90.4	102.3	106.0	60.0	46.8	50.0	58.2	62.3	67.3	53.6	77.9
<b>Total population size</b>	<b>At least 600</b>				<b>520</b>	<b>470</b>	<b>269</b>	<b>282</b>	<b>302</b>	<b>311</b>	<b>259.9</b>	<b>278</b>
<b>% of producing mothers in the population</b>	<b>15,0</b>	<b>15.1</b>	<b>17.1</b>	<b>17.7</b>	<b>11.5</b>	<b>10.0</b>	<b>21.0</b>	<b>20.6</b>	<b>20.6</b>	<b>21.6</b>	<b>20.6</b>	<b>20.6</b>

In 2012, the Caspian seal stock was determined for the first time using modern multispectral aerial photography. The survey results were not doubted by Russian and foreign researchers. The estimated population size of the Caspian seal was estimated within the range of 270 to 320 thousand specimens and was comparable to the number determined by the method of ship route counting in 2001-2012. At present (2013-2024), the Caspian seal stock is formed only under the influence of natural loss, deaths from poaching and deaths from various epidemics (carnivore plague and modified avian influenza, H5N1 strain). The average density of sea beast concentrations based on route counts in the year of the multispectral survey can act as an independent indicator of abundance, with which we can compare the densities obtained from the results of surveys in 2013-2023, as well as assess changes in abundance upward or downward.

Caspian seal breeding efficiency, litter survival and molting depend on ice quality (hummockiness) in the breeding grounds. During 2010-2018, at the time of mass breeding of breeding mothers, the ice cover did not fall below 61% [Kuznetsov and Shipulin, 2019].

In winter 2019, ice extent in January ranged from 63 to 83% and averaged 75% in the first decade of February. In 2020, the coldest month was January, the ice extent in the first and second decade varied 24 to 66%, averaging 48%. In the last decade of January, the ice extent dropped to 21% (31.01.2020), and in the first decade of February there was a noticeable warming and the ice area decreased from 21% (01.02.2020) to 9% (07.02.2020). The following cold weather (09-15.02.2020) increased the ice cover area up to 40-48%.

According to the results of aerial survey it was determined that under the influence of the winter of 2019-2020 the mass breeding period of sexually mature mothers of the Caspian seal was shifted to earlier dates. The moment of mass reproduction of sexually mature mothers occurred in the third decade of January - early February 2020, at maximum ice cover (46-59.7%). The winter period of 2021 was marked by low temperatures and a high percentage of the ice field ranging from 79.8 (15.01.2021) to 90.6% (22.01.2021) in January. In the first half of February, the ice extent amounted to 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 from 98 to 100%. In 2024 as of January 5, the area covered by the ice field reached 45%, by January 25, the coverage reached 92-95%, and by February 20-25, it decreased to 82-85%.

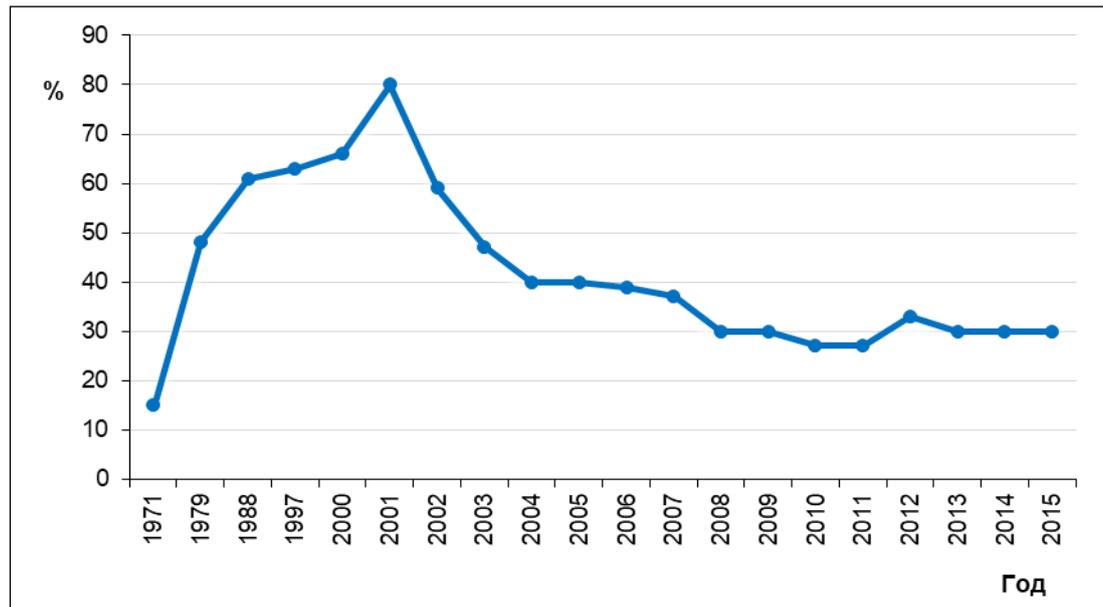


**Figure 6.2.1 Arctic Sea Ice Extent (%) in the North Caspian Sea During the Caspian Seal Breeding Period, in the Multiyear Aspect**

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 [Vorozhcnov 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
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 ABUNDANCE OF THE CASPIAN SEAL POPULATION

In 2024, the total population size of the Caspian seal was calculated using formulas previously tested on harp seal populations in the White Sea and Caspian seal populations in the Caspian Sea from 2012 to 2023. To estimate the Caspian seal population size, a direct dependence on the number of lactating females (each female produces one pup) was used. By knowing the number of offspring produced in one year, the total population size of the Caspian seals can be determined using the calculation method outlined in [Shafikov, 2008; Report. KAPE, RFRIFO, 2019, 2020, 2021, 2022, 2023]. This methodology for calculating the total number of Caspian seals was approved in the Republic of Kazakhstan by the Ministry of Ecology, Geology and Natural Resources Order No. 662 of October 18, 2022, and is included in the rules for preparing a bio-substantiation for the use of wildlife (regulatory paragraphs 67-86 of the document).

$$S = P * K$$

where,

$S$  – population size, thousand spcs.;

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

$K$  – conversion factor per population.

$$K = 1 + 2 * \frac{J_{max}}{(1 - k) * (J_{max} - J_{min})}$$

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 period, with the 2020-2023 amendments, is taken as an infertility index among sexually mature mothers. According to calculations, it is  $k = 0.27$ .

At the same time, it should be understood that the lower threshold of the estimate of a birth rate of the offspring (77888 specimens) and the total population (277999 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 and lower threshold of the total population of the Caspian seal also calculated. The lack of data on the Caspian seal population over the Russian ice field underestimates the total population size in 2024.

To calculate the upper threshold of the estimate of the number of seals, data of 2020-2023 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 2020-2023 on the ice was 159872 specimens, and 242,873 specimens, respectively, among which 20,6% accounted for offspring, 79,6% for adult seals. In 2024, the total number of seals on the ice (offspring, adult seals) was 222965 specimens, therefore, the upper threshold of the birth rate of offspring was 77888.

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

$$S_n = 57310 * 4,850801 = 377999,4 \approx 277\ 999 \text{ spcs.},$$

$$S_b = 77888 * 4,850801 = 377819,2 \approx 377\ 819 \text{ spcs.}$$

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 2024, 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 2024, taking into account the lower (57,310 thousand) and upper (69,689 thousand) thresholds of offspring was 277,999 and 338,047 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 2024 (Kazakhstan Sector)**

Possible thresholds for seal population estimation	Offspring numbers	Total population, specimens
Lower threshold of estimate for seal numbers	57310	277999
Upper threshold of estimate for seal numbers	77888	377819

Analysis of available data for 2012, 2020-2023 showed an increase in the number of reproducing pups in the current year (2024) by 12.8% compared to the data of 2012 and 6.5% compared to the data of 2023. The relative proportion (%) of producing mothers in the Caspian seal population in 2020 and in 2021, had an index equal to 20.6%, in 2022-2023. - 21.6 - 20.6% respectively. The total population size in winter 2024 has an insignificant increase (7.5%) and its lower limit of 277.999 thousand Caspian seal specimens, there is a slow rehabilitation of the population, after mass mortality in 2022-2023.

**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
Multispectral aerial count in 2024	57,31	278,00
<b>Discrepancy of results between the survey years: 2012/2024</b>	<b>12,8% (increase)</b>	<b>3,3% (increase in the total number)</b>
<b>Discrepancy of results between the survey years: 2023/2024</b>	<b>6,5% (increase)</b>	<b>6,6% (increase in the total number)</b>

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

Estimated lower and upper thresholds for the total population size of Caspian seals, based on multispectral aerial survey data of seal ice rookeries in 2024, range from 277,999 to 377,819 seals. Considering estimates from the first half of the last century, when the total population size was approximately 1 million animals [Badamshin, 1966], the current status of the population remains a subject of debate among the scientific community.

For the conservation of the Caspian seal, it is necessary to:

- Continue joint multispectral aerial surveys of reproductive ice seal rookeries throughout the entire North Caspian Sea, both in the territorial waters of the Russian Federation and the Republic of Kazakhstan, to objectively assess the total population size. The results of multi-year monitoring of sexually mature mothers will provide reliable data on population trends over a 5–10 year period in the absence of seal fishery;
- Strengthen monitoring of adult and juvenile Caspian seals through satellite tagging to study and determine foraging and seasonal migrations in the western and eastern parts of the North and Middle Caspian Sea, as well as identify new habitats and resting places on sandy islands;
- Conduct mapping of active islands and sand islands that may be used by harbor seals for resting;
- Recommend that seaports in Russia and Kazakhstan maintain restrictions on maritime navigation in the vicinity of current seal resting places;
- Identify opportunities to create artificial resting places for seals and continuously monitor these and other existing resting places in the North and Middle Caspian Sea;
- Develop long-term programs for the accounting and research of dead seals along the Caspian Sea coast. This should include determining size-weight indices and sampling for age composition from dead specimens as part of periodic releases of dead seals along the coasts of Dagestan (Russia) and the Mangyshlak Peninsula (Kazakhstan);
- Conduct remote sensing studies of seal size parameters using unmanned aerial vehicles (UAVs) and quadcopters on island mixed seasonal haul-outs in the North and Middle Caspian Sea to obtain up-to-date data on the relative proportion (%) of immature specimens in the total population structure of the Caspian seal.

An effective tool for implementing these conservation and rehabilitation plans is the agreed multi-year Interstate Kazakhstan-Russian Research Program (**Appendix D**).

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## CONCLUSION

In the winter of 2024, multispectral imaging of rookeries was carried out to further develop a database on the number and location of Caspian seal aggregations in the waters of the North Caspian Sea. Additionally, an aerial survey of rookeries and molting grounds was conducted in the spring.

In February 2024, the first stage of surveys, a multispectral aerial survey of Caspian seal haul-outs, was carried out. The survey, conducted from the Kazakhstani airplane Piper PA-34, took place in good weather conditions. It utilized two Optris PI450 thermal imagers and three cameras (Nikon D850 and GoPro11) mounted on the lower part of the airplane fuselage. The ice cover in the North Caspian Sea in Russia and Kazakhstan was evenly surveyed using transects. A substantial amount of data was collected, including tens of thousands of images of seals in visible and infrared ranges, as well as images of the ice cover. This ensured objective information on the status of the Caspian seal population.

Using the same technology for instrumental (IR+Photo) aerial surveys in 2012, 2020, 2021, 2022, 2023, and 2024, and employing the same team, minimized inter-annual error in pup counting and identified trends in the status of the Caspian seal population. The instrumental aerial survey from February 24 to March 1, 2024, revealed that most offspring at the sivary stage had size and weight indicators similar to those of older age groups. With moderate ice coverage (about 76-78% of the North Caspian area) at the end of February, some offspring mixed with the herd on the southern ice field, complicating their identification.

In April, the second stage of surveys involved an aerial survey of rookeries and molting grounds. Conducted by a Piper PA-34 airplane with video and photo equipment (2 Nikon D850 cameras, a GoPro11 video camera, and a DJI Osmo Action), the survey covered the North Caspian coast from Kurmangazy settlement to the Zhaik River, sand islands on the Ural seashore, and further east to the Zhem River, the North Caspian Marine Channel (artificial islands), sea sand islands north and south of the NCMC, Durneva Island, the coast of Buzachi Peninsula, Tyupkaragan, Tyuleni islands, and the areas of the Kalamkas field and Karazhanbas Sea.

The high-quality photographic materials provided additional information about the seals (size, fatness, coloration). Many well-fed, barrel-shaped seals (adults and pups) were observed, indicating good population health. In April, significant parts of adults and their young migrated to the southern Caspian Sea. From April 8 to 12, 2024, twenty three sites of seal rookeries on sand islands were recorded in the southwestern part of the Kashagan field and areas north and south of the North Caspian Sea channel, including the Kalamkas field and Karazhanbas Sea. Desk processing indicated a total of 43,993 seals on these islands, with occupancy ranging from 6 to 9,472 seals per island.

In spring 2024, 64 carcasses of dead seals, likely due to an ongoing epidemic of carnivore plague and influenza infection, were recorded on Kulaly Island and Tyupkaragan sand-bank.

The number of Caspian seals on the KSCS ice field in February 2024 was 189,415, while 43,993 were recorded on sand islands in the spring. This decrease may indicate the onset of foraging migrations to the southern parts of the sea. Considering that many seals had already migrated, only about 23.2% of those counted in February remained on the sand islands.

Taking into account the current status of the Caspian seal population in 2024, the age structure, time of puberty, and percentage of infertile mothers, the population conversion factor was assumed to be 4.63. The estimated total population size in 2024, considering the lower (57,310,000) and upper (77,888,000) litter thresholds, was 277,999 and 377,819 seals, respectively.

Analysis of data from 2012, 2020, 2021, 2022, 2023, and 2024 showed a 12.8% increase in reproducing pups in 2024 compared to 2012, and a 6.5% increase compared to 2023. The percentage of producing mothers in 2020, 2021, and 2023 was 20.6%, and 21.6% in 2022. The total population size in winter 2024, considering natural mortality, epidemic deaths, pulmonary infections, and entanglement in fishing nets, was 278,000 seals.

To identify trends in the Caspian seal population, regular surveys using modern aerial survey methods and tools are necessary. Due to significant annual variations in seal haul-out distribution

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in Russia and Kazakhstan, depending on winter severity and ice conditions, surveys should cover the entire North Caspian Sea area.

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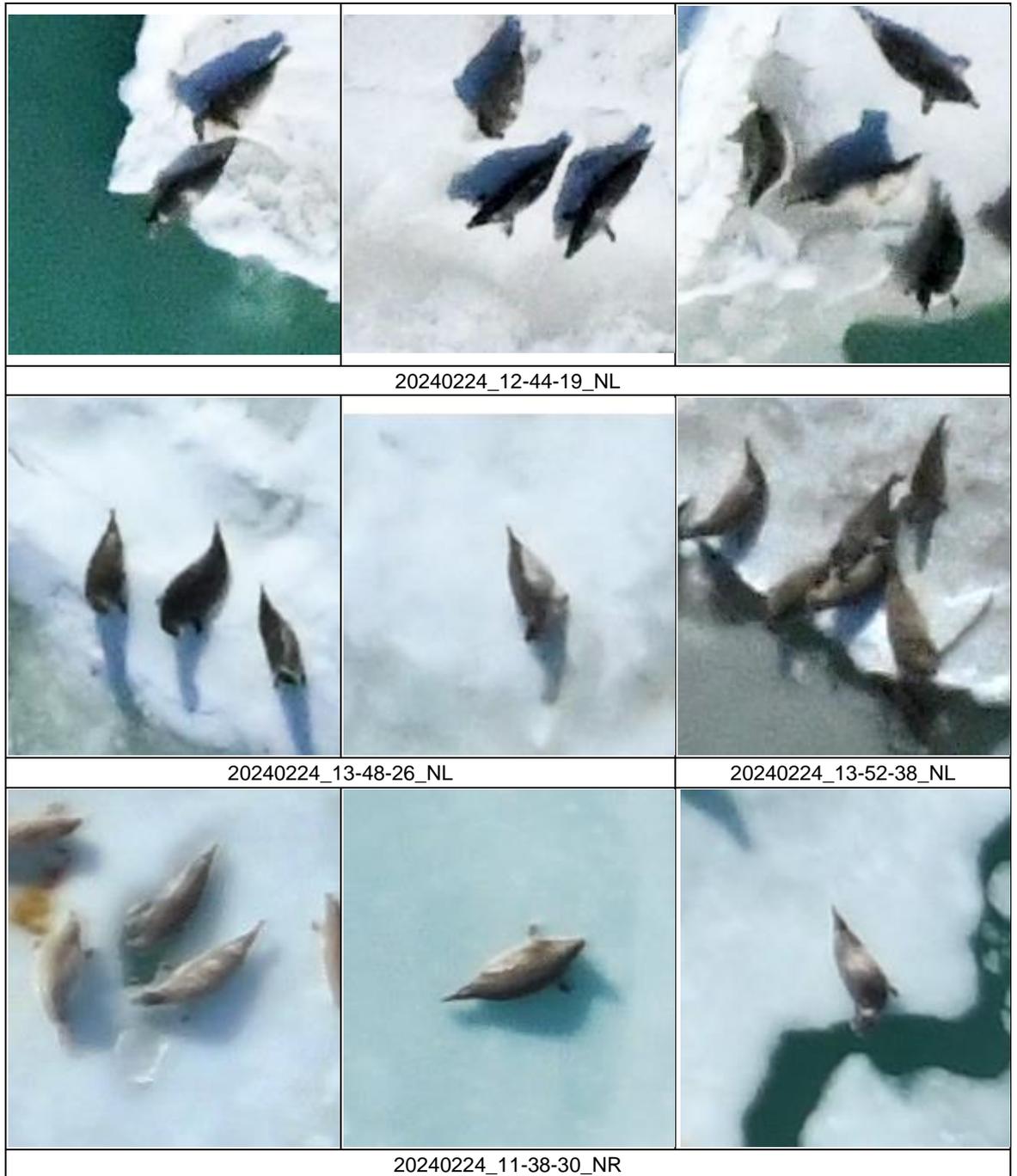
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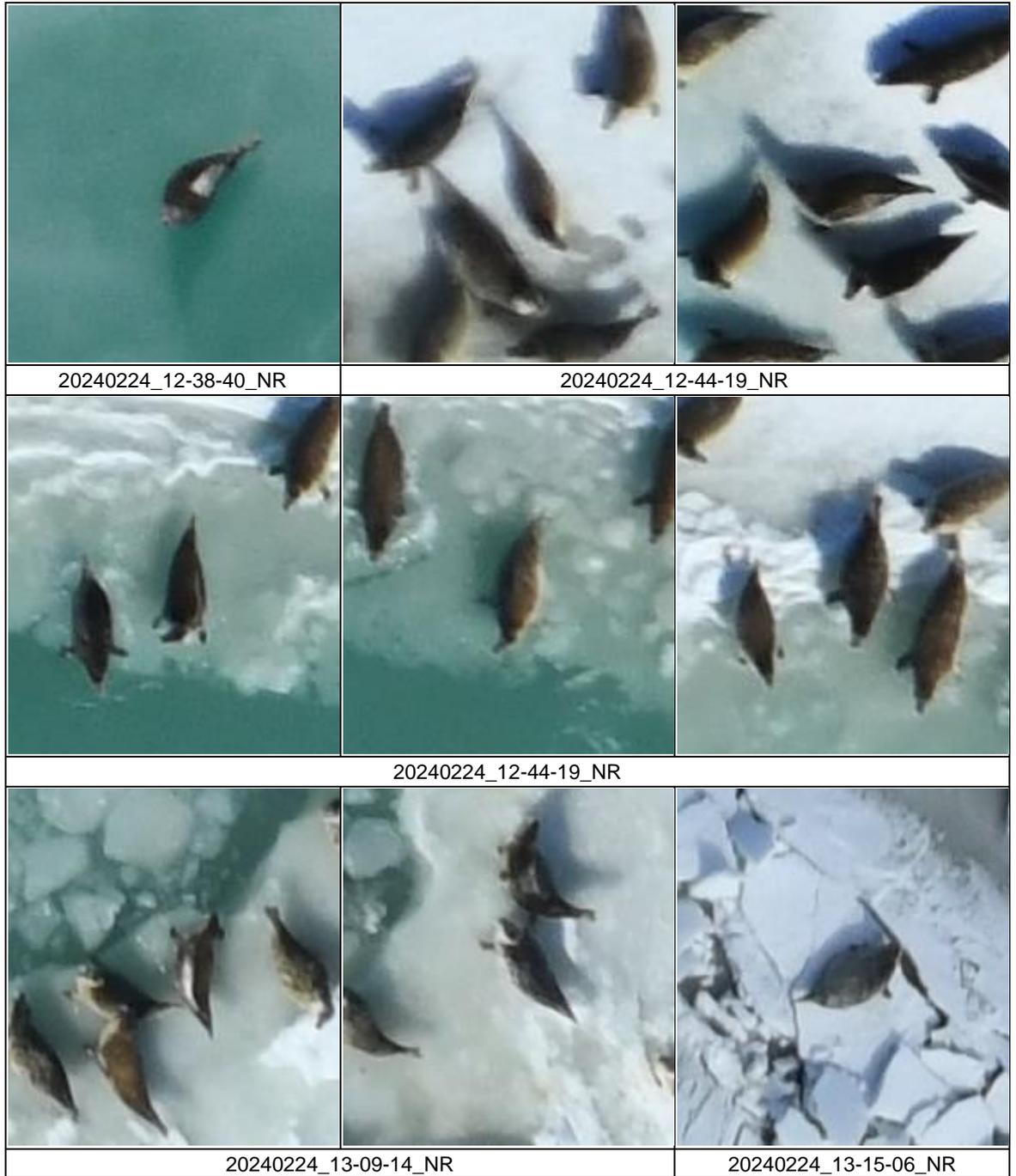
**APPENDIX A    GEOREFERENCE OF THE PHOTO TO A SINGLE AIRPLANE TIMELINE**

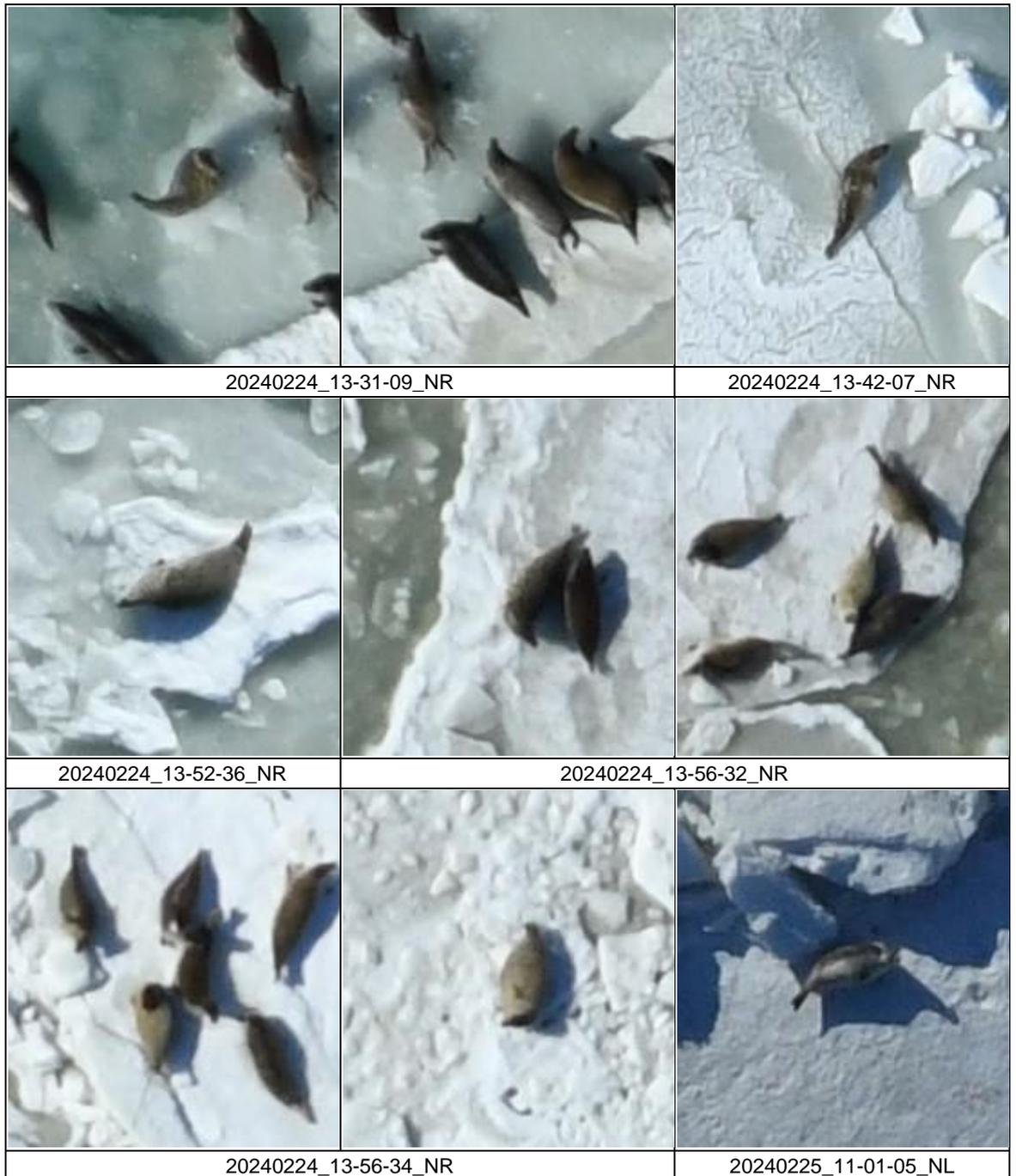
**A.1    ADULT SEALS**



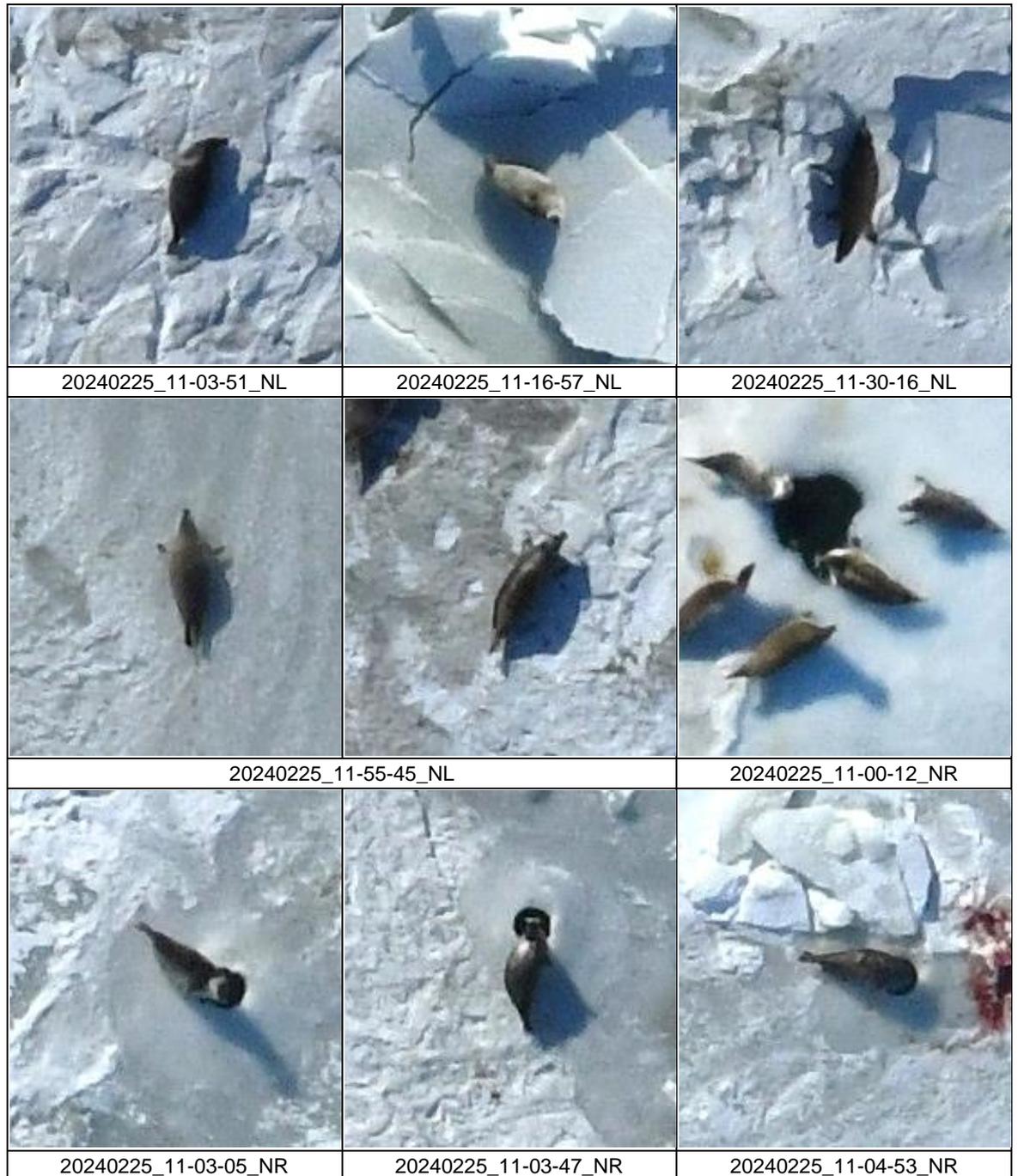
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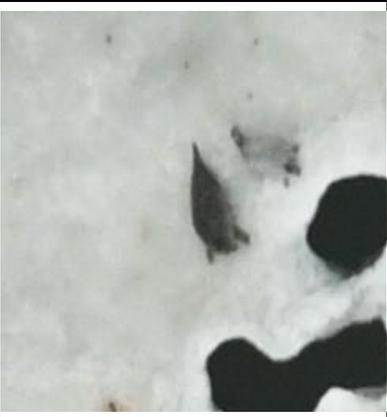




**A.2 MOTHERS WITH PUPS**

		
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

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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



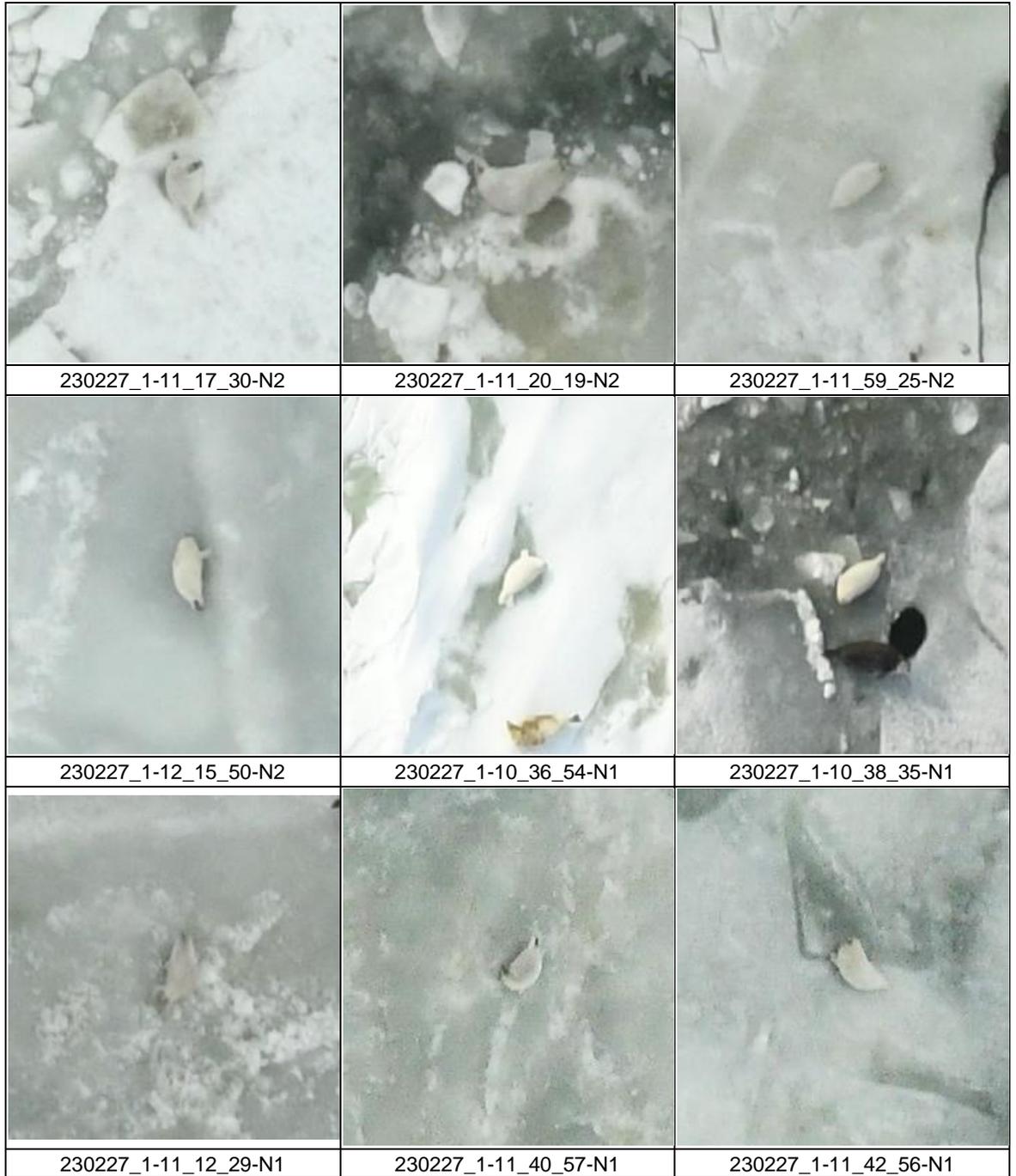


**A.3 BABY SEALS**

		
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

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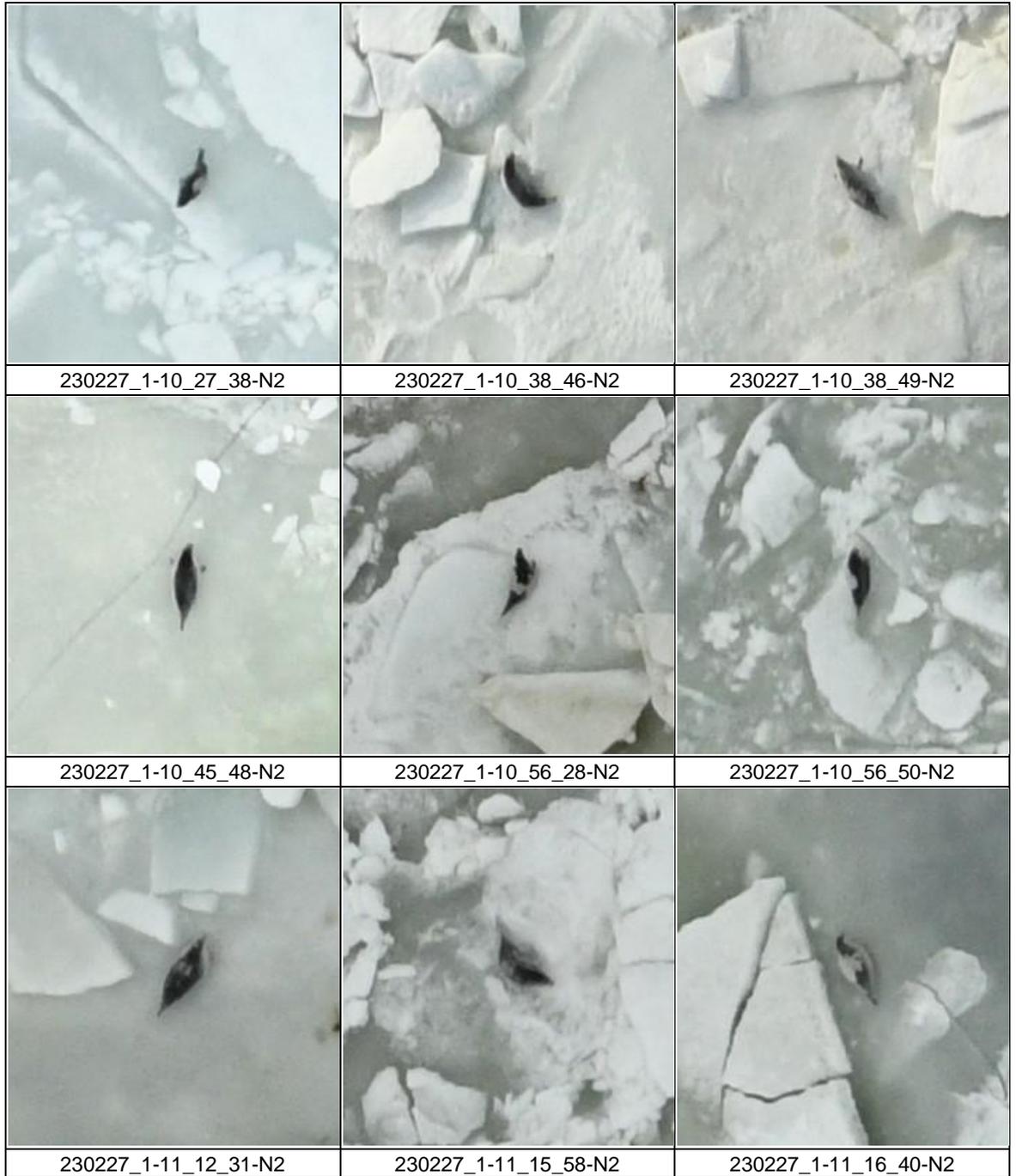
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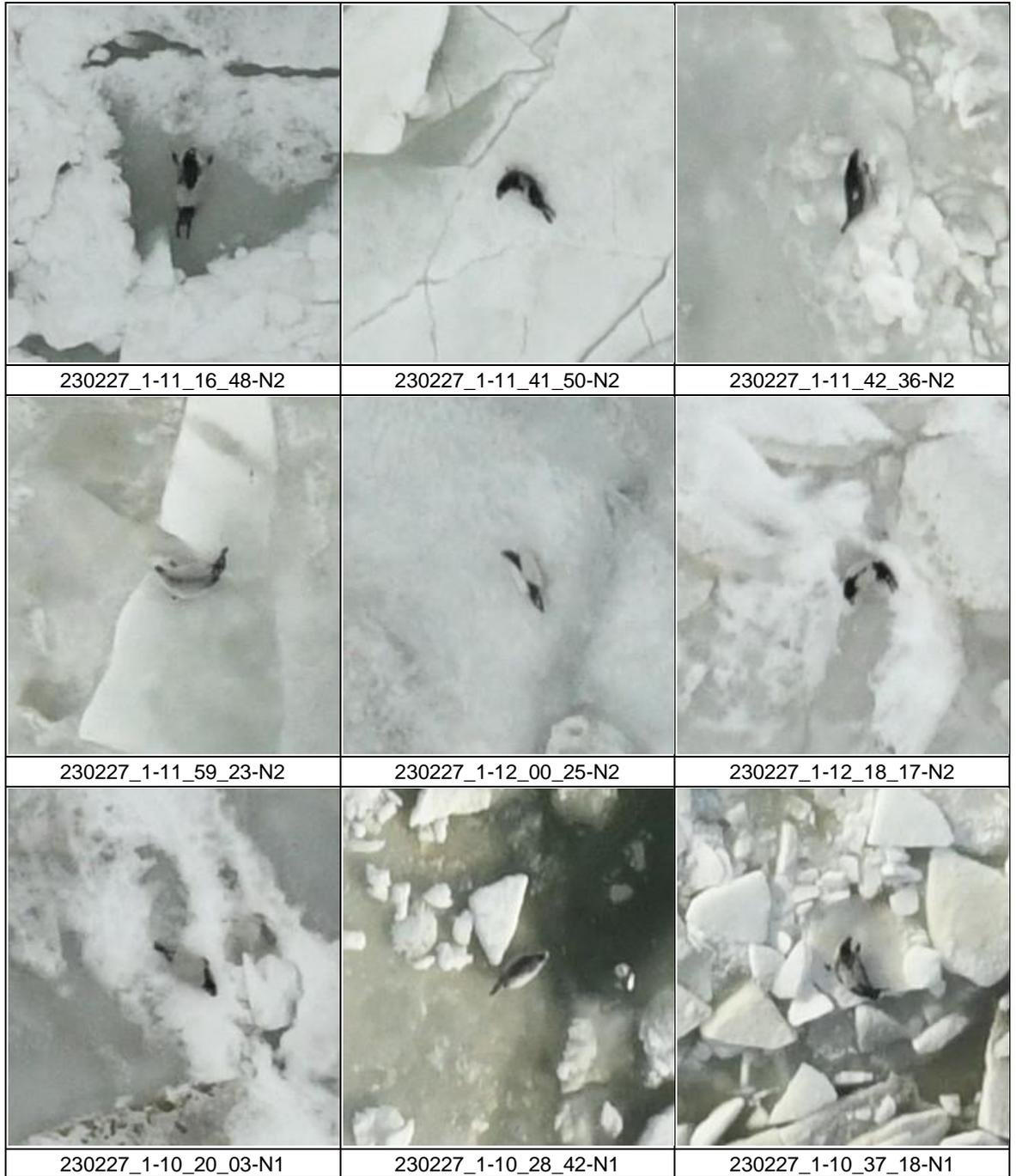
		
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230227_2-16_07_27-N2	230227_2-16_13_21-N2	230227_2-16_13_30-N1
		
230227_2-16_13_43-N1	230227_2-16_23_37-N1	230227_2-16_23_37-N1

**A.4 SEAL PUPS AT DIFFERENT STAGES OF MOLTING**

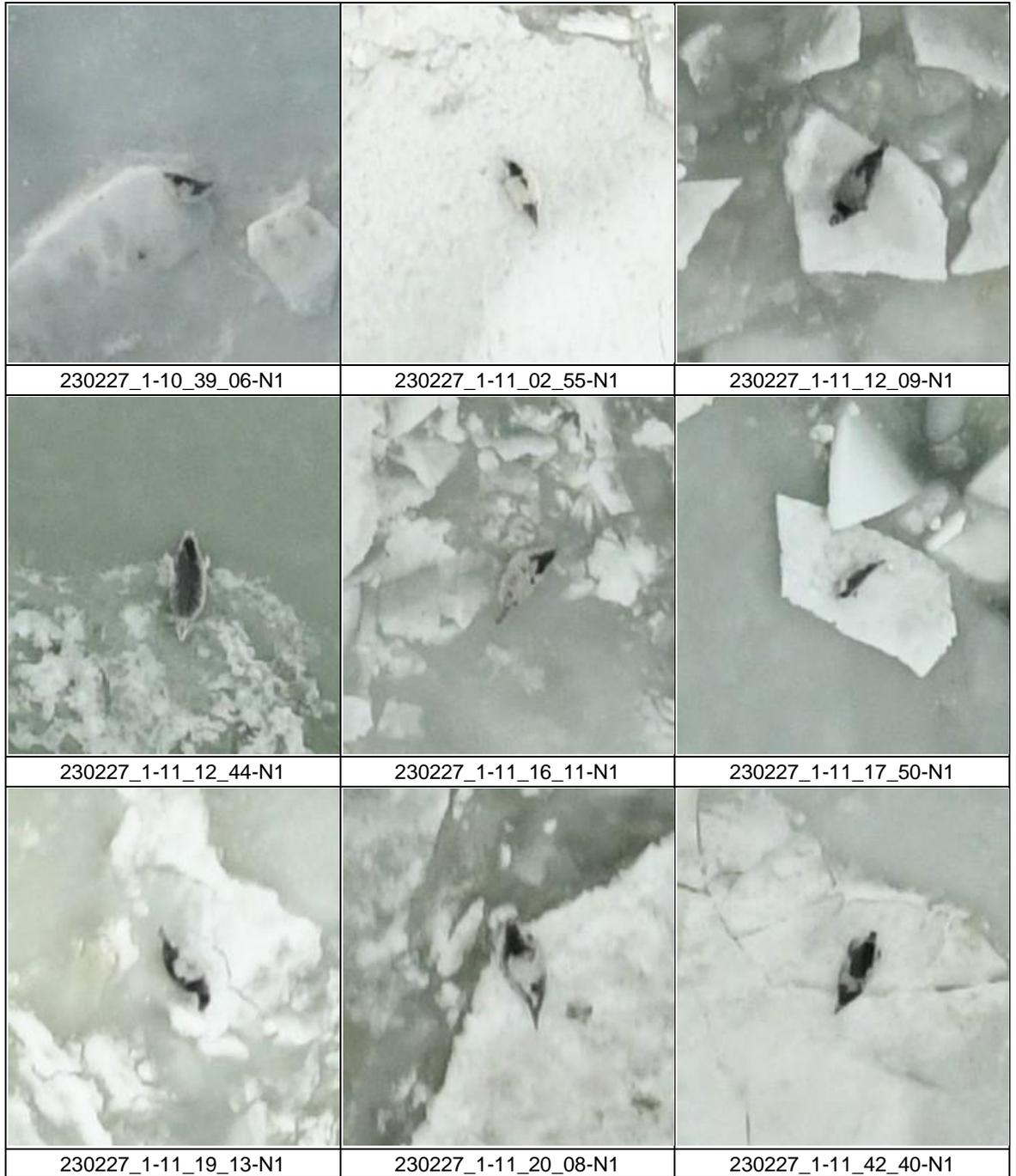


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230227_1-11_43_42-N1	230227_1-11_59_21-N1	230227_1-12_17_36-N1
		
230227_2-15_17_51-N2		
		
230227_2-15_35_48-N2	230227_2-16_01_20-N2	230227_2-16_23_26-N2

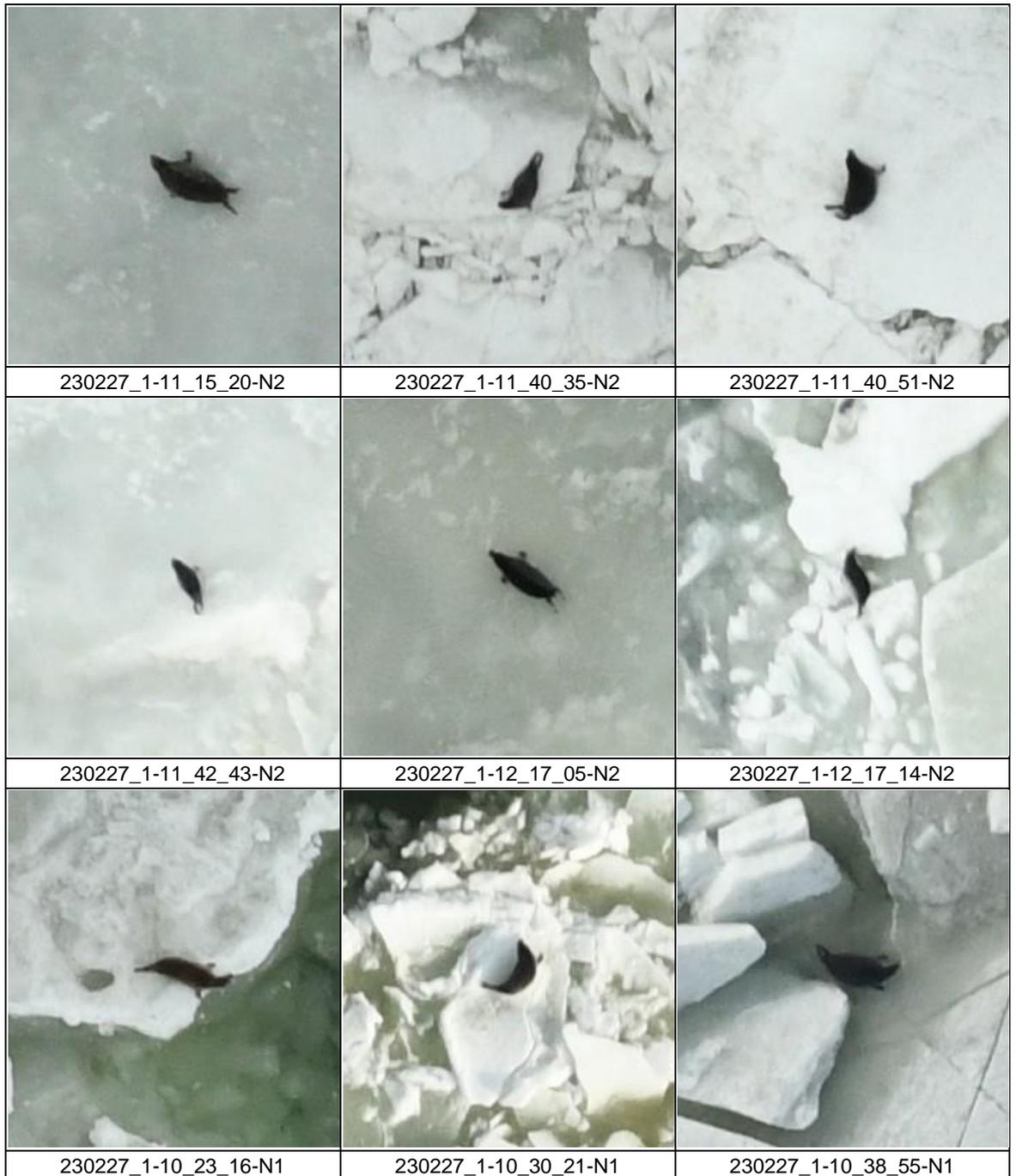


**A.5 SIVARS**

		
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

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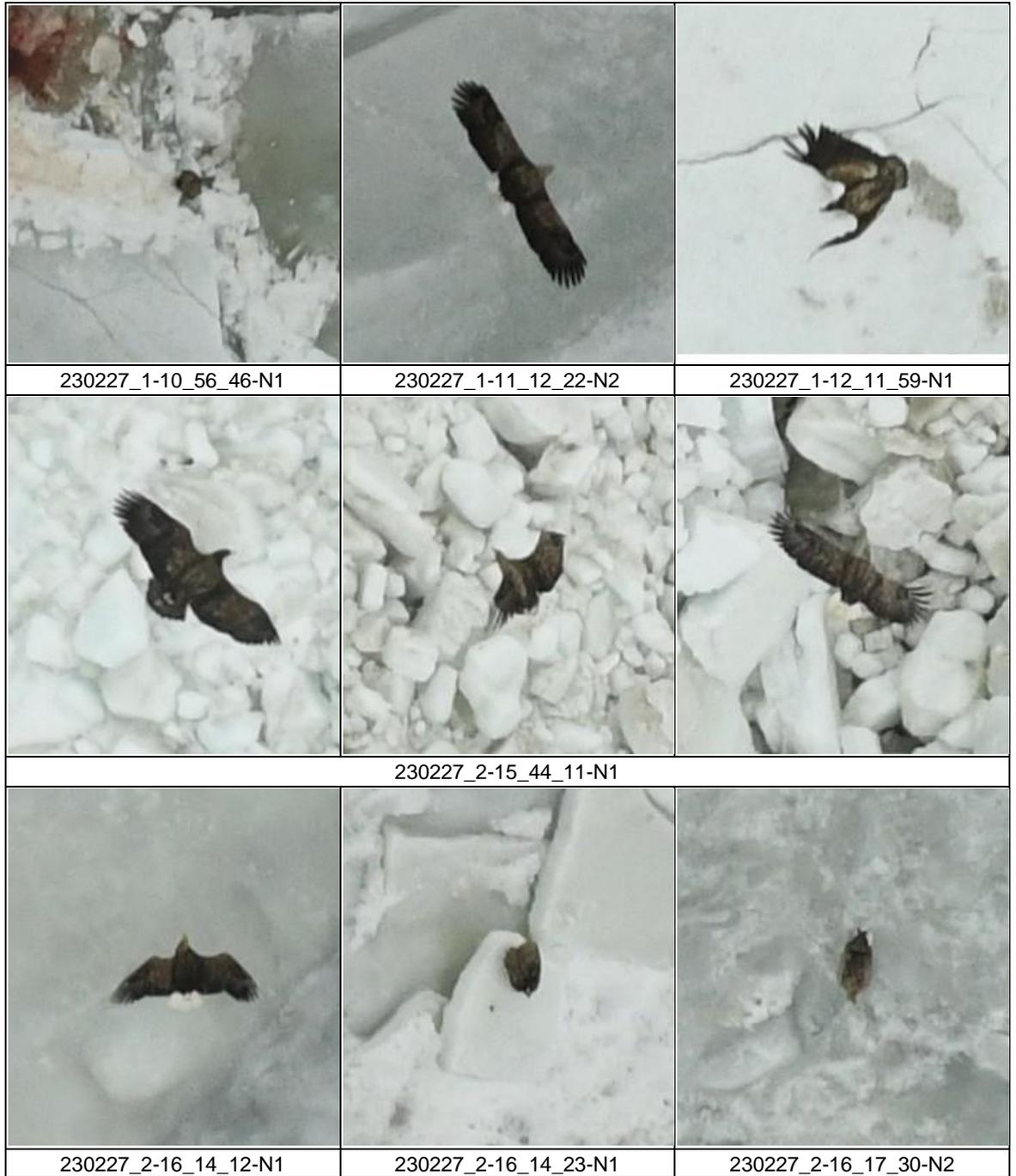


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230227_1-11_12_11-N1	230227_1-11_14_06-N1	230227_1-11_15_16-N1
		
230227_1-11_15_56-N1	230227_1-12_04_55-N1	230227_2-15_03_05-N2
		
230227_2-15_19_38-N2	230227_2-15_05_58-N1	230227_2-15_32_59-N1

**A.6 BIRDS**



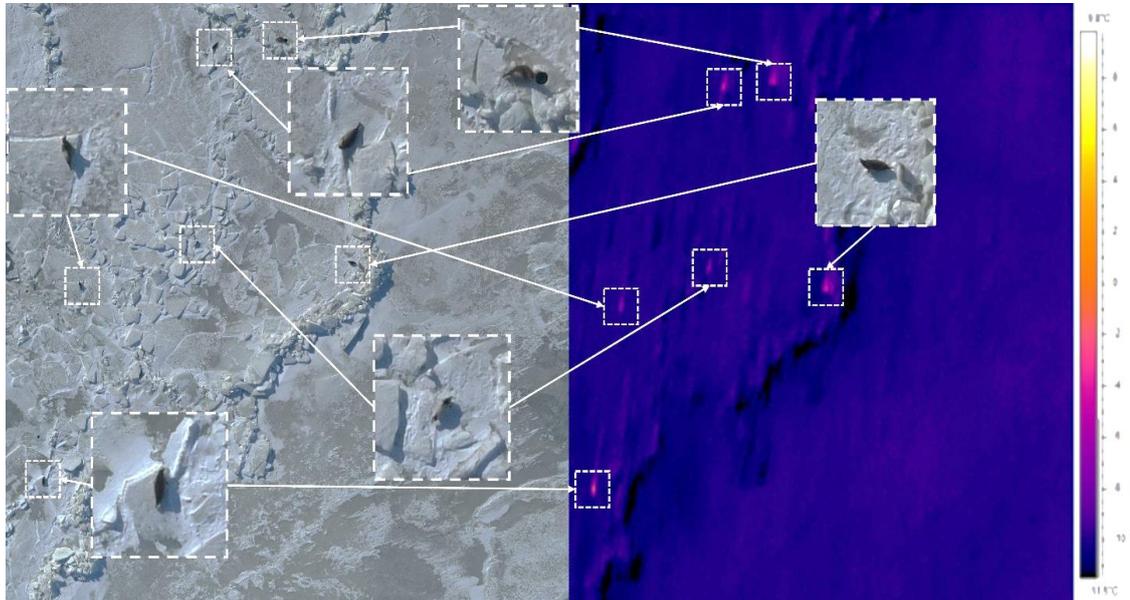


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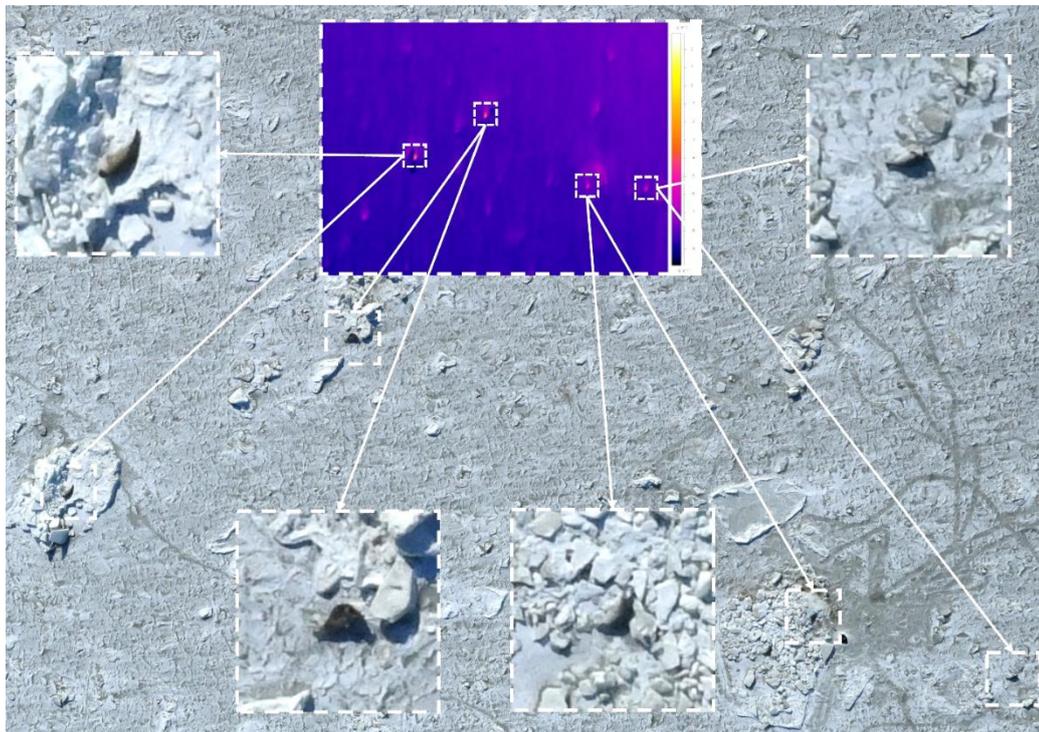




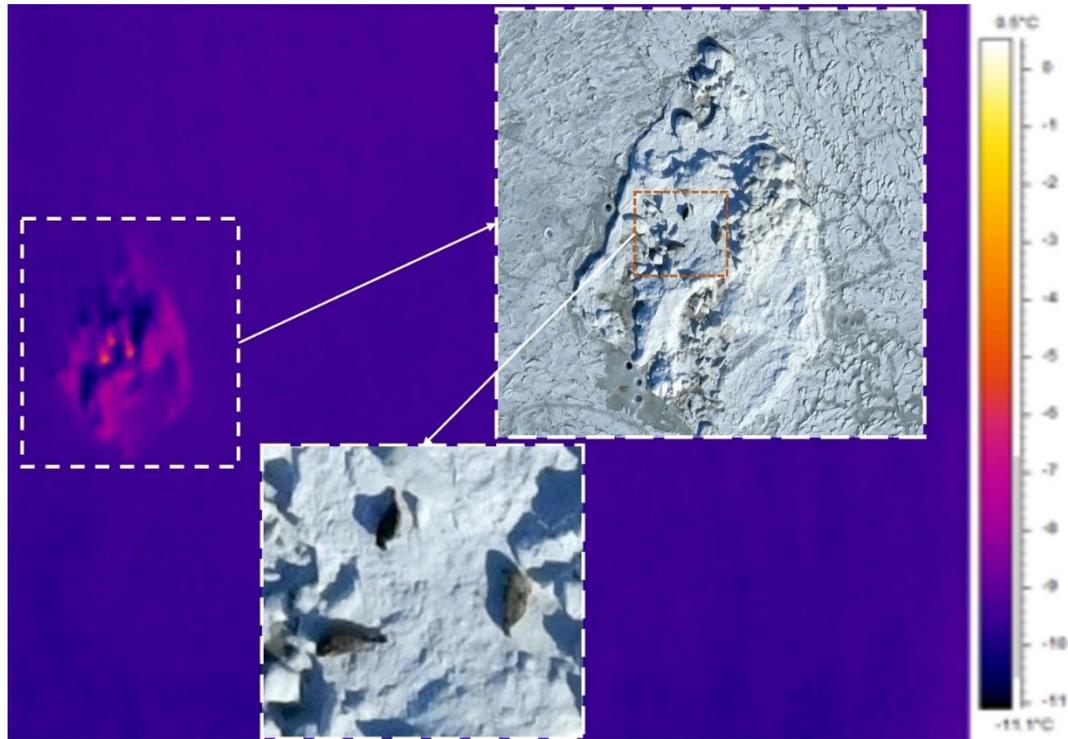
**A.7 EXAMPLES OF JOINT PROCESSING OF IR AND STILL IMAGES**



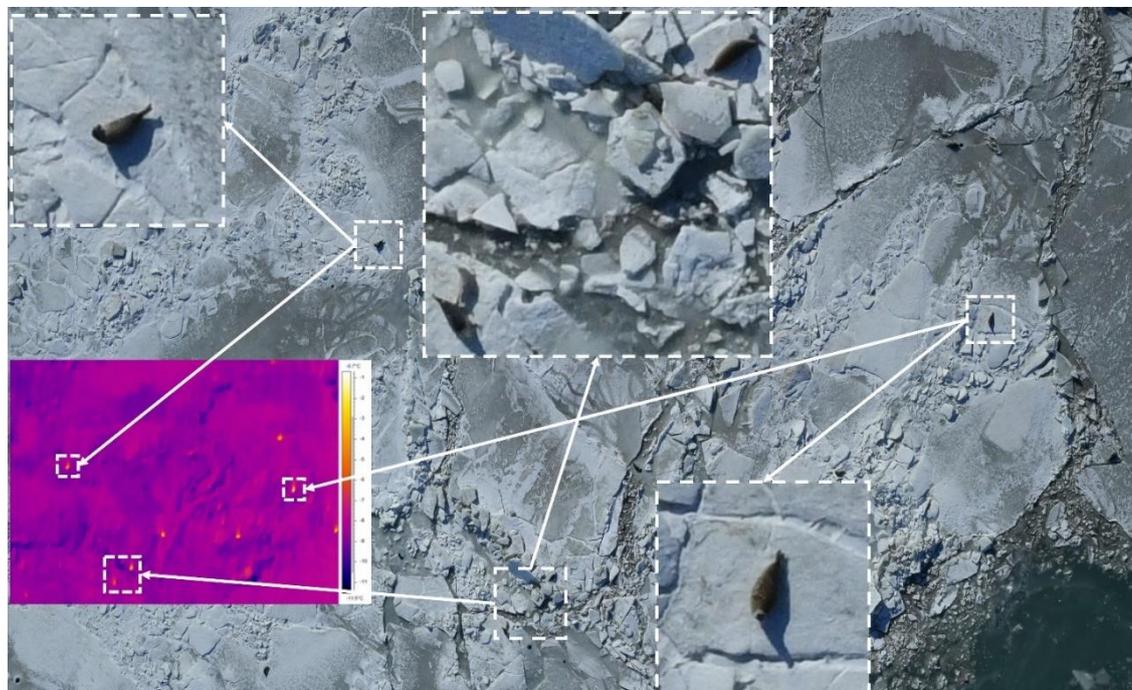
**Figure A.7.1** High-resolution photo of seals on Caspian Sea ice (February 25, 2024, 11:03:45, left side of Piper PA-34 airplane) and respective thermal image



**Figure A.7.2** High-resolution photo of seals on Caspian Sea ice (February 25, 2024, 12:32:03, left side of Piper PA-34 airplane) and the respective thermal image



**Figure A.7.3** Infrared image of the Caspian Sea ice surface with seals and enlarged fragments of the respective photo (February 25, 2024, 11:27:18, left side of Piper PA-34 airplane)



**Figure A.7.4** Infrared image of the Caspian Sea ice surface with seals and enlarged fragments of the respective photo (February 25, 2024, 11:55:43, left side of Piper PA-34 airplane)

**APPENDIX B EXAMPLES OF JOINT PROCESSING OF IR AND STILL IMAGES**

Caspian seal counts were made during three aerial survey flights conducted on February 24-25, 2024. Each survey was carried out during one daylight hours on parallel transects of different length but the same width, as the altitude was kept constant during these flights. The interval between transects was the same. This allowed the transects to be combined and the calculations were made using Kingsley's method (Kingsley et al, 1985) outlined below.

Adult seal and pup numbers for the  $i$ -th aerial survey were calculated separately using the formula:

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

where,

$J_i$  - number of transects in the  $i$ -th aerial survey;

$K_i$  - weight coefficient for the  $i$ -th survey, defined as the ratio of transect spacing to transect width;

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

The variance estimate was based on the series of differences between transects and was calculated using the formula:

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

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

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

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

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 of transects.

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

$$\hat{N} = \sum_{i=1}^I N_i \quad (5.5)$$

Where,  $I$  is the number of surveys.

The total variance of the estimate was calculated by the formula:

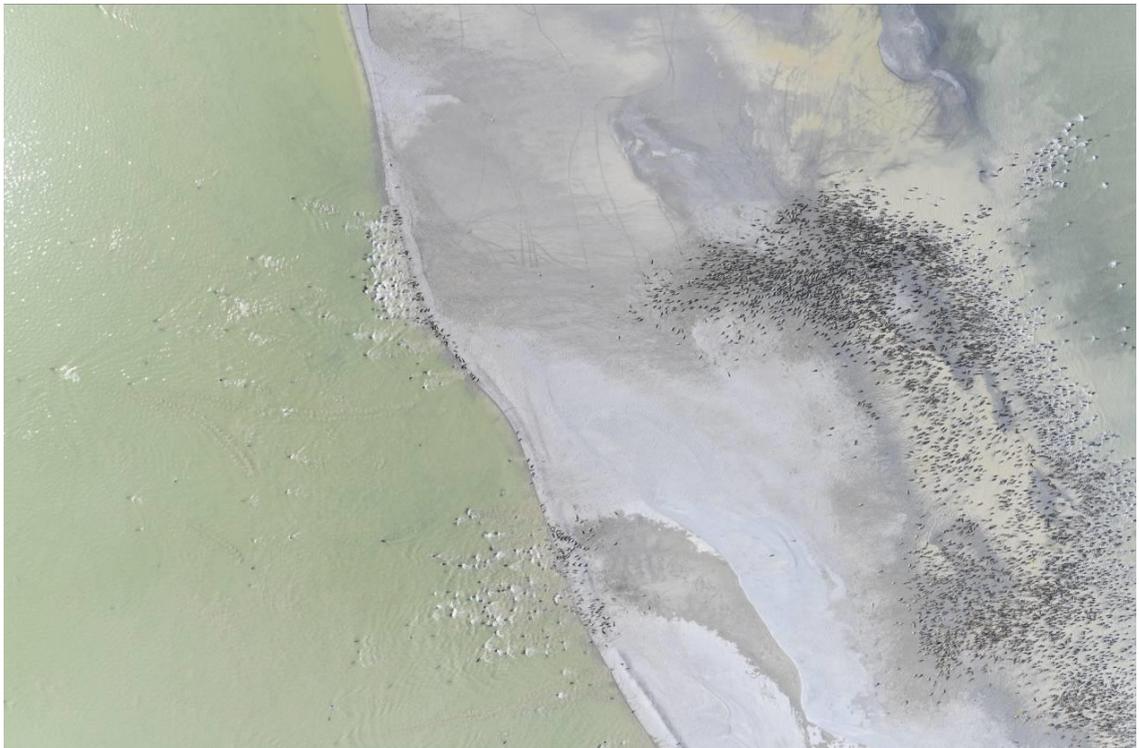
$$\hat{V} = \sum_{i=1}^I V_i \quad (5.6)$$

**APPENDIX C**

**CASPIAN SEALS ON SAND ISLANDS OF THE KAZAKHSTAN SECTOR OF THE CASPIAN SEA, 2024**



**No. 1** Submerged long sand island



**No. 2:** Long elongated sand island (fragment)



**No. 3:** Submerged elongated sand island (fragment)



**No. 4:** Long submerged sand island (fragment)



**No. 5:** Sand island in the shape of a frying pan



**No. 6:** Small sunken sand island



**No. 7:** Oval sunken sand island



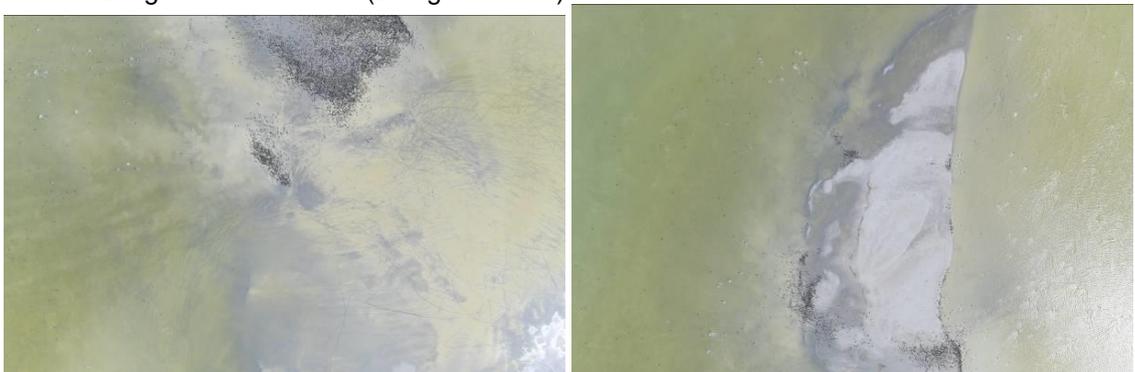
**No. 8:** Long elongated sand island divided by a strait (fragment)



**No. 9:** Long elongated sand island



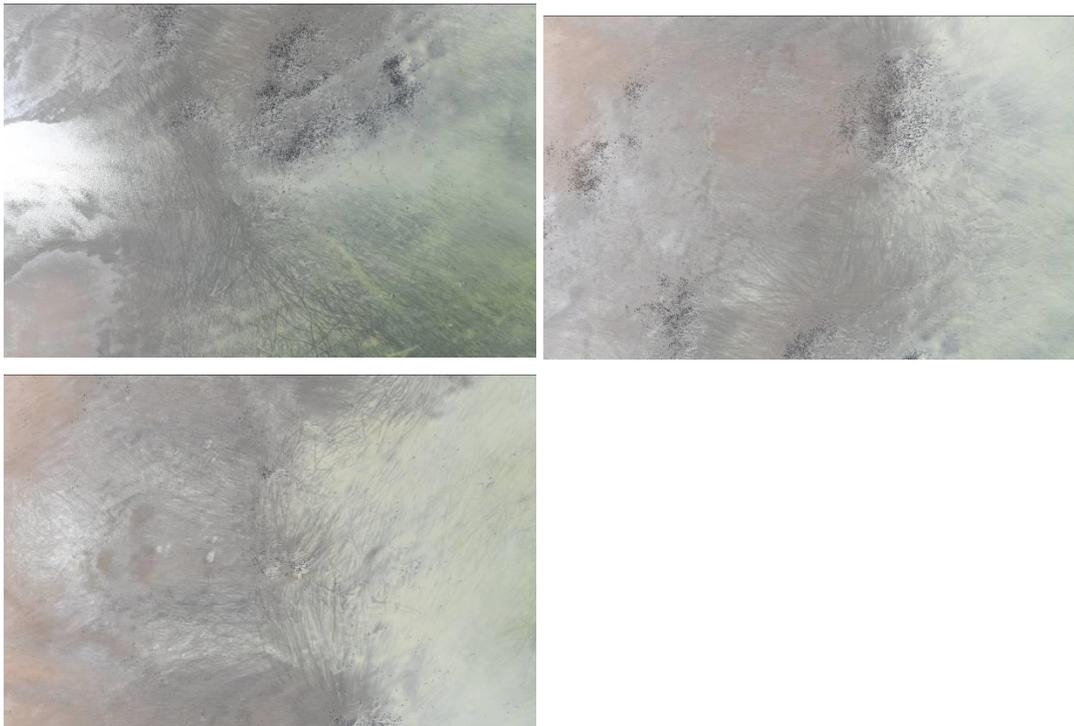
**No. 10:** Long oval sand island (2 large clusters)



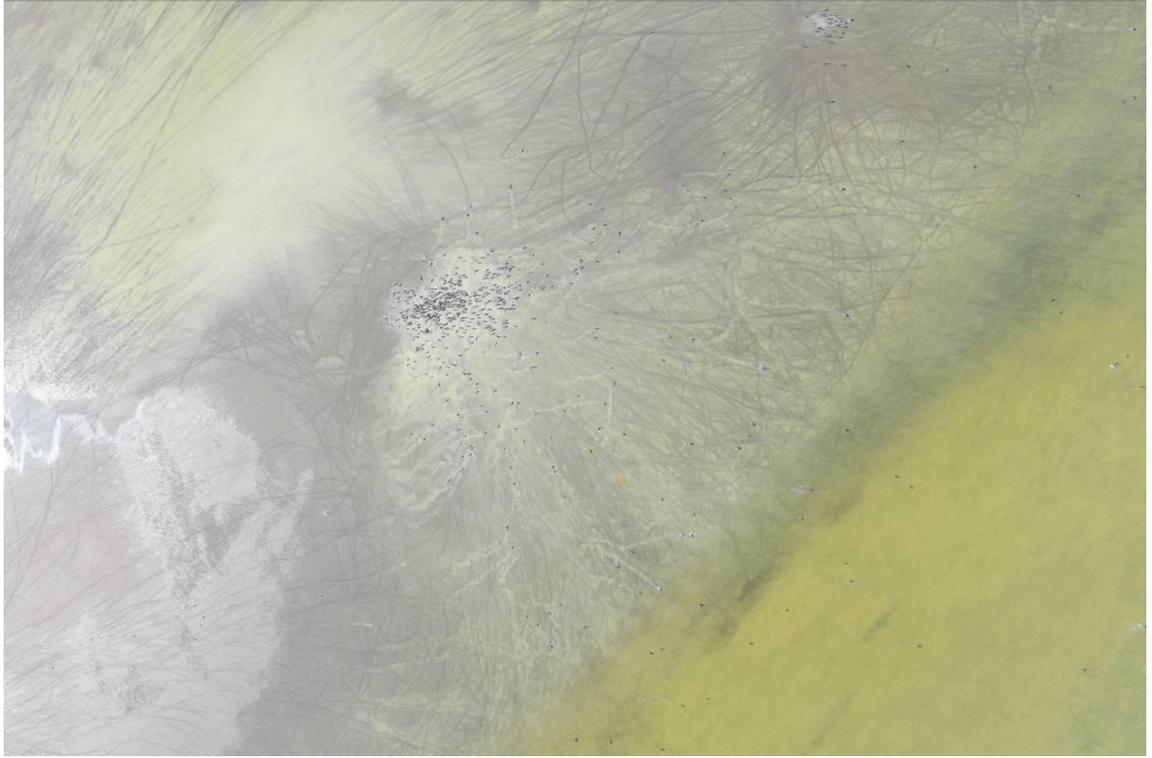
**No. 11:** Knife-shaped sand island (several clusters)



**No. 12:** Long submerged sand island (several small clusters)



**No. 13:** Narrow elongated sand island (several clusters)



**No. 14:** Long submerged sand island (fragment)



**No. 15:** Long submerged sand island



**No. 16:** Narrow elongated sand island (fragment)



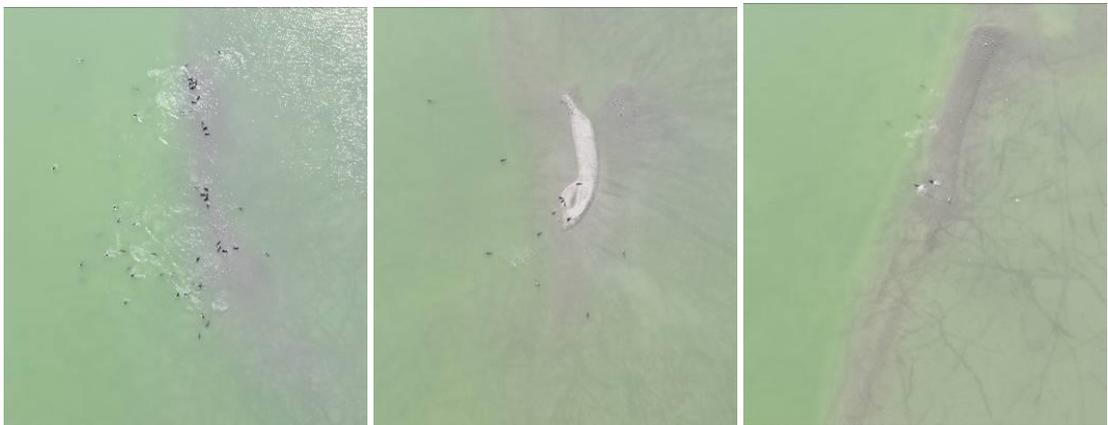
**No. 17:** Seal-shaped sand island



**No. 18:** Chain of small submerged sand islands (fragments)



**No. 19:** Submerged sand island with two islands



**No. 20:** Chain of small submerged sand islands (fragments)



**No. 21:** Small elongated submerged sand island



**No. 22:** Elongated submerged sand island



**No. 23:** Elongated submerged narrow sand island (fragments)

**APPENDIX D INTERNATIONAL RESEARCH PROGRAM**

**«СОГЛАСОВАНО»**

Федеральное агентство по рыболовству  
Российской Федерации

Заместитель Руководителя

П.С. Савчук

« \_\_\_\_\_ » \_\_\_\_\_ 2020 г.



**«СОГЛАСОВАНО»**

Комитет лесного хозяйства и животного  
мира Министерства Экологии, геологии и  
природных ресурсов Республики Казахстан

Заместитель Председателя

Н. Т. Жунусов

« \_\_\_\_\_ » \_\_\_\_\_ 2020 г.



**«РАЗРАБОТАНО»**

Федеральное государственное  
бюджетное научное учреждение  
«Всероссийский научно-  
исследовательский институт рыбного  
хозяйства и океанографии»  
(ФГБГУ «ВНИРО»)

Директор

К.В. Колончин

« \_\_\_\_\_ » \_\_\_\_\_ 2020 г.



**«РАЗРАБОТАНО»**

ТОО Казахстанское Агентство  
Прикладной Экологии (ТОО «КАПЭ»)

Генеральный директор

В.А. Скольский

« \_\_\_\_\_ » \_\_\_\_\_ 2020 г.



**ПРОГРАММА РАБОТ**

**по теме «Оценка численности, распределения и естественного воспроизводства  
каспийского тюленя на Казахстанской и Российской акватории Северного Каспия  
в 2020-2024 гг.»**

2020 г.

KAZAKHSTAN AGENCY OF APPLIED ECOLOGY  
RUSSIAN FEDERAL RESEARCH INSTITUTE OF  
FISHERIES AND OCEANOGRAPHY

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**APPENDIX D                      INTERNATIONAL SURVEY PROGRAM**

**AGREED WITH**

Federal Agency for Fisheries of the Russian Federation

Deputy Manager

\_\_\_\_\_ P.S. Savchuk  
\_\_\_\_\_ 2020

**AGREED WITH**

Committee of Forestry and Wildlife of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan

Deputy Chairman

\_\_\_\_\_ N.T. Zhunussov  
\_\_\_\_\_ 2020

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Director

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\_\_\_\_\_ 2020

**DEVELOPED BY**

Kazakhstan Agency of Applied Ecology LLC (KAPE LLC)

General Director

\_\_\_\_\_ V.A. Skolskiy  
\_\_\_\_\_ 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**

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**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.

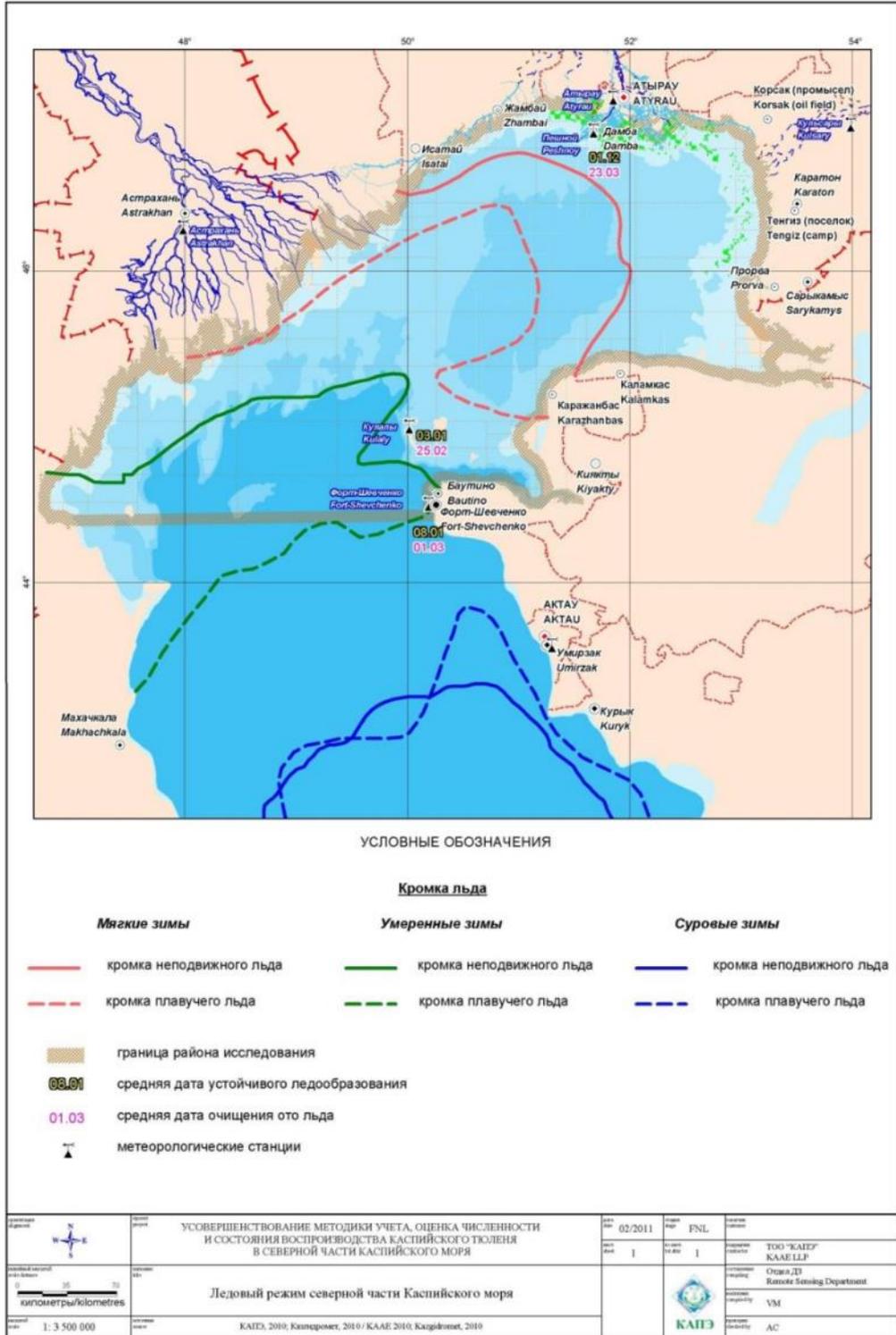


Figure 1 Ice regime in the northern Caspian Sea

## 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 ICE5 (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 Pentilateral 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.

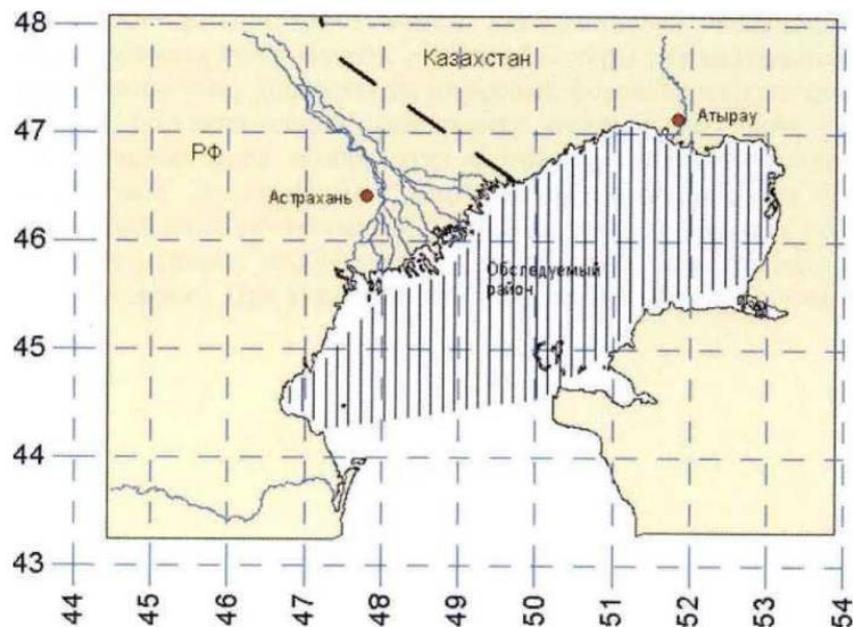


Figure 2. Tacking scheme in the winter seal survey flights.

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.

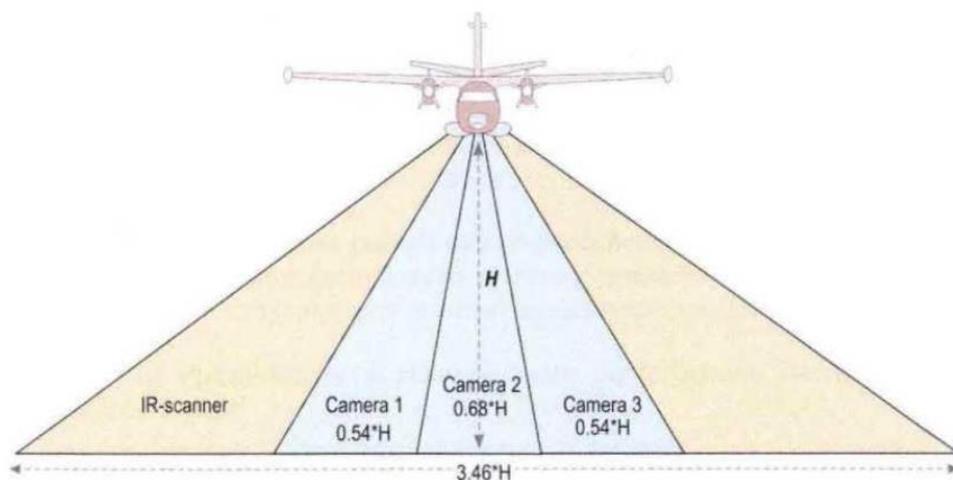


Figure 3. Camera and thermal imaging camera viewbands

For large-scale seal surveys a 4<sup>th</sup> 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**

<b>Ref No:</b>	<b>Stages</b>	<b>Deadline</b>
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