# Seasonal distribution of ringed seal in the White Sea monitored by satellite tagging

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## Abstract

Data on the seasonal distribution and ecology of ringed seals (*Pusa hispida*) were obtained from the results of seal tagging with satellite telemetry transmitters (STT) in the White Sea. STT "Pulsar" worked in the Argos system. Catching and tagging of ringed seals were carried out in the Dvina Bay of the White Sea in autumn 2008 and 2016 and in the summer of 2020. 5 tags were installed on seals of different ages. It was shown in the summer the ringed seals did not make long movements and remained on the littoral. The seals moved long distances in autumn, the average daily distance between observation points was 43 km per day. The ringed seal preferred areas with open water and the sea edge of landfast ice in winter. The ringed seal could stay for more than two months in the pelagic zone above the depth of 20 m. Priority directions of movement haven't been identified. We suggest this feature of the seals' behavior in the White Sea is associated with the seasonal distribution of food.

***Key words:*** satellite telemetry, migration, seasonal distribution, ringed seal, White Sea

***List of abbreviations:*** STT - satellite telemetry transmitter

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## Introduction

The ringed seal (*Pusa hispida*) has a circumpolar distribution in the northern hemisphere. This seal can be found on coastal and drifting ice, in high northern latitudes, and also at the pole. The seal is well adapted to the harsh Arctic conditions. The total (expert) seals number reaches 2 million in the Russia Arctic sector, from the Barents to the Bering Seas (including the White Sea). There are more than 20,000 seals in the White Sea, and more than 30,000 in the eastern part of the Barents Sea (Chapsky 1976, Svetochev and Svetocheva 1995, Ognetov et al. 2003, Kolpashchikov and Ognetov 2005, Lukin and Ognetov 2009, Krasnov et al. 2012).

Ringed seal inhabits the White Sea all year round. Seals constantly maintain

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breathing holes, use cracks in fast ice, and therefore are distributed throughout the fast ice in winter. In the period of February-March, female arranges a lair in the ice hummocks, where she gives birth and nurses a pup. Females built pup lairs in areas of ice hummocks and sufficient snow cover. After nursing the pup (30-35 days), seals begin mating and moulting. Ringed seal moults on fast and drifting ice in April. The molting continues for quite a long time; in early July, single molting seals are still seen lying on the coastal shallows (Ognetov et al. 2005).

Ringed seal doesn't migrate and remains in the White Sea when the ice edge shifts to the high latitudes of the Barents Sea in early July (unlike harp seal). However, the seals distribution in summer and autumn differs from the distribution on the ice in winter, as it was shown by telemetric data. In the White Sea, permanent feeding grounds for ringed seals aren't known yet. In the Barents Sea, the sea ice edge in summer and autumn is a feeding area for ringed seal living near Spitsbergen (Freitas et al. 2008, Lone et al. 2019).

The food qualitative composition of ringed seal includes up to 50 species of aquatic organisms in the White Sea, mainly mass species of small fish and benthic pelagic crustaceans. Different species dominate the seal's food depending on the season: species such as sand eel, capelin, herring, gobies, polychaetes and amphipods. Ringed seal is labile in the food choice, the seal usually feeds on available objects that it can find in sufficient quantities (Svetochev and Svetocheva 1995, Svetocheva 2002, Svetocheva and Svetochev 2010, Svetochev and Svetocheva 2015, Svetocheva and Svetochev 2015). The White Sea is unique, most of fish and invertebrate species are hardly available for seal feeding due to the peculiarities of the hydrological and temperature regimes during the year. For example, pelagic amphipods are available for ringed seals in early spring, herring and capelin in April-June, and stickleback and navaga in summer. The food inaccessibility causes a wide feeding range for ringed seal in the White Sea (Berger 2007, Svetocheva and Svetochev 2010).

Therefore, study of the seasonal distribution and migrations of seals in the White Sea by tagging started in 1989 in order to evaluate typical migration routes. Seals were caught in stationary net traps in the Onega Bay during the summer from 1989 to 2004. Plastic marks were attached to seals on the hind flippers. In total, 174 seals were marked, but there were very few tag returns, only 4 through all the time (Svetocheva and Svetochev 2010). These marks were obtained from seals caught during the autumn commercial fishery.

For the first time the satellite telemetry method was used for biological monitoring of the ringed seal in the White Sea in 2008; this method has also been successfully used to study the migration of harp seals, bearded seals and beluga whales in the White Sea (Svetochev et al. 2007, 2015, 2016, 2019; Kavtsevich et al. 2020, 2021).

## Material and Methods

Satellite tagging of ringed seal was carried out in autumn 2008, 2016 and in summer 2020. The Unskaya Bay (in Dvina Gulf) was a place of capture, where seals rest on rocky banks in the amount of 100 individuals or more from May to November (Fig. 1).

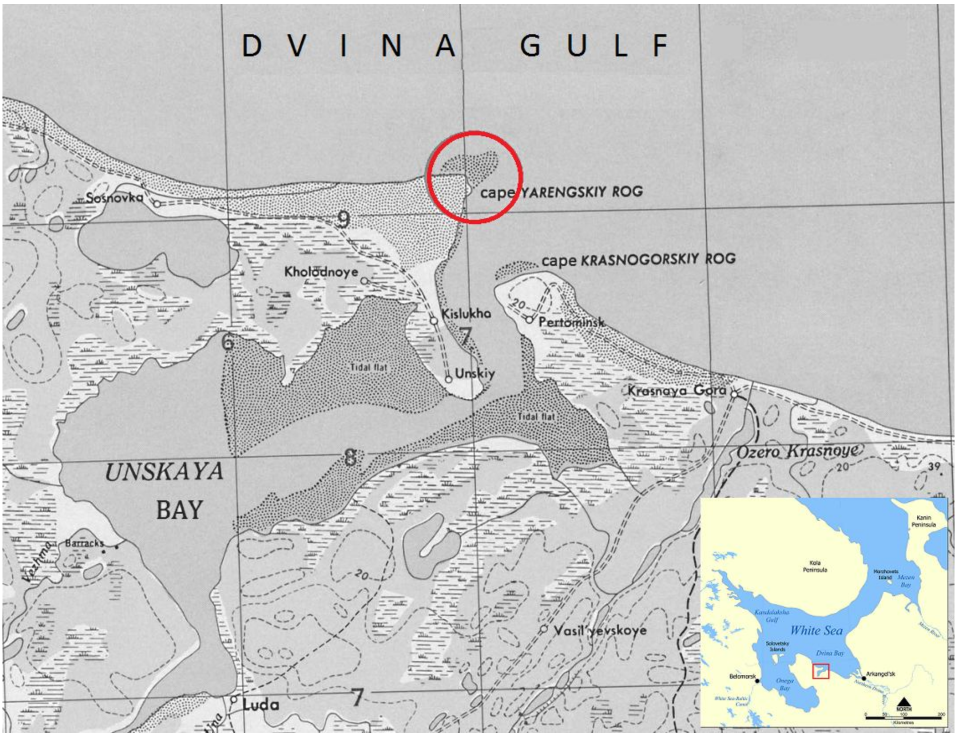


**Fig. 1.** Unskaya Bay (Dvina Gulf of the White Sea). The red circle is the location of seals catching and tagging. *Source:* https://arni.petrsu.ru/2014/tb4155.html

Russian-made «Pulsar» satellite telemetry transmitters were used. These tags work in the Argos system and transmit information about the location of the animal (Table 1) (Svetochev et al. 2015, 2019, [1]). Six ringed seals were caught in total, satellite telemetry transmitters (STT) were placed on five of them. Seals were caught in net traps (stationary floating traps with a wooden frame and a net). Traps (2-7 pieces) were anchored at a depth of 3-4 m (at distance of 250-350 m from the shore). Traps and their use were described in detail earlier (Svetocheva and Svetochev 2010). The seals were pulled out of the trap carefully and brought to the shore. Preparations for immobilization were not used. During tagging, the seal was placed in a net bag for fixation. Tag was glued on the seal's back with a two-component waterproof epoxy-based adhesive (Poxipol). The whole process took about 2 hours, after what the seal was released back to the sea (Figs. 2-3).

Seal location data from Argos was filtered using an algorithm based on swimming speed and error radius. All locations with quality class Z were removed using a filter [1]. The positioning point was saved if the seal's movement speed was no more than 2 $m.s^{-1}$, and the radius error did not exceed 1000 m. The remaining points were used to describe the daily movement. The principle "one day - one observation" was used to describe the daily movement of seals as well. The closest position to 9-00 UT was chosen as a "daily" observation.

**Fig. 2.** Transmitter on the seal's back.


**Fig. 3.** Ringed seal with tag released back to the sea.

| No. | Year | STT number (ID) | Sex of seal | Age (by claw), years | Release coordinates | Start of STT transmission | Stop of STT transmission | Time of STT work, day |
|---|---|---|---|---|---|---|---|---|
| 1 | 2008 | 84578 | female | 2 | 64°47,672 N 38°24,066 E | 29.10.2008 | 07.12.2008 | 40 |
| 2 | 2016 | 151208 | female | 1 | 64°50,595 N 38°22,526 E | 26.09.2016 | 04.11.2016 | 40 |
| 3 | 2016 | 151210 | male | 10+ | -“- | 26.09.2016 | 09.02.2017 | 137 |
| 4 | 2016 | 152004 | male | 0 | -“- | 28.09.2016 | 07.03.2017 | 161 |
| 5 | 2020 | 61930 | male | 10+ | -“- | 04.07.2020 | 23.08.2020 | 41 |

**Table 1.** Ringed seal's (*Pusa hispida*) data with satellite telemetry transmitters (STT) in the White Sea.

## Results and Discussion

Data on the ringed seal with a tag moving in the White Sea for the first time were obtained in autumn 2008 (Fig. 4). The tag (STT No. 84578) transmitted information about the seal location from October 29 to December 07 (Table 1). The sensor worked for 40 days, and then the seal lost the tag because the sensor could work much longer. A total of 1011 fixations of the location of the seal were received, which is an average of 25 fixations of the location per day. Ringed seal remained in the catch place (the Unskaya Bay) for 3 days after tagging, and then left for the open part of the Dvina Gulf.

Then, for 10 days, the ringed seal moved from the Gulf to the open part of the sea. The ringed seal didn't approach the shores and remained in the pelagic zone. The seal kept at the 100 m isobath and more. The seal left for the Onega Gulf on November 09. It has passed 318 km along the coast above the depths of 20 and more m from 10 to 15 November. For the next 6 days, the seal was moving actively and ran at least 290 km above the depth of 20 m, remaining in the southern part of the Onega Gulf.

Then the seal moved along the Karelian coast in the direction from south to north. In autumn, the littoral near the Karelia coast is a good feeding area for ringed seal, however, the seal didn't stay there, but returned back to the Onega Gulf. The seal has run at least 275 km in 6 days.

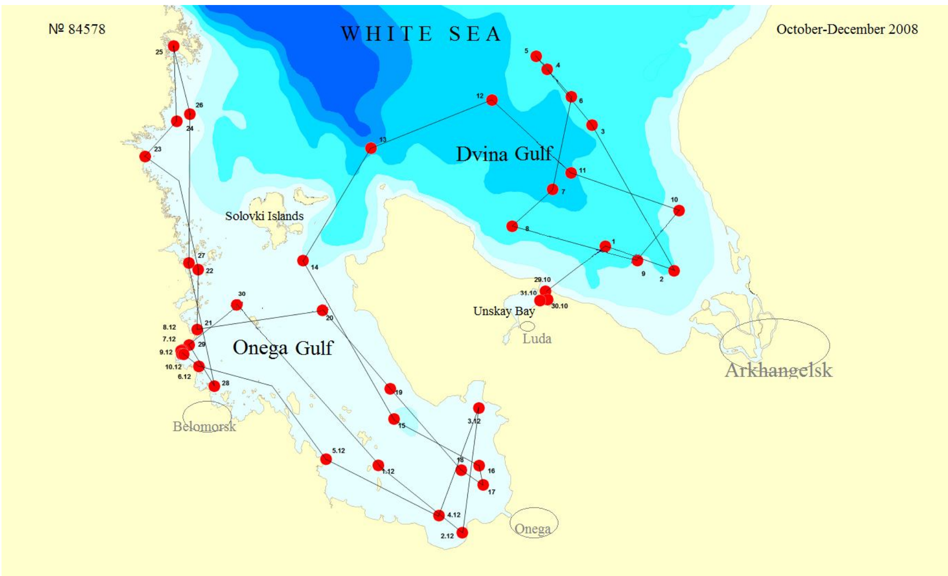


**Fig. 4.** The moving of the ringed seal with STT (No. 84578) in autumn 2008.

The ringed seal returned to the Onega Gulf in early December, it has run almost 290 km. Then the ringed seal crossed the Gulf twice, the distance covered from December 1 to 7was at least 470 km.

The ringed seal moved quickly and covered long distances, it remained in the open sea for a long time in autumn (before fast ice began to form) according to telemetry data. The average daily distance between observation points was 43 km over 40 days. The obtained data on the ringed seal movement didn't confirm the seals are distributed near the shore in autumn, and there was doubt about the settled life of the seals during the year as well.

The study of the ringed seals seasonal distribution continued in the autumn of 2016. Three ringed seals were caught in September, and tags were set on the all seals. The tags transmitted information about the seal's location in 2016 and 2017, 862 locations were received for STT No. 151208, 1089 - for STT No.151210 and 3118 - for STT No.152004 in total.

The average number of location fixes per day was 22, 8 and 19 for each seal, respectively. Seals left the catch place (the Unskaya Bay) after tagging and went in different directions (Figs. 5-7).

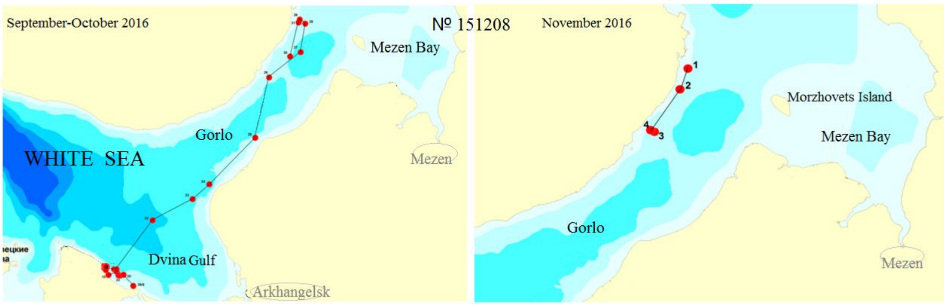


**Fig. 5.** The moving of the ringed seal with STT (No.151208) in autumn 2016.

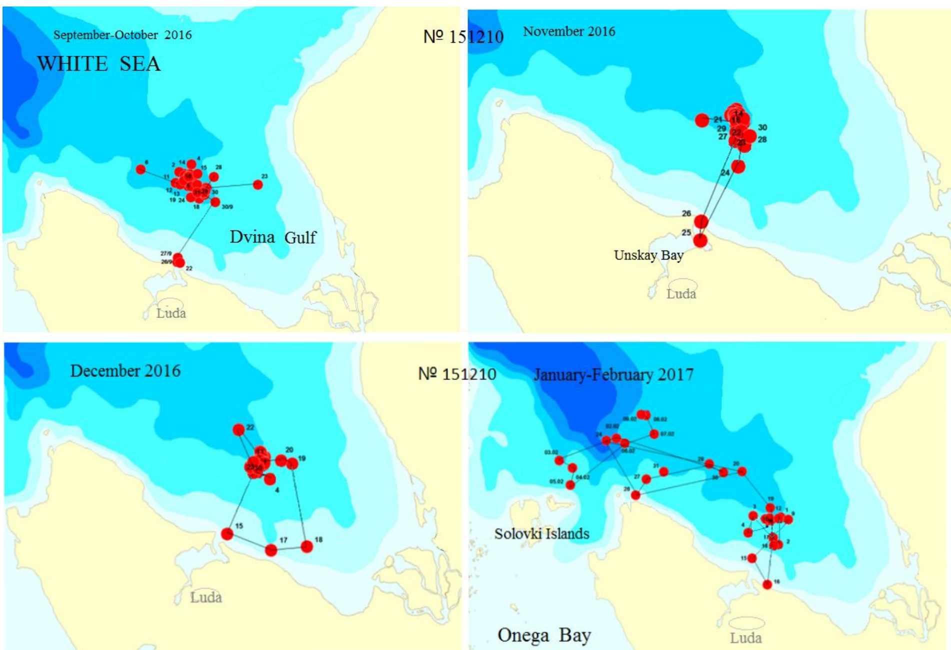


**Fig. 6.** The moving of the ringed seal with STT (No.151210) in autumn and winter 2016.

The seal with tag No.151208 remained at the catch place until October 21, at then it quickly moved to the northeastern sea part (Voronka). The ringed seal remained there until 11.04.2017, when the tag stopped transmitting. The average daily distance between observation points was 13 km for the entire observation period (40 days).

The second ringed seal with tag No. 151210 went to the pelagic zone of the Dvina Gulf, where the seal stayed until mid-January 2017. Moreover, the seal had returned to the catch place for 2-3 days periodically, and then went again to the open sea. The seal finally left to the Solovetsky archipelago at the end of January. The average daily distance between observation points ranged from 6.3 km to 18.7 km. Probably, the seal went to the open sea due to intense ice formation in the Dvina Gulf in January 2017.

The third ringed seal with tag No.152004 immediately left the catch place and went to the northwest. The seal crossed the Basin on October 8 and stopped near the Murmansk coast. The seal remained there until March 7, 2017, when the tag stopped working. The seal kept at the 20 m isobath between 37030 E and 38040 E in October. The average daily distance between observation points was 6.4-10.9 km.

Intensive sea ice formation began near the Murmansk coast in December 2016, the fast ice width was about 300 m. There were almost no drifting ice fields in the period from January to March in this area. Perhaps this is why the seal stayed at the sea edge of fast ice until the tag stopped transmitting.

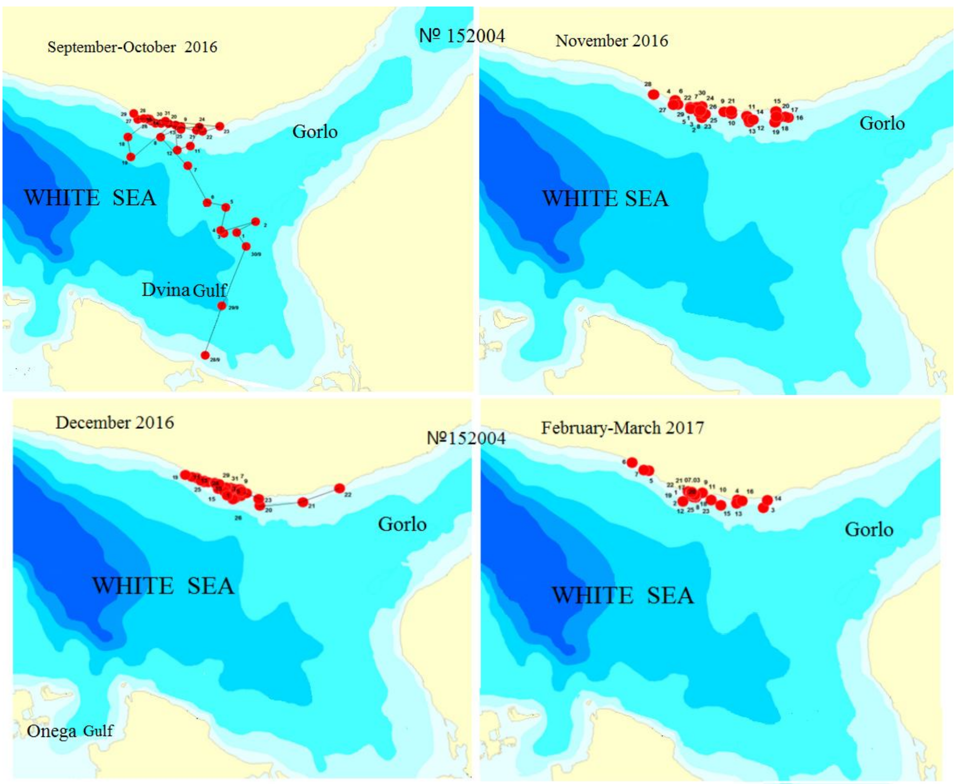


**Fig. 7.** The moving of the ringed seal with STT (No.152004) in autumn and winter 2016.

The study of the ringed seal distribution with STT continued in the summer of 2020 (Fig. 8). Two ringed seals were caught in early July, the tag No.61930 was placed on one of the seals. There were 587 seal position signals received in July, the average daily movement was 4.15 ± 0.73 km. One ringed seal remained in the catch place, the seal kept at the 20 m isobath in August, the average daily movement was only 5.99 ± 0.63 km, there were no significant differences between the samples. Data stopped coming on August 23, 2020.

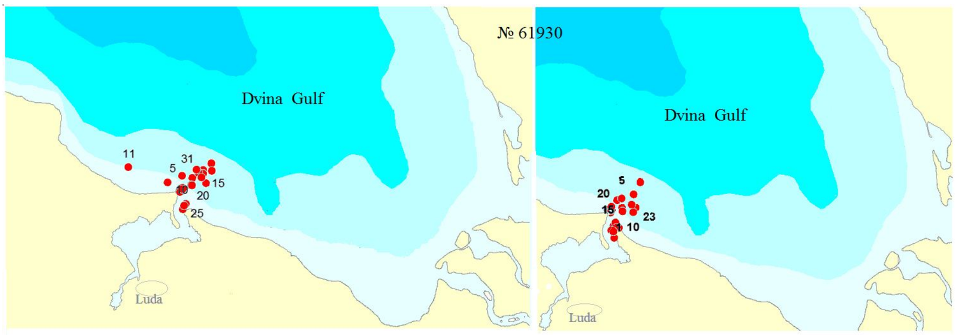


**Fig. 8.** The moving of the ringed seal with STT (No.61930) in summer 2020.

The results of tagging showed the differences in ringed seal distribution summer and autumn period in the White Sea. The seal didn't make movements over long distances in the summer of 2020, it remained practically in the same place in the littoral during July and August. Perhaps this behavior is due to the food availability in the area (Svetocheva and Svetochev 2010).

The ringed seal feeds daily in July-August after the end of the molt (Svetocheva and Svetochev 2010). Data on a significant increase in body weight and subcutaneous fat at the end of summer are the proof of regular feeding of the seal. For example, the thickness of fat (cm) on the chest in absolute terms is almost twice as much in August than in July: 4.5 ± 0.2 and 2.5 ± 0.2, respectively (Svetochev and Svetocheva 1998, Krasnov et al. 2012).

The body weight of seals in August is also higher than in July: by 25.5% for males and by 23.4% for females (Svetocheva and Svetochev 2010). The seals fatness increases in August, but it is much less than in September. The regression line relating the zoological length and girth of the seal body in August is located below the regression line in September for seals aged 2 years or more (Svetochev and Svetocheva 1998).

Sand eel (*Ammodytes hexapterus marinus*), capelin (*Mallotus villosus villosus*), gobies (*Cottidae*), small navaga (*Navaga navaga*), two types of sticklebacks (*Gasterosteus aculeatus* and *Pungitius pungitius*), as well as herring are noted in the seals diet. These species are the only available food for seals in summer. All this fish is massively kept in the littoral or pelagic zone of the sea. Therefore there is no need for seals to travel long distances in search of food in summer (Svetochev and Svetocheva 1998, Krasnov et al. 2012).

In autumn the ringed seals distribution changed. Seals moved actively in the autumn of 2008 and 2016. All seals left the Dvina Gulf with the beginning of active ice formation. In autumn the seal can obviously cover long distances, and it can also stay in the pelagic zone for a long time. At this time seals don't have a priority direction of movement, they move throughout the sea (possibly, with the exception of the Kandalaksha Gulf).

The body weight of young seals is minimal in June, and increases in October by 56% on average (Svetochev and Svetocheva 1998). The body weight of adult seals (5 years and more) also grows, but at different rates. The body weight (kg) of females, on average, is less than that of males in October, 52.6 ± 3.65 and 53.3 ± 2.1, respectively. However, in autumn, females have higher fatness than males, the mass of subcutaneous fat (kg) is 30.9 ± 1.76 and 28.2 ± 1.45, respectively (Svetochev and Svetocheva 1998). By December, the body weight of the seal almost doubles due to the growth of subcutaneous fat reserves (Tymoshenko 1978). In autumn, more than 40 species of fish and invertebrates are represented in the diet of ringed seal in the White Sea; about 15 species of aquatic organisms dominate in food in different areas of the sea (Svetocheva and Svetochev 2010). It should be noted that the polar cod (*Boreogadus saida*), which dominates in the seals diet in the Kara Sea and in the Svalbard region, is absent in the White Sea (Svetochev and Svetocheva 1998, Svetochev et al. 2006, Bengtsson et al. 2020). Perhaps this is one of the reasons why the White Sea ringed seal has a wide food range and many dominant species in the diet in autumn. Obviously, in September-November the ringed seal makes the most of the food supply of the White Sea in order to achieve high fatness.

In winter, with the appearance of landfast ice, ringed seals are more evenly distributed in the White Sea, the seals are found on ice in all gulfs, including the Kandalaksha Gulf, as well as in the mouth areas of large rivers (Chapsky 1976, Polezhaev et al. 1998). As the results of satellite tagging in 2016-2017 showed, the movings of young and adult seals are different. The young seal, that went to the Murmansk coast through the entire White Sea, remained there until November. When fast ice appeared, the seal preferred the sea edge of the fast ice, and the seal was still staying on the sea edge above depths of up to 20 m in December-March. The ice edge moved depending on the winds and tidal currents, and the seal moved with it. At the same time, an adult seal actively moved throughout the Dvina Gulf, as well as in the Basin among drifting ice over depths of more than 50 m until the end of February.

Ice and food conditions are important parameters of the well-being and survival of ringed seals. The White Sea is the only one of the Arctic seas which is located almost entirely south of the Arctic Circle [2, 3]. The White Sea is located south of the Barents Sea. The two seas are connected through a narrow and shallow strait called Gorlo. The presence of a shallow strait with fast tidal currents makes it difficult not only for water exchange between the seas, but also for the entry of the Barents Sea hydrobionts. However, saltier and warmer Barents Sea waters, penetrating through the Gorlo into the interior areas of the White Sea, play an important role in forming its hydrological conditions and have a serious impact on marine biocenoses.

The White Sea water has a lower salinity and average annual temperature than in the Barents Sea, since the flow of large rivers into the bays has a great influence here (Berger 2007). Due to its freshness, landfast ice forms in the mouths of rivers and bays by November. In winter, one-year drift ice prevails in the central and north parts of the sea - the Basin and the Voronka. This ice is periodically replenished by landfast ice torn from the shore by strong winds. Mixed ice fields persist in bays until early May (Berger 2007). In such unstable conditions the ringed seal feeds on small bottom-pelagic fish and near-bottom crustaceans (Berger 2007, Svetocheva and Svetochev 2010).

It was traditionally believed the ringed seal of the White Sea doesn't make seasonal migrations and large movements. Seals can indeed be daily observed resting on coastal rocks and shallows on all the White Sea shores throughout summer and autumn. However, telemetry data in 2008 and 2016-2017 showed ringed seal actively move (wander) throughout the sea in autumn. The mobility of the seal as an element of the White Sea ecosystem is explained not only by a wide food range, but also by the proven fact the spatial seal distribution is variable in different seasons of the year. A ringed seal can stay in a local habitat in winter or summer if it finds a sufficient amount of at least one food group there (fish or crustaceans).

In autumn, the qualitative food composition of the ringed seal expands. Feeding conditions become more favorable, since many species of crustaceans and fish, as well as polychaetes, become available. However, feeding conditions in autumn are unstable, changeable from year to year; due to low water temperatures during the summer and changes in hydrological conditions, the productivity of sea biocenosis often remains low. And as a result, the number of some prey objects, such as herring, navaga and capelin, decreases in autumn. Therefore seals become very active in autumn and move long distances up to the formation of landfast ice in November-December. Seals search the bays and the open part of the sea looking for available and plentiful food, they quickly reach the northernmost and southernmost areas, go deep into the bays and rise up the rivers. Therefore, the ringed seal, such a small and unremarkable seal, can rightly be called a North wanderer.

**Fig. 9.** Head of the marine mammals laboratory Nikolai Kavtsevich, Onega Bay, 2013.

## In memory of our colleague

Our friend, colleague, participant of difficult and interesting field expeditions, a talented and purposeful researcher of Arctic marine mammals, head of the marine mammals laboratory of the Murmansk Marine Biological Institute of the Russian Academy of Sciences (MMBI RAS), Doctor of Biological Science Nikolai Nikolaevich Kavtsevich passed away in 2021.

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