Movements of the bearded seal in the White Sea monitored by satellite telemetry

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Abstract

Movements and distribution data of the bearded seal (*Erignathus barbatus*) in the White Sea during summer and autumn were obtained as a result of tagging with satellite telemetry transmitters (STT). Russian-made Pulsar STTs operated in the Argos system. Catching and tagging of bearded seals was carried out in the Onega and Mezen bays in 2014, 2015 and 2017. Altogether, 7 STTs were installed on seals of different ages and sexes. Analysis of satellite telemetry data showed that during the non-ice period bearded seals were tied to local habitat areas, and the dynamics of their movements differed in the inner and open parts of the sea. The STT data suggest that these differences in distribution are due to lability in feeding and show good adaptation of the bearded seal in the conditions of poorly accessible feed base of the White Sea. The diverse feeding strategy of the bearded seal in the White Sea, and its adaptation to the difficult feeding conditions of the sea, may help the species to survive in the region and ensure stable population numbers in changing environmental conditions.

Key words: satellite telemetry, movements, distribution, bearded seal, White Sea

List of abbreviations: STT - satellite telemetry transmitter

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Introduction

The use of modern telemetry tags makes it possible to obtain data on the state of the aquatic environment in the Arctic seas. Seals can be used as convenient objects that can carry STTs of varying levels of complexity (Fedak 2004, 2013). Pagophilic

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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.

seals may be vulnerable to projected warming and the exploitation of hydrocarbon deposits on the northern shelf, so biological monitoring of such species remains an important task. One of such seals is the bearded seal (*Erignathus barbatus*), a widespread species in the Arctic seas. Bearded seal have a circumpolar distribution and primarily inhabit coastal areas of shallower depths with seasonal pack ice cover. The seal is generally split into two subspecies, the *Pacifc E. b. nauticus* (Pallas 1811) and the *Atlantic E. b. barbatus* (Erxleben 1777). Generally, bearded seal distribution is described as patchy with relatively low densities (Crance et al. 2022, Fuirst et al. 2023). The bearded seal, that live in the White, Barents, Kara and Laptev Seas, belong to the Atlantic subspecies. They reach a length of 3 m, a body weight up to 200 kg, and are capable of wearing big tags with a large set of sensors. The main breeding areas for the bearded seal are the White Sea and the eastern part of the Barents Sea. During summer feeding movements when the ice melts, the bearded seal go to the north of the Barents Sea, to the Kara Sea and the Laptev Sea (Chapsky 1976). In recent years, cases of the baby birth in the Kara Sea have been noted (Svetocheva et al. 2016).

The bearded seal is found in the White Sea all year round. Its numbers are stable and in the summer are up to 6 000 seals (Bondarev 2004). Most authors believe the bearded seal prefer drifting ice; in February-March, females whelp on first-year drifting ice; in March-April, seals can be found even on small ice floes (Potelov 1998, Lukin and Ognetov 2009, Kingsley et al. 1985). It is known the seal also lives at the edge of fast ice (Svetochev and Svetocheva 1995, Bondarev 2004). In the winter, the bearded seal lives on the littoral at shallow depths. In the spring, adult seals come to the Gorlo (Tunnel) and Voronka (Funnel) for giving birth and mating and moulting on the drifting ice, but females with pups are also found in the inner sea areas – the Basin, the Solovetsky Straits. The pups are with their mothers on the ice without hideout. Potelov (1998) suggests that after the fast ice melts, some of the adult seals leave the sea, so in summer and autumn there are predominantly juvenile seals in the White Sea.

There is almost no information about feeding areas of bearded seal. There is also no data on the seals movements during the non-ice period (summer-autumn). The main questions are: are seals able to move all over the sea or are their migrations limited? Can bearded seal go to the Barents Sea during the feeding, and are there priority feeding areas in the White Sea? The number of adult seals in summer and their locations are also unknown. Insufficient information does not allow us to identify connections between the summer (feeding) and winter (reproductive) habitats of the bearded seal. The seasonal distribution of juvenile and adult seals remain unstudied. To fill the gap, we studied the movements of *Erignathus barbatus* by STT. The purpose of this study was to obtain detailed information about the movements of bearded seal during feeding in different areas of the White Sea – in its inner (closed) and open parts.

Material and Methods

The bearded seal is found in all White Sea areas, they rest on sandy and rocky shallows during low tide (Fig. 1) (Krasnov et al. 2012, Potelov 1998, Svetochev and Svetocheva 2014). Possible migrations of the bearded seal in the White and Barents Seas have not been studied.

Fig. 1. Bearded seals on the sandbanks of the Mezen Bay, July 2017, White Sea.

Russian satellite telemetry tags "Pulsar", operating in the ARGOS system (for details *see* [1]) in the marine environment, were used for tagging the bearded seal. The advantages of these tags are: specialization for working in the marine environment at different depths; the ability to equip tags with additional sensors; long-term operation in different modes; availability of ARGOS system databases, convenient work with data and the possibility of using domestic tags. The ARGOS system provides seal location data with different accuracy classes. Upon receipt of 4 signals from the tag per 1 flight of satellite, the system is able to evaluate and assign each received coordinate the relevant accuracy class. The class ”0” – shows that the accuracy of determination the coordinates was more than 1000 m. Class ”1” – has positioning accuracy of less than 350-1000 m, the class ”2” – 150-350 m, and the class ”3” – has positioning accuracy less than 150 m. Upon reception of the three signals from the tag per one flight of satellite, the system determines the position of the tag, but does not assess the accuracy of observation, such data is assigned class ”A”. Upon reception of two signals the system also determines the position of the tag, but does not determine the accuracy of observation, such data is assigned class ”B” [2]).

Bearded seal tagging was carried out in the Onega Bay (inner part of the sea) and in the Mezen Bay (open part). Seals were caught in 2014 and 2015 (Onega Bay) and in 2017 (Mezen Bay). Altogether, 7 seals were tagged. Tagging was carried out on the spot of catching (Fig. 2, 3; Table 1). The tags were mounted on the seal’s back with special glue (quick solidifying two-component resin Contact or Poxipol). The seals were fixed with a net for about 2 hours, then the seals were released to the sea. This technique was routinely used for tagging harp seal, ringed seal and hooded seal in the White and Barents seas (Svetochev et al. 2015, 2016, 2018).

From 10 to 50 seals are usually found in the catching place in Onega Bay in summer. Catching places are rocky shallows in the eastern part of the bay. Seals were caught on shallows located 5 km from the base. In the Mezen Bay, the bearded seal was caught on sandbanks at the mouth of the Mezen River, 20 km from the base. In summer, up to 70 bearded seals rest on these shallows. This is an area with substantial tidal activity. There are high tides up to 10 m twice a day, high current speed, and low salinity. At low tide, the sea moves 6-7 km from the coast, exposing the muddy bottom.

STT number (ID)	Sex of seal	Age (by claw), years	Release coordinates	STT operating time, day			Obser-vation number / mean, day
				Start	Stop	Total	
111353	fem	4	64°18”062 N 37°48”024 E	28.06.2014	02.11.2014	128	3877/30
111354	male	3	-“-	05.07.2014	09.11.2014	128	4099/32
151206	male	5	-“-	29.06.2015	23.11.2015	148*	776/11
110719	fem	7	-“-	02.07.2015	29.11.2015	151	981/6
151207	male	3	-“-	04.07.2015	12.09.2015	69	619/9
112857	fem	4	-“-	05.07.2015	19.11.2015	136	533/4
61744	male	2	66°00 N 44°00 E	22.07.2017	15.10.2017	86	1151/13

Table 1. Bearded seal’s data with satellite telemetry transmitters (STT) in the White Sea.
Note: *On September 8, 2015 a brown bear caught and dragged a seal (No. 151206) to taiga. The tag operated until November 23, 2015 in standby mode, but it could not be detected.

Fig. 2. Bearded seal with STT, on rocky shallows, July 2015, Onega Bay, White Sea.

Fig. 3. Bearded seal with STT, on sandy mudflats, July 2017, Mezen Bay, White Sea.

The principle: "one day – one observation" was used to describe the daily movement of the seal. The closest position to 12-00 MSK (8-00 UTC) with the highest accuracy class and minimum error radius was selected as a "daily" observation. The daily movement should not exceed the distance that the animal is capable of covering, moving at a speed of no more than 3 m s^{-1}.

Results

In the following text, the results are structured according to the locations and given for the Onega Bay and Mezen Bay separately.

Onega Bay. In summer, bearded seals made multidirectional movements in the littoral or near islands in the eastern part of the bay. The seals periodically returned to the shallows to the catching place; one seal went to the Dvina Bay. In autumn, 4 seals moved to the Onega River mouth and remained there until the tags stopped working. Tags were installed on juvenile (No. 111353, 111354, 151207, 112857) and adult seals (No. 151206, 110719). All young bearded seals stayed at the depths of up to 10 m. The adult female (No. 110719) lingered above depths of more than 10 m. The adult male (No. 51206) spent a short time above depths of more than 20 m during the moving to the Dvina Bay (Table 2). The maximum daily movements of bearded seals were more than 60 km in 2014 and more than 80 km in 2015.

Year	No. STT	Daily movements, km					
		Summer (June-August)			Autumn (September-November)		
		average	min	max	average	min	max
2014	111353	10.4 ± 1.49 N=64	0.01	47.3	9.1 ± 1.12 N=61	0.01	33.5
	111354	15.4 ± 2.39 N=56	0.03	64.4	15.1 ± 2.25 N=61	0.03	64.4
2015	110719	11.4 ± 0.84 N=58	0.31	30.0	11.3 ± 0.94 N=69	0.09	38.9
	112857	10.7 ± 0.9 N=60	1.15	31.5	12.2 ± 1.23 N=60	0.33	50.3
	151206	12.3 ± 1.55 N=68	0.1	58.7	-	-	-
	151207	12.5 ± 1.67 N=70	0.1	84.0	-	-	-

Table 2. The average daily movements of bearded seal, Onega Bay, White Sea.

Seals were distributed along the eastern coast of the Onega Bay to Chesmensky Cape in 2014 (Fig. 4). In summer, the bearded seal (No. 111353) went to the islands in the pelagic part of the bay. In autumn, this seal moved southeast to the Onega River mouth; the tag stopped working when the bearded seal was in the Onega River (02.11.2014).

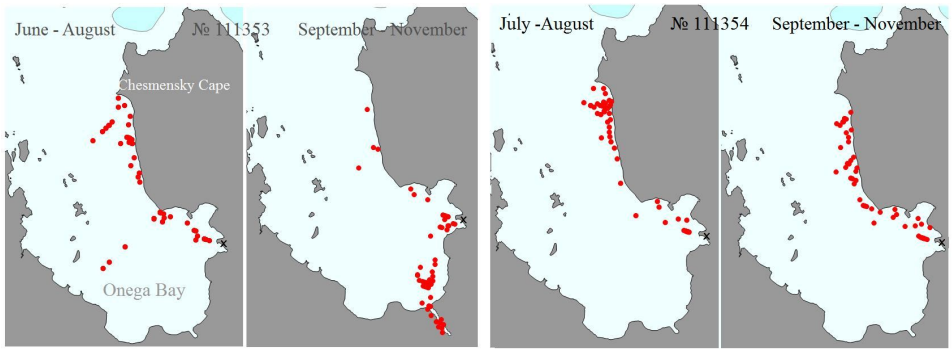

Fig. 4. Movements of bearded seals with tags in Onega Bay in 2014. The location of the expedition base is shown as "X".

In 2015, bearded seals were located in the southeastern part of the bay. In summer, the seals moved from the littoral to the pelagic part of the bay. One seal (No. 110719) spent a short time above depths of 20 m or more. Two seals (No. 110719 and No. 112857) went to the small islands (Purluda – 0.16 km^2, Osinki – 0.55 km^2,

Khedostrov – 5.2 km^2), and one bearded seal (No. 151206) moved to the Dvina Bay. In autumn, two tags stopped working in early September, one seal (No. 151207) was in Onega Bay, and the other (No. 151206) – in the Dvina Bay at that time. In September-November, the remaining seals were in the southern part of the bay until their tags stopped working (Fig. 5, 6).

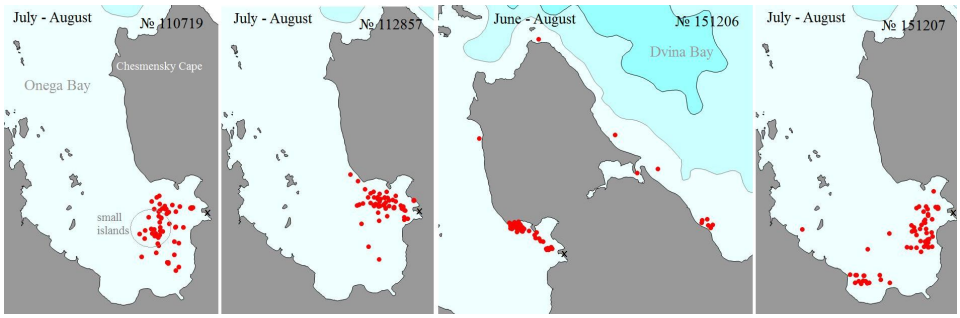

Fig. 5. Movements of bearded seals with tags in Onega Bay in the summer of 2015.

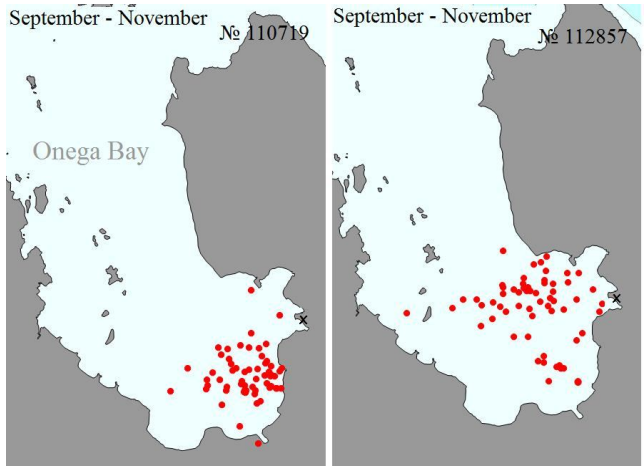

Fig. 6. Movements of bearded seals with tags in Onega Bay in the autumn of 2015.

Mezen Bay. The bearded seal (No. 61744) made long distances to north several times, but each time returned to the sandbanks to the Mezen River mouth, where it was caught. In summer, the seal went to the Voronka (Funnel), and also moved to the Barents Sea; in autumn, the seal remained in the Mezen Bay.

The seal ended up in the Barents Sea for 3 days after tagging, approximately 300 km from the catching place. The seal stayed in the Barents Sea for 29 days, it swam over the depths of 50-100 m and in shallow waters (Kaninskoye shallow and shallow the Eastern area). The average daily movement was 11.3 km (Fig. 7). The seal returned to the White Sea on August 25, specifically to the shallows at the Mezen River mouth on August 28. The seal rested for 11 days here. During high tide it went into the water, but did not leave this location.

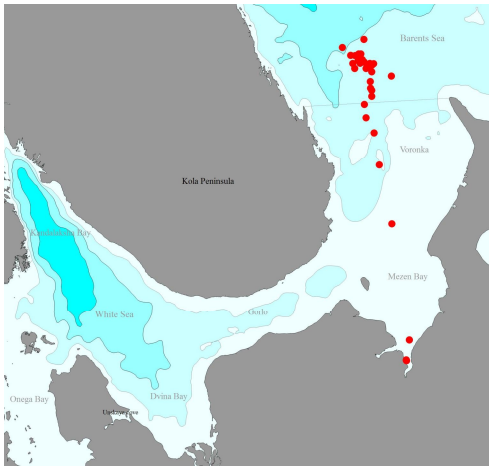

Fig. 7. Movements of bearded seal with tag (No. 61744) in the open part of the White Sea and the Barents Sea in July-August 2017.

The seal left the sandbanks at the Mezen River mouth on September 8 and went to the north. The bearded seal ended up in the central part of Voronka on September 13, 170 km from the Mezen River mouth. Depths reach 50 m in this area, there is a constant flow to the north, and there is a vast Northern Shoal. The seal remained in this area until September 28. Average daily movements were 7.4 km (Fig. 8). The seal returned to the Mezen River mouth on October 1, its rest on the sandbanks was short and took 4 days. Then the bearded seal went to the north again, at a distance of 70 km. The seal moved to shallow waters of the eastern coast of the Mezen Bay on October 6. The seal remained there until October 15 when its tag stopped working (*see* Fig. 8).

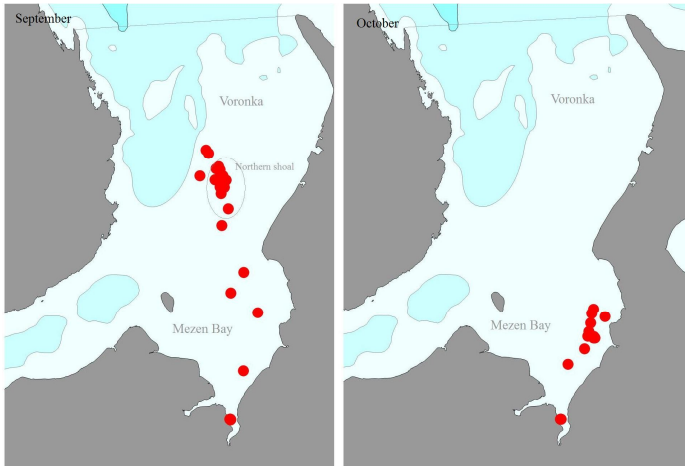

Fig. 8. Movements of bearded seal with tag (No. 61744) in the open part of the White Sea in September-October 2017.

Discussion

The tagging results in the White Sea showed that bearded seal are more attached to local habitat than ringed seal during summer and autumn (Svetochev and Svetocheva 2023). Immature bearded seals didn't leave the Onega Bay from June to November, with the exception of one seal (adult male), which went to the Dvina Bay. Cameron et al. (2018) showed, that ice habitat selection of the bearded seal in the Bering Sea is the result of behavioral differences related to age. The young bearded seals selected locations near the ice edge, but adults prefered areas farther north and in heavier pack ice. The average daily movements of seals in the White Sea were 7.4-15.4 km, but these aren't the longest recorded distances that a seal can travel per day (*see* Table 2). For example, the average daily movements of bearded seals in the Okhotsk Sea were 95.6 km (Solovyeva et al. 2021).

In the Onega Bay, bearded seals remained in the eastern shallow part until the new freeze-up in November. Obviously, seals find enough food during the feeding season here, and a large number of shoals and shallow waters provide resting places for seals. Therefore, the daily movements were rather short. However, bearded seals sometimes returned to the shallows where they were caught.

In the Mezen Bay, the bearded seal regularly traveled long distances; it went north several times and even went out into the Barents Sea. It should be noted that each time the bearded seal returned to the shallows where it was caught. The resting time was directly proportional to the time the seal spent moving and feeding in Voronka and the Barents Sea (Svetochev and Kavtsevich 2018). In our opinion, it is obvious that such "rushes to the north" are associated with the food items search; bearded seals are forced to make regular movements in this part of the sea. It is likely that bearded seals constantly return to the Mezen Bay sandbanks to rest and spend up to 20% of the total time there in summer and autumn.

In autumn, the distance between the resting place and the seal's feeding area decreased to 70 km, and the seal's resting time on the shallows also decreased. The behavior of the bearded seal was similar to that of the Atlantic walrus (*Odobenus rosmarus rosmarus*), when the animal spends approximately a quarter of his time resting on land (Lydersen et al. 2012). It is obvious the feeding conditions of the bearded seal differ in the open and inner parts of the White Sea during the non-ice period.

The White Sea is an almost enclosed water body of "bucket" type with an area of about 90 000 km^2 It has a weak connection with the neighboring Barents Sea through a narrow and shallow Gorlo. The Gorlo separates the inner areas – Dvina, Onega, Kandalaksha Bays and the Basin – from the open parts, Mezen Bay and Voronka. Therefore, living conditions of hydrobionts in these two parts are very different. One of the differences is the cold water in open areas and strong summer water heating in inland shallow and coastal areas. The mouths (and adjacent sea areas) of the Onega, Northern Dvina, and Mezen rivers have low salinity (Nadezhin 1966, Tambovtsev 1971). Living conditions in the inner and open sea parts differ not only in temperature and salinity, but also in the height and speed of daily tides. In Voronka and Mezen Bay (as well as in Gorlo) the tides move at high speed and reach 10 m, and in Onega Bay – up to 3.5 m. The food supply in each bay has its own characteristics and differs in the bottom communities composition.

The White Sea food supply is reasonably considered to be scarce, not because of low reserves, but these reserves are difficult to access throughout the year (Kuznetsov 1960, Gerasimova and Podzhanskaya 1987). Marine mammals have to adapt to

use the White Sea food resources. White whale (3 000-5 000 whales) migrate to the White Sea in early summer and feed in summer and autumn, then most whales migrate to the Barents Sea for the winter. In winter, 2 million harp seals come to the sea to replace the white whale; this population stays in the White Sea until May and also feeds there. And the ringed seal and bearded seal feed there all year (Svetochev and Svetocheva 2015, Svetochev et al. 2015, 2016).

The White Sea is an almost closed Arctic sea, so food resources there are limited and have a limiting effect on the phocid number. The penetration of new species into hydrobionts of the White Sea is difficult, therefore, benthic communities here are poorer than those in the Barents Sea and account for 50–70% (Babkov and Golikov 1984, Berger 2007). The bearded seal, like the ringed seal, is one of the main consumers of the White Sea food supply. In the White Sea, the bearded seal feeds on benthic and benthic-pelagic invertebrates and fish. Decapods and fish are more important than mollusks, and fish takes up almost 40% of the food. Boreal mollusks dominate the bearded seal diet in the Barents Sea (Krasnov et al. 2012, Potelov 1971, Svetocheva 2013). In the Far East bearded seals populations, the great importance of fish in the bearded seal diet of the Okhotsk Sea has been reported (Solovyeva et al. 2021).

The food of the White Sea bearded seal includes 25 species and groups of hydrobionts from different ecological zones (Krasnov et al. 2012, Svetocheva 2013, Svetochev and Svetocheva 2015). During summer in the inner parts of the sea, seals feed on decapods (crabs, shrimp) and fish (smelt, gobies, flounders), as well as worms and bivalves. In autumn, the food of the bearded seal is dominated by pelagic shrimp and benthic amphipods *Anonyx nugax*, and bivalves *Mya arenaria*. Among the fish in food there are gobies (*Cottidae*), navaga (*Eleginus navaga*), cod (*Gadus morhua marisalbi*) and flounders (*Pleuronectidae*)(Svetochev and Svetocheva 2015, Svetocheva and Svetochev 2016). The bearded seal feeding in open sea areas has not been studied. According to the authors' observations there is evidence, that seals feed on navaga, cod and flounder during summer, as well as the mollusk *Mya arenaria*. The question of the feeding of *Chlamys islandica* also remains unexplored. Large reserves of this bivalve mollusk are located in the Barents Sea (Kaninskoye shallow and shallow the Eastern) (Zolotarev 2016). The bearded seal with tag (No. 61744) has been in these areas in the summer of 2017. It should be noted the food of Barents Sea bearded seals is dominated by mollusks (genera *Buccinum, Cardium, Mya, Saxicava*), but decapods and fish aren't of great importance(Potelov 1971). Cameron et al. (2018) believe that the first year of life is typically the most critical to long-term survival of bearded seal. Proficiency at feeding, habitat selection and seasonal movements, are important factors and their better understanding is critical for developing sound conservation and management plans.

The shallow of the Onega Bay provides bearded seals with food during the feeding period from summer to autumn, which allows seals not to travel long distances in food search. In this area, bearded seals with tags preferred depths of up to 10 m. Seals with tags didn't go to the Solovetsky Islands, although it was there (Topi Islands) where bearded seals haulouts (up to 100 or more individuals) were previously recorded in the summer (Krasnov et al. 2012, Potelov 1998). In the Mezen Bay, conditions are different; here seals have to travel long distances. Food items (fish, decapods and mollusks) are found in sandy shallow waters in the Barents Sea and the Voronka. However, the fact the seal stayed for a long time above depths of 50-100 m in the pelagic part of the Voronka and the Barents Sea suggests the bearded seal also found food there.

Tagging results in 2014, 2015 and 2017 showed the distribution and feeding migrations of juvenile bearded seals during the feeding period differ in the inner and open parts of the White Sea. It seems likely the differences are due to a lability in the selection of food items. The diverse feeding strategy of the bearded seal in the White Sea, and its adaptation to the difficult feeding conditions of the sea ensure survival and stable population numbers in changing environmental conditions.

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