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# First Satellite Tagging of the Northern Fur Seals (*Callorhinus ursinus*) on the Tyuleniy Island, the Sea of Okhotsk

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In October 2018, three Northern fur seals (two adult females and one juvenile male) were deployed with satellite tags on the Tyuleniy Island in the Sea of Okhotsk. The operational time of the tags ranged from 33 to 203 days. The adult females started their winter migration in the first half of November; the initial stage of their winter migration occurred in the Japan/East Sea, which they entered through the La Perouse Strait. The juvenile male left the rookery in mid-October, crossed the Sea of Okhotsk in a north-western direction and returned to the south. The male had reached the coastal areas of Hokkaido Island, Japan by the end of November. From the Sea of Okhotsk, the male entered the Pacific Ocean through the Yekaterina Strait and subsequently entered the Japan/East Sea via the Tsugaru Strait. The winter foraging of the male occurred within the north-eastern part of the Japan/East Sea just off the Tsugaru Strait. After 3 months, the male returned to the Pacific and remained off the Sanriku Coast (Honshu Island).

**Key words:** Northern fur seal (NFS), On-shore (reproductive) period, Sea (pelagic) period, Winter migration, Sea of Okhotsk, Japan/East Sea, North-Western Pacific.

## BACKGROUND

The Northern fur seal (*Callorhinus ursinus*, NFS) is the most abundant species of pinniped from the family of eared seals (*Otariidae*), which is broadly distributed in the northern Pacific. There are various stocks of the NFS in Russian and North American waters (Kuzin 2014b; Muto et al. 2021; Panin 1970), of which one is confined to a rookery on Tyuleniy Island in the Sea of Okhotsk (a small island just to the east of the Sakhalin Island). However, in the last century, there was a significant reduction in the population of NFS throughout the range due to commercial overfishing (Fedorov 1964). Therefore, to prevent species extinction, the states participating in the sealing concluded with several agreements in studying the NFS and regulation of their commercial removal (including the Conventions of 1911 and 1957) (Fedorov 1964). These agreements greatly contributed to the restoration of the NFS population, particularly with the stock of Tyuleniy Island, which increased from approximately 50,000 individuals at the end of the last century (Kuzin 2014b) to 115,000 individuals in 2013 (Kuzin 2014a).

The annual NFS cycle is clearly divided into two periods: the on-shore (reproduction) period (summer-autumn), when almost all adults concentrate on rookeries to participate in reproduction, and the sea (pelagic) period (autumn-spring), during which the animals migrate to feeding grounds and back. Therefore, methods associated with their labeling are widely used

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to study the migratory behavior of these animals. In the last century, data on NFS migrations were obtained by tagging these animals with numbered tags. Notably, the tags were metal plates attached to the flippers of these animals. More than 210 000 individuals were marked with metal tags on the Tyuleniy Island alone during the 1957–1984 period (Kuzin 2014b). In addition, in the wintering areas, the tags were mainly recovered during the pelagic harvesting of the NFS for scientific needs. Therefore, migrations were judged based on the return of tags. However, the information obtained through this process was incomplete as it was often limited by the places of birth and death of the animal.

Recently, the primary directions of the NFS migrations are generally understood. It has been established that the winter feeding of adult NFSs from the Tyuleniy Island stock occurs in the Japan/East Sea (Kuzin 2014b; Panin 1970), whereas the winter feeding of the young NFSs occurs mainly in the Pacific waters east of Japan (Ashchepkov and Kuzin 1986 1987; Kuzin 2014b; Panin 1970). However, there is no accurate information about the routes of the NFS to the feeding grounds. Concurrently, satellite telemetry could provide detailed information about the movements of the NFS. In Russian waters, tagging with satellite transmitters was performed during the study of the populations of NFS from the Commander (Belonovich 2011) and Kuril Islands (Waite et al. 2012); however, there has been no attempt so far to apply this method to study the NFS stock of the Tyuleniy Island.

Therefore, to clarify the details of the winter migrations of the NFS stock of Tyuleniy Island, we tracked three NFSs with satellite tags in the autumn of 2018. This study aimed to determine the timing and routes of migration of the fur seals to their wintering grounds.

## MATERIALS AND METHODS

The NFSs were tagged with SPOT-293A satellite tags (ARGOS SPOT, Wildlife Computers, Inc., Redmont, USA) on the rookery of the Tyuleniy Island (48°50'N, 144°63'E) on October 10, 2018. The tags were installed on two adult females and one juvenile (presumably three-year-old) male. All tags were fixed to the fur in the crown area using a quick-drying Loctite™ Type 422 glue (Henkel Corp., Dusseldorf, Germany) (Horning et al. 2019) (Fig. 1).

### Data pre-processing

The data that was pre-filtered by ARGOS (Kalman filter algorithm) was additionally processed using the SDA (Speed-Distance-Angle-filter) filtering algorithm (Freitas et al. 2008) executed in the ARGOS filter R package (R Development Core Team 2007). The speeds of less than 4.1 m/s (Kuzin 2014b) at distances greater than 5 km and the angles between path segments of less than 15° at distances of 2.5 km and less than 25° at distances of 5 km were considered acceptable when filtering using the SDA method. Next, after both the Kalman and SDA algorithms were successfully applied to the data set, additional manual filtering was performed to eliminate the locations detected on the land outside the 1 km zone from the water and locations with speeds of more than 10 m/s (regardless of the distances covered by the NFS).

### Statistical data processing

One feature of the nursing female NFS behavior during the coastal period is the short, several-days-long, foraging trips (Kuzin 2014b; Merrill et al. 2021). Therefore, the distance from the rookery (distance and direction to the furthest point of the feeding trip) and the total duration in days were determined for each foraging trip direction. The end of the on-shore period (including the beginning of winter migration) was considered to be the day when the tagged female left the rookery without returning to it during the current season.

Visualization of the boundaries of statistically significant areas for male #55024 was performed using Hot Spot Analysis (Getis and Ord 1992). This method was implemented in ArcMap/Spatial Statistics. Notably, the polygons formed by meshes with values of a standard score $Z(G_i^*) \geq 2.58$ were identified as significant for the male (hereinafter: key areas, KA). In the key areas, the test male spent significantly ($p < 0.01$) more time than in the rest of the area within his route. The same method was used to determine the areas of statistically significant changes in the horizontal velocity of the male. The assessment of the locations as "cold" ($Z(G_i^*) \leq -2.58$) or "hot" ($Z(G_i^*) \geq 2.58$) conformed to a statistically significant ($p < 0.01$) decrease (in "cold" locations), or increase (in "hot" locations) of the horizontal velocity of the male. Furthermore, a constant decrease in the horizontal speeds was considered a marker of the feeding activity (assuming that the male was spending more time in vertical movements under the surface) or a marker of resting on the water surface. The key areas within which the clusters of "cold" locations were observed were considered primary for male #55024. In contrast, other key areas were considered secondary.

In this study, we used the maps obtained from the open sources as follows: the OpenStreet land contour (OpenStreet 2019) and the GEBCO Maps

bathymetric map (GEBCO 2020). All calculations were performed in an equidistant conic projection for the north of Asia (Asia North Equidistant Conic); the maps made in WGS-84 were used as illustrative material. The information received from the tagged seals was processed using ArcMap 10.3, MS Office Excel, R3.4.3, and GraphPad 6 software.

## RESULTS

### Females #55015 and #55019

Until November, both females remained tied to the rookery of the Tyuleniy Island, making feeding trips (median duration: Me = 6.8 days and interquartile range: IQR = 4.5–8.6 days) in the northern (number of cases: $n$ = 3), eastern ($n$ = 1), and southern ($n$ = 1) directions (Fig. 2). After the tagging and before the beginning of winter migration, female #55015 made two of such trips, and the female #55019 made three. The females traveled for a median distance, Me = 195 km, from the rookery (IQR = 185–219 km), while the median distance covered during the trips was 384 km (IQR = 213–466 km). Female #55015 began her winter foraging migration on November 06, 2018 and reached the La Perouse Strait in 4.0 days, having traveled at least 429 km. Conversely, female #55019 began her winter migration on November 14. The female traveled from Tyuleniy Island to the La Perouse Strait (498 km)


**Fig. 1.** Tagging of NFSs at Tyuleniy Island with SPOT-293A satellite tags. A, Capturing of NFS male into a hoop net (photoed by Sergeev AF). B, Satellite tag 55024 / 17U1712 fixed to the fur in the crown area of NFS male. C, NFS male with satellite tag attached to his head. D, Releasing of a tagged NFS female from hoop net (photoed B–D by Ryazanov SD).

in 11.5 days. Then, through the La Perouse Strait, females #55015 and #55019 entered the Japan/East Sea on November 10 and 23, respectively. The satellite tag of female #55015 stopped working in the Tatar Strait on November 12. Female #55019 spent 3 weeks in the Japan/East Sea in a relatively restricted deep-water area west of Hokkaido Island. The last location signal from #55019 was received on December 10. Note that after a prolonged period of radio silence, another final signal was received from tag #55019 on January 19, 2019, but it did not provide information about the device's location (Table 1).

### Male #55024

The male remained at the rookery for 4 days after tagging. On October 14, the male made a long trip to the north-western coast of the Sea of Okhotsk (Table 2; segments No. 1–2). He reached the north-western coast of the Sea of Okhotsk near the mouth of the Tukchi River after passing the immediate vicinity of Iona Island (Fig. 3). The trip took 27.3 days, during which the male covered 2,060 km. From the mouth of the Tukchi River, the male returned to the southeast, followed the open sea areas, crossed the Sea of Okhotsk and reached Iturup Island by mid-December. This 3,345 km segment was completed in 40.5 days (Table 2; No. 3–6). Subsequently, by December 23, the male reached the coast of Hokkaido Island near the mouth of the Horonai River. Furthermore, moving along the northern coast of Hokkaido and Kunashir islands, the male approached the Yekaterina Strait between the islands of Kunashir and Iturup of the Kuril archipelago. Finally, he entered the Pacific Ocean on December 27. Tracking showed that the male traveled a total length of at least 6,264 km in the Sea of Okhotsk (Table 2; No. 1–8) in 74.4 days.

Notably, in the Sea of Okhotsk, male #55024 had two secondary key areas KA-1 and KA-2 (Fig. 3).

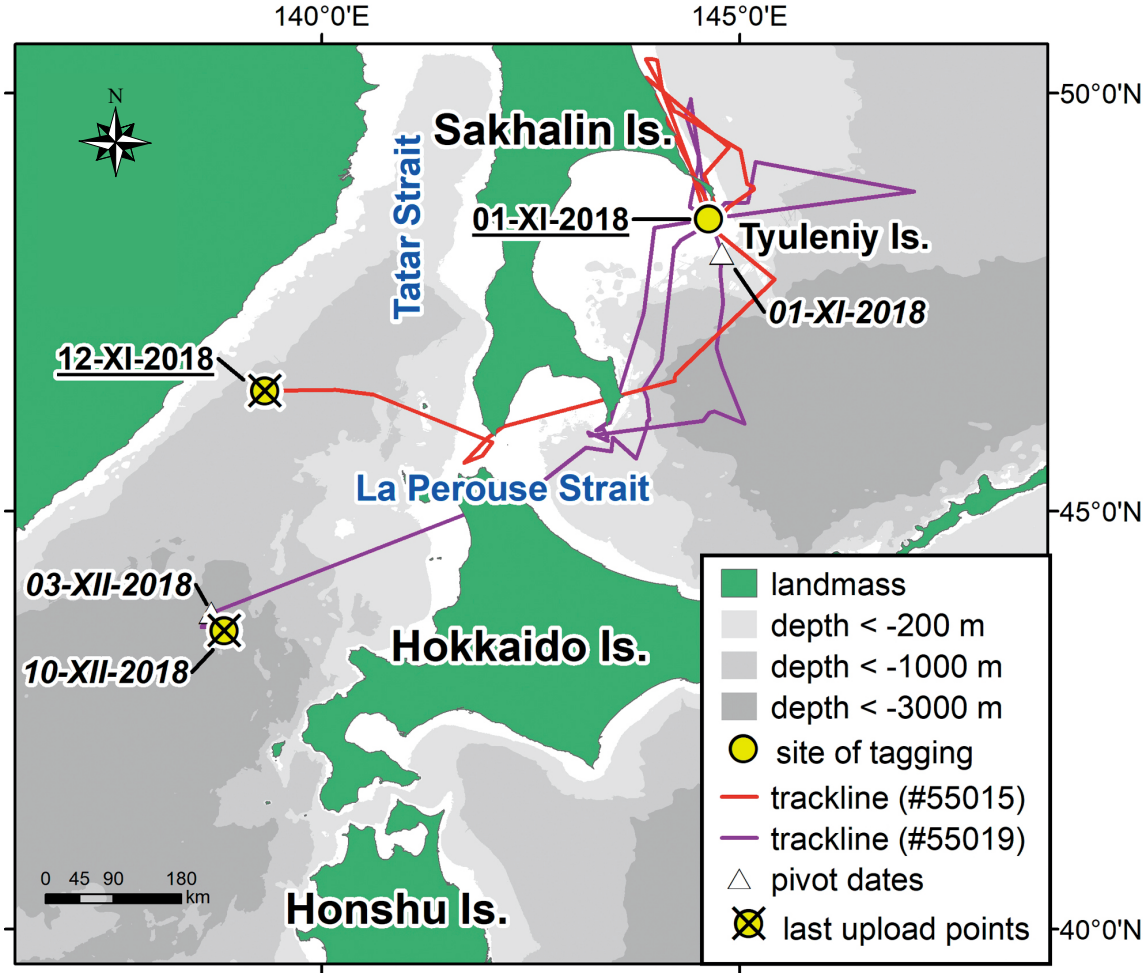


**Fig. 2.** Autumn-winter transitions of NFS females #55015 (straight underlined font) and #55019 (Italic font). Pivot dates are the working datum closest to the beginning of each month (provided for clarity). The land contour for this map was obtained from Open Street (OpenStreet 2019) and the bathymetry was obtained from GEBCO Maps (GEBCO 2020).

The short segments of faster motion locations were observed on the periphery of these key areas, whereas no movement slowing down was observed within the KAs. This trend shows that the juvenile male did not forag or rest for prolonged periods while traversing the Sea of Okhotsk.

In the Pacific, the male moved south down to 42°N and, following deep-water areas (over 2 km), headed west to the coast of Japan. On January 15, 2019, he passed the Tsugaru Strait and entered the Japan/East Sea. Along the segment from the Yekaterina Strait to the Tsugaru Strait (Table 2; No. 9–10), the male passed 1,396 km in 18.2 days. In the Japan/East Sea, the seal immediately entered the third key area, KA-3 (Fig. 3). Notably, the KA-3 area covered the shelf of Honshu Island and the deep-water areas of the Japan/East Sea within 300 km of the coast. Throughout February, the male lived in a vast area northwest of the Tsugaru Strait. In March-April, he began short trips in the south-western direction; however, he never crossed the 39°N latitudes. The movement of the seal inside the KA-3 occurred with a constant statistically significant slowing down of its horizontal velocity. In this key area, the male spent 94.9 days covering 6,136 km (Table 2).

Three months later, the male left KA-3, passed the Tsugaru Strait again toward the Pacific Ocean, and entered the fourth key area, KA-4, on April 19 (Fig. 3). In KA-4, the animal's tracks were linked with the area of continental slope (1 km depth) along the coast of Sanriku (northeast of Honshu Island). Similar to KA-3, a general slowing down of the male's speed was observed. However, the male's tag transmitter stopped working on May 08, 2019.

**Table 1.** Characteristics of the collected data

| Tag PTT/SN | 55015 / 17U1710 | 55019 / 17U1711 | 55024 / 17U1712 |
|---|---|---|---|
| Status of NFS | Adult female | Adult female | Juvenile male |
| Date of the first transmitted location | 10.10.2018 | 11.10.2018 | 11.10.2018 |
| Date of the last transmitted location | 12.11.2018 | 10.12.2018 (19.01.2019)[a] | 08.05.2019 |
| Number of transmitted locations received from the ARGOS satellite data processing center | 87 | 140 | 3488 |
| Number of transmitted locations left after pre-processing | 46 | 84 | 2953 |

[a]Date of last transmitted message (record without information on position of tag).

**Table 2.** Parameters of male #55024 movements during the sea period, 2018–2019

| Track segment No | Segment location (Fig. 3) | Start date of the segment | Distance traveled, km | Duration, day | Weighted mean speed, km/day (m/s) |
|---|---|---|---|---|---|
| 1 | Tyuleniy Is. → A | 14.10.2018 | 1 087 | 13.8 | 78.8 (0.9) |
| 2 | A → Tukchi River (KA-1) [a] | 28.10.2018 | 973 | 13.5 | 72.1 (0.8) |
| 3 | Tukchi River → B (KA-1) | 10.11.2018 | 1 088 | 12.8 | 85 (1.0) |
| 4 | B → C | 23.11.2018 | 1 446 | 17.7 | 81.7 (0.9) |
| 5 | C → D (KA-2) | 11.12.2018 | 368 | 6.1 | 60.3 (0.7) |
| 6 | D → E | 17.12.2018 | 443 | 4 | 110.8 (1.3) |
| 7 | E → Horonai River | 21.12.2018 | 327 | 2.6 | 125.8 (1.5) |
| 8 | Horonai River → Yekaterina Strait | 23.12.2018 | 532 | 3.9 | 136.4 (1.6) |
| 9 | Yekaterina Strait → F | 27.12.2018 | 537 | 7.1 | 75.6 (0.9) |
| 10 | F → Tsugaru Strait | 03.01.2019 | 859 | 11.1 | 77.4 (0.9) |
| 11 | KA-3 | 15.01.2019 | 6 136 | 94.9 | 64.7 (0.7) |
| 12 | KA-4 | 19.04.2019 | 1 227 | 18.1 | 67.8 (0.8) |
| Summary | | 11.10.2018–08.05.2019 | 15 023 | 205.6 | 86.4 ± 24.5 (1.0 ± 0.3) [b] |

[a]The key areas (KA) associated with particular segment of the track, [b]This cell only: arithmetic mean ± standard deviation.

## DISCUSSION

### Females #55015 and #55019

Feeding trips of NFS females preceding the wintering migration are associated with the lactation of pups (Kuzin 2014b). However, our estimates of the duration of foraging trips had low reliability due to the low accuracy and few records obtained from the NFS females. Nevertheless, our estimates do not disagree with published data, which report the foraging trips to range from less than 3 to 10 days (Bartholomew

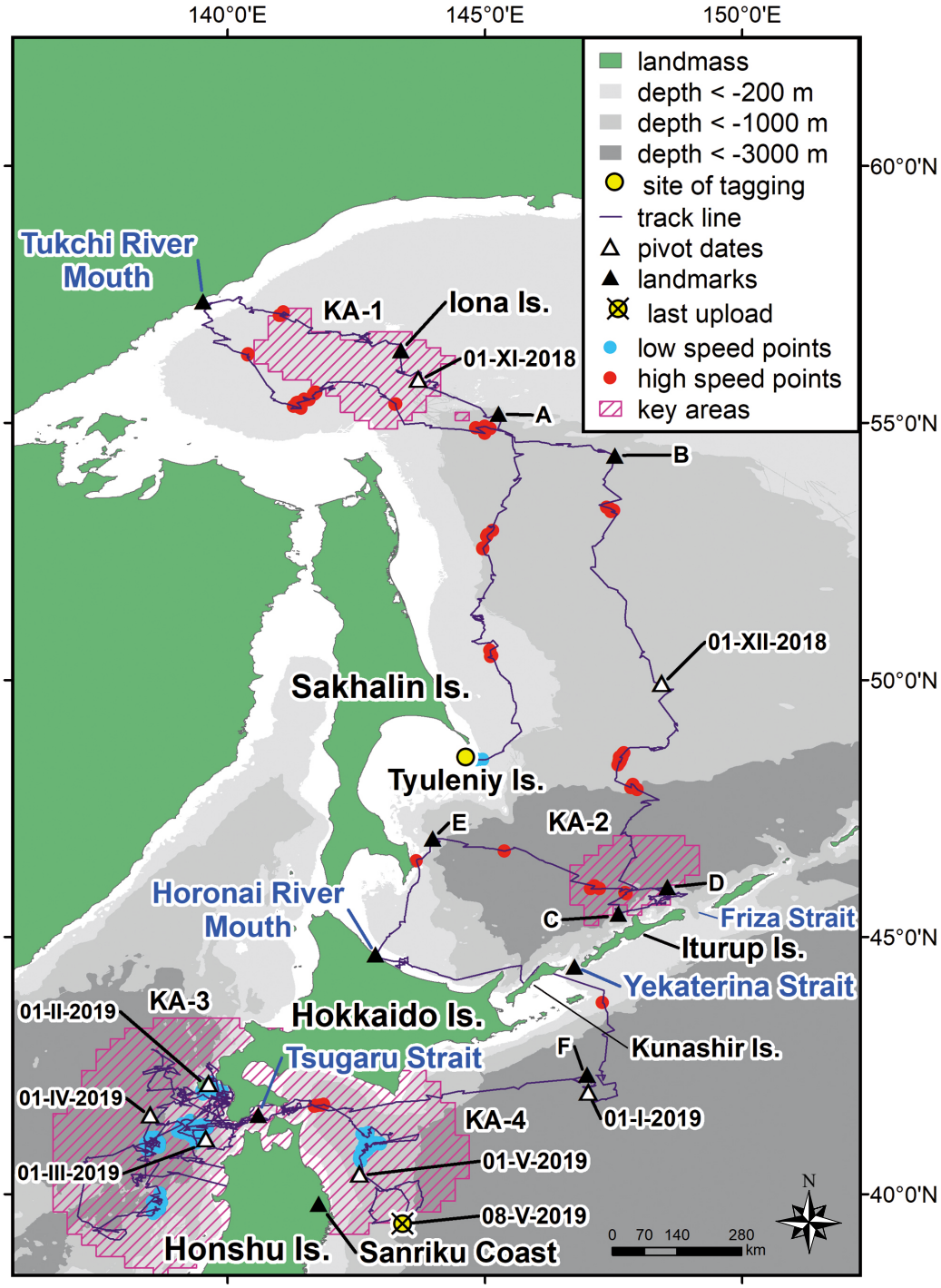


**Fig. 3.** Autumn-spring transitions of the male NFS #55024. Notations as in figure 2. The land contour for this map was obtained from Open Street (OpenStreet 2019) and the bathymetry was obtained from GEBCO Maps (GEBCO 2020).

and Hoel 1953; Kornev et al. 2012). It is known that the termination of the lactation period of the NFSs coincides with the beginning of their winter migration (Kuzin 2014b). In our study, the winter migration began in the first half of November, which aligns with the time frame determined by previous studies (Bychkov 1964; Evdokimov 1964). Furthermore, the distance to the feeding areas used by the females generally agrees with the earlier published estimates (Kuzin 2014b), but the location of the feeding areas was different. According to AE Kuzin (2014b), the NFSs feed mainly in the sea areas southeast of Tyuleniy Island during the summer. However, more than half of the autumn foraging trips we recorded were directed north along the coast of Sakhalin Island (Fig. 2). Arguably, the observed differences may be associated with the temporary reorientation of the NFS females to abundantly feed on the moment fish species, such as chum salmon (*Oncorhynchus keta*) (Gritsenko 2002). Notably, the ability of the NFS to feed on large salmon has been confirmed by several studies (Belonovich et al. 2010; Blokhin 2010; Kuzin 2014b; Panina 1970).

Furthermore, the predominance of the adult individuals in the NFS foraging group within the Japan/East Sea is a fact (Horimoto et al. 2017; Kuzin 2014b; Panin 1970). The main migration route from the Sea of Okhotsk to the feeding areas of the Japan/East Sea through the La Perouse Strait is also uncontroversial (Evdokimov 1964; Kuzin and Maminov 2016; Panin 1970). There was no information on the speed of transition of the adult NFS females from the Tyuleniy Island to the winter foraging sites; however, considering the available information (Belonovich 2011), the ability of females to move along the winter migration routes in a short time, following the straightened trajectories is uncontroversial.

### Male #55024

The presence of the NFSs in the northern regions of the Sea of Okhotsk has been reported repeatedly (Evdokimov 1964; Nikolaev 1970; Tikhomirov 1964; Tiupeleev et al. 2018). However, according to existing expert estimates, NFS visits to the north of 50°N should be considered accidental (Kuzin 2014b). Note that the few published data practically do not cover the entire autumn that opens the sea period in the annual cycle of the NFS. AT Ashchepkov and AE Kuzin (1986) noted that the NFSs leave Tyuleniy Island between mid-October and mid-November, and only reach the Pacific coast of Hokkaido Island in December. These observations are consistent with our results. Furthermore, in the absence of comprehensive information on the migration routes of the NFS, the earlier researchers (Ashchepkov and Kuzin 1986) calculated the wintering migration rate straightly — by attributing the length of the proposed migration route to the time interval between the start of migration and the arrival of the NFS at the coast of Hokkaido. The resulting estimate of 12.6 miles/day (~20.3 km/day) is noticeably lower than ours (arithmetic mean: M(X) = 86.4 km/day, standard deviation: SD = 24.5 km/day) (Table 2). According to our data, it can be assumed that at the end of the on-shore period, the juvenile NFSs from Tyuleniy Island do not migrate to the Pacific coast of Hokkaido Island immediately but may roam the adjacent waters for some time. Note that the absence of primary key areas in the Sea of Okhotsk along the route of the male #55024 suggests that this part of its sea period was not related to the foraging.

The movement of the NFSs from the Sea of Okhotsk into the Pacific Ocean through the Yekaterina and Friza Straits has been recognized for a long time (Evdokimov 1964). Conversely, the possibility of NFS migration from the Pacific Ocean to the Japan/East Sea and back through the Tsugaru Strait has been controversial until recently. Some researchers accepted such a possibility (Panin 1970; Panin and Panina 1968), but AE Kuzin (2014b) expressed strong skepticism about this in his monographic study. The results of satellite tagging enable us to unequivocally state that the NFSs use the Tsugaru Strait to travel from the Pacific Ocean into the Japan/East Sea and back (Mitani et al. 2018; our data).

Furthermore, the main wintering area of male #55024 was the key area KA-3 in the northeastern Japan/East Sea. According to existing data, the main foraging areas of the NFSs in the Japan/East Sea are located in the western and central parts of the sea (Kuzin 2014b). However, Russian (Panin and Panina 1968) and Japanese (Horimoto et al. 2016) researchers have reported on a large population of NFSs near the Tsugaru Strait in the winter-spring months. Male #55024 returned to the Pacific Ocean in the third decade of April, which aligns with these observations. Subsequently, the male moved south to the area off Sanriku in Honshu Island (Fig. 3), where he continued foraging. AT Ashchepkov and AE Kuzin (1987) suggested the start of a general movement of the NFS to the north along the Pacific coast of Japan in April–May and noted that, by the time the seals reached north of 40°N, the age composition of the NFS from the Tuyleniy Island stock changed towards a predominance of juveniles. The authors considered this change in age structure to be the result of the redistribution of pinnipeds between various areas in the Pacific. However, they did not consider the possibility of adding juvenile NFSs from the Japan/East Sea. Our data show a greater complexity of the NFS

migration route in the east of Japan. Additionally, the possibility of NFS movement into the Pacific Ocean in spring directly from the Japan/East Sea has been confirmed by recent Japanese studies (Li and Mitani 2021; Mitani et al. 2018).

## CONCLUSIONS

As a result of using satellite telemetry detailed information was obtained for the first time regarding the features of the migration of NFSs from the largest rookery of the species of pinnipeds in the Sea of Okhotsk. Before the start of winter migration, both tagged females made foraging trips not only to the south, as was reported by previous researchers, but also to the north, along the coast of Sakhalin Island. This new finding may be explained by the high abundance of salmon off the coast of Sakhalin during this season. In the first half of November, females began wintering migrations to the Japan/East Sea through the La Perouse Strait along the shortest routes.

Compared with the females, a juvenile male, before reaching winter grounds, crossed the Sea of Okhotsk up to the north-western coast, turned back to the Kuril Islands and Hokkaido Island, and finally entered the Pacific Ocean, covering a distance of more than 6,000 km. This trend is a remarkable result. However, further studies should be conducted to confirm how typical this migratory behavior is for young NFSs. Furthermore, the winter foraging of the male occurred in two areas: in the Japan/East Sea and the Pacific off Honshu Island. Its migration to the Japan/East Sea at the start of winter and back to the ocean in spring passed through the Tsugaru Strait.

Conclusively, our observations show a greater complexity of the migration trajectories of the Tyuleniy Island NFSs than was previously assumed.

### List of abbreviations

NFS, Northern fur seal.
SDA, Speed-Distance-Angle filter.
KA, key area.
Me, median value.
IQR, interquartile range.
n, number of cases.

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**Authors' contributions:** AMT, VBL carried out overall project management. VBL, HWK, SGC attracted funding. AMT, PAP, SDR resolved organizational issues. HWK, SGC provided the satellite tags. PAP and SDR designed the study, carried out the field work, performed the statistical analyses, and wrote the manuscript. VBL, HWK, supervised the English version of original manuscript. All authors participated in revising the manuscript. All authors read and approved the final manuscript.

**Competing interests:** PAP, SDR, AMT, VBL, KHW, SGC declare that they have no conflict of interest.

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**Ethics approval consent to participate:** Animal handling and tag attachment procedures were permitted by the Federal Agency for Fisheries of the Ministry of Agriculture of the Russian Federation and approved by the Pacific Fisheries Research Center (order No. 818 of 05.12.2017). Application and exploitation of satellite tags was permitted by Federal Service for Technical and Export Control of Russia (conclusion No. 316 of 12.02.2018). All tags were registered by Federal Service for Supervision of Communications, Information Technology and Mass Media, Russia (certificates 25 18 No. 06279, 25 18 No. 06280, 25 18 No. 06281).

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