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New data about annual female moose (*Alces alces*, Cervidae) home range in the southern taiga subzone in Northwestern Russia

Nickolai V. Sedikhin* & Alexandr N. Minaev

ABSTRACT. This article presents the results of telemetry monitoring of two female European moose in the southern taiga subzone of Northwestern Russia. The study subjects were a wild adult female, named «Mashka», and a yearling female bred in an enclosure, named «Kalina». The moose were released into the wild in the Vyborgsky and Lodeynopolsky districts of Leningrad Province in 2024. For the first time in the study area, detailed data on movement patterns and home range sizes of female moose were obtained. The monitoring period for both females lasted approximately one year. Home range sizes were 1173.2 ha for «Mashka» and 1325.5 ha for «Kalina» (KDE 95%, h = 200 m). Hourly movement distances did not exceed ~80 m in 75% of cases (third quartile). Daily path was higher in summer (in average 2000–3000 m) compared to the demi-seasons–winter period (1000–1500 m). Daily displacement averaged between 22% and 52% of daily path, depending on the month. No directed long-distance migrations to winter habitats were observed. Clusters identified using the ST-DBSCAN method comprised locations recorded over several months across different seasons. The dynamics of movement intensity reflected typical seasonal and daily activity patterns. «Kalina» died in May 2025; no further information on «Mashka» has been available since her transmitter ceased operation in May 2025. The authors propose hypotheses regarding potential differences in spatial behavior between the animals and present a comparison of the results with data from Fennoscandia.

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KEY WORDS: telemetry, home range estimation, GPS/GSM-transmitters, animal immobilization, movements.

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Новые сведения о годовых участках обитания самок лося (*Alces alces*, Cervidae) в южной подзоне тайги Северо-Запада России

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РЕЗЮМЕ. В статье представлены результаты телеметрических наблюдений за двумя самками европейского лося в южной подзоне тайги на Северо-Западе РФ. Наблюдаемыми объектами были дикая взрослая самка («Машка») и годовалая самка, выращенная в вольере («Калина»). Лосихи были выпущены в естественную среду в Выборгском и Лодейнопольском районах Ленинградской области в 2024 году. Впервые для исследуемой территории были получены подробные значения о перемещениях и размерах участков обитания самок лося. Время наблюдения за обеими самками составило около года. Площади участка обитания составили: у «Машки» — 1173.2 га, у «Калины» — 1325.5 га (KDE 95%, h = 200). Перемещение лосих в час в 75% случаев (q_3) не превышали 80 м. Летом суточный ход был выше (в среднем 2000–3000 м), чем в переходный зимне-весенний период (1000–1500 м). Суточное перемещение составляло в среднем от 22 до 52% от величины суточного хода в зависимости от месяца. Целенаправленных длительных кочёвок к участкам зимовок не наблюдалось. Выделенные методом ST-DBSCAN кластеры включали в себя местоположения, оставленные в течение нескольких месяцев разных сезонов. Динамика интенсивности перемещений отражает типичную сезонную и суточную активность животных. «Калина» погибла в мае 2025 г., сведений о «Машке» после разрядки передатчика в мае 2025 г. также не появилось. Авторами сделаны предположения о возможных различиях в пространственном поведении животных, а также представлено сравнение результатов с данными из Фенноскандии.

КЛЮЧЕВЫЕ СЛОВА: телеметрия, измерение участка обитания, GPS/GSM-передатчики, иммобилизация животных, копытные.

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Introduction

The application of telemetric tracking systems for observing mammals is widely represented in the literature (Kays *et al*., 2011; Petrunenko *et al*., 2016; Balmer *et al*., 2023; Miettinen *et al*., 2023). On a global scale, such remote monitoring has long been a common practice for studying the behavioral and ecological characteristics of populations. In the Russian Federation, due to the lack of mass development of transmitters specifically designed for this purpose, the rate of new research and results is relatively low. In addition due to this, the focus of telemetry observations in Russia is shifted towards protected species of mammals in various protected areas (Salman & Rozhnov, 2010; Rozhnov *et al*., 2014; Seryodkin, 2014; Panchenko *et al*., 2021, 2024). The observation results for numerous species are presented as single occurrences (Seryodkin, 2014; Kirilyuk *et al*., 2019; Mamaev, 2023) or in large numbers, but only for a specific territory (Seryodkin, 2025). Moose, *Alces alces* (Linnaeus, 1758) is no exception. Some results of completed observations of wild moose in Russia have been published (Pavlov, 2013; Sedikhin & Minaev, 2024, 2026). Nevertheless, this data is insufficient for comprehending the principles of seasonal migrations, the formation and utilization of home range in certain regions of the country. In our view, the development of an innovative approach to calculating the seasonal carrying capacity of territories for particular animal species, based on movement patterns identified through telemetry, could serve as the foundation for a rational policy and strategy for human-wildlife interaction.

As part of an ongoing study motivated by the participants' personal interests, it is occasionally possible to equip wild moose with transmitter collars. Most often, this happens when animals end up in a human-made environment and are unable to exit it safely without human help. Another way to equip animals with transmitters is to release captive-bred moose into the wild after they spend the first year of life in captivity (Sedikhin & Minaev, 2026). This paper presents the results of monitoring the movements of two females released into the natural environment in the southern taiga subzone of the North-West of the Russian Federation. The aim of this study was to investigate the spatio-temporal characteristics of moose habitat use. The main objectives were to determine annual and seasonal home range sizes and to identify seasonal and daily movement patterns.

Material and methods

Observed animals, immobilization and tracking system

The first object is a wild female, 2–3 years old. In March 2024, it was immobilized in a restricted, unused area of the Lada AvtoVAZ factory (former Nissan Manufacturing), Saint-Petersburg, where she had presumably entered in December 2023, accompanied by two males. The cow was mechanically immobilised with a 1 cm diameter loop of metal cable, followed by a remote injection of the drug (dart from an injector) equine meditin (1% solution of medetomidine hydrochloride, at a dose of ~0.4 ml/100 kg, or 1 ml per animal). The female was released into the wild in the Gladyshevskiy Nature Reserve (= Gladyshevskiy zakaznik, Saint Petersburg, Kurortny District), on the border with the Leningrad Province.

The second object is a one-year-old captive-bred female. She was released from a large pen where she had been kept with a one-year-old male since the loss of her mother in a car accident in the spring of 2023. The moose was sedated in the pen using Rometar (2% solution of xylazine hydrochloride at a rate of 1 ml per 100 kg of body weight. The female tolerated human approach relatively well, and consequently, drug administration was unproblematic. The moose was released into the wild in the Lodeynopolsky District of Leningrad Province, 5 km south of the village Oyat'. Upon release, the wild female was named «Mashka», and the female from the enclosure was named «Kalina». In the following text, these designations will be used to facilitate easier and quicker reference to the observed individuals.

The animal tracking system consists of a GPS transmitter, worn by the animals, a pairing station and a server, where movement data is visualised. Every hour, the device records the coordinates using GPS/GLONASS, and once a day it sends a text message with the data via the GSM cellular network. A detailed description of the system with some technical details (Minaev & Purikov, 2015) is available in the library of https://moose-farm.ru at https://moose-farm.ru/GPS+GSM-for-site.pdf.

Methods for assessing home range size and movements

The home range size was measured using three methods:

1) Minimum convex polygon (Hayne, 1949; Nilsen *et al*., 2008; Adam *et al*., 2015; Gregory, 2017) (MCP, 100% and 95% locations using FixMean and FixMedian of points),
2) Point Kernel Density Estimation (Silverman, 1986; Powell, 2000; Kie *et al*., 2010) (KDE, raster cell size = 25; 95% and 50% probability contours, method — Standard Sextante Biweight Kernel (w_max = 1));
3) Local Convex Hull (Getz & Wilmers, 2004; Getz *et al*., 2007) (LoCoH, 99% probability contours).

The «h» and «r» criteria for polygon delineation using the KDE and LoCoH methods were set to 200 m, 100 m, and the values of the third quartile of female movement distances per hour calculated over the entire observation period. To identify the most intensively used habitat zones, a cluster analysis of female moose locations was conducted using the ST-DBSCAN algorithm (Ester *et al*., 1996; Derya & Kut, 2007; Peca *et al*., 2012) within QGIS 3.28.10.

To assess the quantitative characteristics of movements, we measured daily path, daily displacement, and movement distance per hour. Daily path was calcu-

lated as the sum of hourly movement distances over the subsequent 24-hour interval for each location. Daily displacement was calculated as the Euclidean distance between the current moose location and the location 24 hours later, computed using the Euclidean distance formula in two-dimensional space based on the obtained coordinates for each location. The distance measurement error was 0.3%. To analyze total movement activity over the entire observation period, a moving average with a 6-day window (144 hours — the current hour was included in the first 72 hours) was calculated for each location. For comparison, moving averages were also calculated using 11-day, 30-day, and 45-day windows. To compare the current data with previously obtained results from two bulls (Sedikhin & Minaev, 2024, 2026), we restricted our analysis to the daily path for relatively homogeneous time intervals corresponding to a specific season of the year, namely summer (July–August) and winter (January–February). This condition was imposed to minimize the accumulation of error associated with the unequal duration of the overall observation periods and the effect of recovery phases following immobilization and premortal deterioration on the parameter under study. However, it should be noted that it was not possible to exclude from the initial samples the influence of factors varying between years (temperature, snow depth, anthropogenic pressure, predation), which undoubtedly affect animal movements, due to the lack of the necessary information. Data from the summer and winter periods (based on calendar seasons) were also used to analyze the daily movement activity of the observed females. Descriptive statistics were used as the primary method for presenting the observation results. Movement metrics were analyzed using the Kruskal-Wallis test, followed by post-hoc analysis via the Dunn test with the Holm correction. Testing was implemented in the R programming environment (R Core Team, 2025).

Results

Brief chronology of observations

«Mashka» was released into the wild on March 25, 2024, in the Gladyshevskiy Zakaznik (= Reserve), Saint Petersburg. The animal was transported to the release site in a small enclosed trailer. Prior to transport, the moose had been restrained with ropes. The effect of the immobilizing agent was weak; therefore, immediately after being freed from the ropes, the moose fled. The first locations were recorded on March 26, 2024, at a distance of approximately 3.7 km from the release site. Over the following 8 days, the female showed minimal movement. From April 3 onward, stable movements were observed northeast of the village Privetninskoye and Smolyachkovo, within a forest area bounded by public roads and settlements. Throughout the entire observation period, the data obtained on the moose's movements indicated a relatively sedentary pattern of habitat use. Short-distance movements alternated with prolonged stays in specific environmental conditions (likely foraging sites). Notably, movements during September 2024 (the mating season) were distinctly different. Locations were recorded in areas cow had not previously visited. In the third decade of September, it abruptly moved approximately 4 km to the southeast, crossed the railway line, and remained for about a week in a small forest area bounded by the railway and a settlement. On September 29, moose crossed the railway again in the opposite direction. Subsequent movements were consistent in character with those previously identified. No directed nomadic movements were observed. The presence of a calf or pregnancy was not reliably confirmed. On May 9, 2025, the collar transmitter stopped working as a result of battery exhaustion.

«Kalina» was released on June 17, 2024. Following immobilization, the female remained relatively close to the release site (no more than 1.5 km away) for several days. Five days after release, we recorded the moose moving southeast — a journey of approximately 7 km. However, after one day, the animal returned, following the same trajectory back to the fields. Until the end of June, the moose's locations were recorded near and south of the release site. On July 1, 2024, the moose moved north, closer to the Domozhirovo–Aleshchovshchina highway (41K-133), near village Rassvet. In July and August, most of her locations were recorded on and near the gas pipeline corridor, which represents an area of forest regeneration with young growth. Additionally, several locations of the moose were recorded directly adjacent to the highway. During September, the moose remained associated with the gas pipeline corridor situated further west, nearer to the Murmansk railway. Extended looping movements were observed across the adjacent territories. October 2024 was characterized by a reduction in movement activity and a distinct mosaic pattern of locations near the railway and an area of abandoned agricultural land. In November, December 2024, and the first half of January 2025, all moose locations were recorded within a forest area bounded to the east by the Murmansk railway, to the north by the Vikshenga River, to the west by the R-21 «Kola» highway, and to the south by the swampy headwaters of the Babya River. On January 13, the moose crossed the railway to the east and traversed an area of fields. For several days, she moved in the vicinity of the release site; then, on January 25, she again crossed the field area, this time in a westerly direction, and shifted northward closer to the railway. For the remainder of January and the first half of February, her locations were recorded near the railway within the abandoned agricultural land, in a small forest tract, and along a section of the gas pipeline corridor. During the night of February 14–15, we documented a substantial southward translocation of the moose of approximately 4.3 km, following the margin of the field area to a small patch of forest regeneration (presumably a clear-cut). On the same day, the moose was observed moving north, also along the edge of the field area, approximately to the release site. On February 20, a movement along the same trajectory was recorded, back south toward the clear-

cut. During the second half of February and March 2025, the moose's locations were recorded at a specific clear-cut and in an adjacent bog area. We also noted an identical transition in late February — to an area closer to the release site and back. From 1st April onward, a slow northward movement of the moose was observed along the edge of the field area, toward the release site and further to the gas pipeline corridor. During the first half of May, the moose revisited the vicinity of the release site (to the south) and returned (to the north) to the forest area south of the gas pipeline corridor. In the second half of May 2025, the female reduced her movement activity to a minimum. We hypothesized that the female was pregnant and approaching the calving period. However, on May 25, the moose moved from her location and emerged onto a power line corridor, along which she moved extremely slowly over the following two days. On May 28, data received from the transmitter indicated that the moose had remained at a single location for the previous 24 hours. Personnel of the Committee for the Protection, Control, and Regulation of Wildlife Use of Leningrad Province who visited the site confirmed the animal's death. A visual inspection by committee staff and subsequent analysis of biological samples by the state veterinary service did not identify the cause of death.

Home ranges

The monitoring period for «Mashka» lasted 409 days, during which we obtained 9172 locations. «Kalina» was monitored for 345 days, yielding 7986 locations. Home range size data based on all valid locations, calculated using the respective methods, are presented in Table 1. Subjectively, we did not detect any abrupt or critical changes in the spatial behavior of the moose that could be attributed to seasonal environmental shifts; therefore, we were unable to visually delineate distinct seasonal home ranges. No directed migrations between summer and winter habitats were observed.

For each female moose, we sought to delineate specific habitat zones through location clustering, distinguished by both spatial location and temporal patterns of occupancy. Initially, we tested ST-DBSCAN clustering parameters comparable to those used in a prior study involving a young bull (Sedikhin & Minaev, 2026), specifically: a minimum of 6 points per cluster, a maximum distance between points within a cluster of 600 m, and a maximum time interval between points of 30 days Under these parameters, approximately 94% of all locations for «Mashka» were grouped into three large clusters (two clusters containing 40–43% of locations each, and one cluster comprising approximately 10%). For «Kalina», approximately 76% of locations were grouped into a single cluster, with the second largest containing 7% of locations, and subsequent clusters containing even smaller proportions. This classification seemed too crude for assessing the spatial behavior of animals, so we tested other clustering parameters to identify the habitats used by moose cows in more detail.

In our opinion, the clustering option that adequately reflects the spatial and temporal features of moose hab-

Table 1. Annual home range size of observed moose. Calculation criteria (*) clarifies the methods and sizes of parameters used for calculation. For MCP «%» identifies the number of locations involved in the calculation; for KDE, «%» is the value of the particular probability contour, based on which the polygons of home range were created.

Method	Calculation criteria*	Annual home range, ha	
		«Mashka» (cow#1)	«Kalina» (cow#2)
Minimum convex polygon	100%	2139.1	7133.6
	95% using fixed mean	1828.1	5627.2
	95% using fixed median	1787.2	5919.7
Kernel Density Estimation	95% h = 200 m	1173.2	1325.5
	95% h = 100 m	905.1	964.9
	95% h = third quartile of movement in an hour (78 m for «Mashka», 81 m for «Kalina»)	808.2	829.5
	50% h = 200 m	260.4	227.7
	50% h = 100 m	183.7	159.1
	50% h = third quartile of movement in an hour (78 m for «Mashka», 81 m for «Kalina»)	157.6	137.5
Local Convex Hull - R	R = 200 m	1178.1	1120.3
	R = 100 m	659.9	565.0
	R = third quartile of movement in an hour (78 m for «Mashka», 81 m for «Kalina»)	482.4	429.0

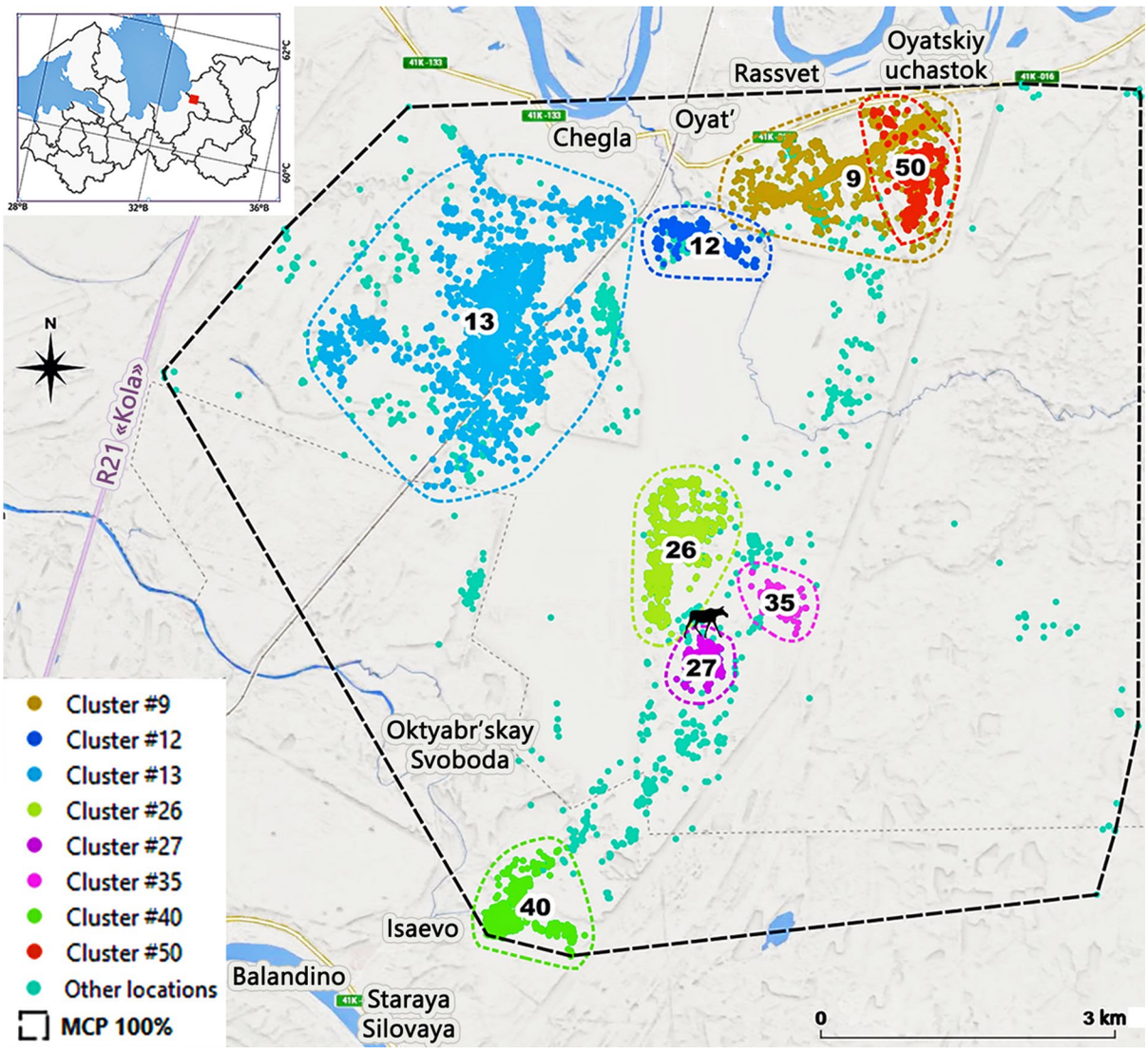

Fig. 1. «Kalina»'s home range, locations, and location clusters, identified by the ST-DBScan method (designated according to Table 3). Criteria for combining locations into clusters — see «Results». The black silhouette of the moose is the place of release.

itats was obtained as follows. We reduced the "maximum distance between locations" parameter by half to 300 m, but increased the maximum time between locations to 45 days. With these parameters, we believe that the resulting clusters for the «Kalina» moose more accurately represent the main habitats throughout the observation period, particularly the clusters with more than 100 locations each (Fig. 1).

According to the parameters mentioned above, all locations of the moose «Mashka» are grouped into 72 clusters. 13 of these clusters contain more than 100 locations each and account for 80.6% of all locations (Fig. 2). The two largest clusters contain 23.2% and 21.5% of all locations, respectively. 203 locations (2.2%) do not belong to any of the clusters. For «Kalina», the locations were grouped into 51 clusters based on the results of clustering. 8 clusters collectively contain 85% of the locations. The largest cluster contains 36.4% of all locations, while the next largest cluster contains 15.7%. 261 locations of the moose (~3.3%) were not grouped into any cluster. The proportions of the cluster compositions by month are presented in Tables 2 and 3.

Dynamics of movements

We note that the movement dynamics of moose exhibit a fractal nature with multiple frequency levels (Fig. 3). Furthermore, variations in movement activity (peaks and declines) were consistently observed irrespective of the moving average calculation parameters tested. It is hypothesized that the primary frequency levels are the «seasonal» level, followed by (let us call it) «some cyclic, unknown, indeterminate period», and subsequently the «daily» (or approximately 24-hour) cycle. Based on the results of the entire study period,

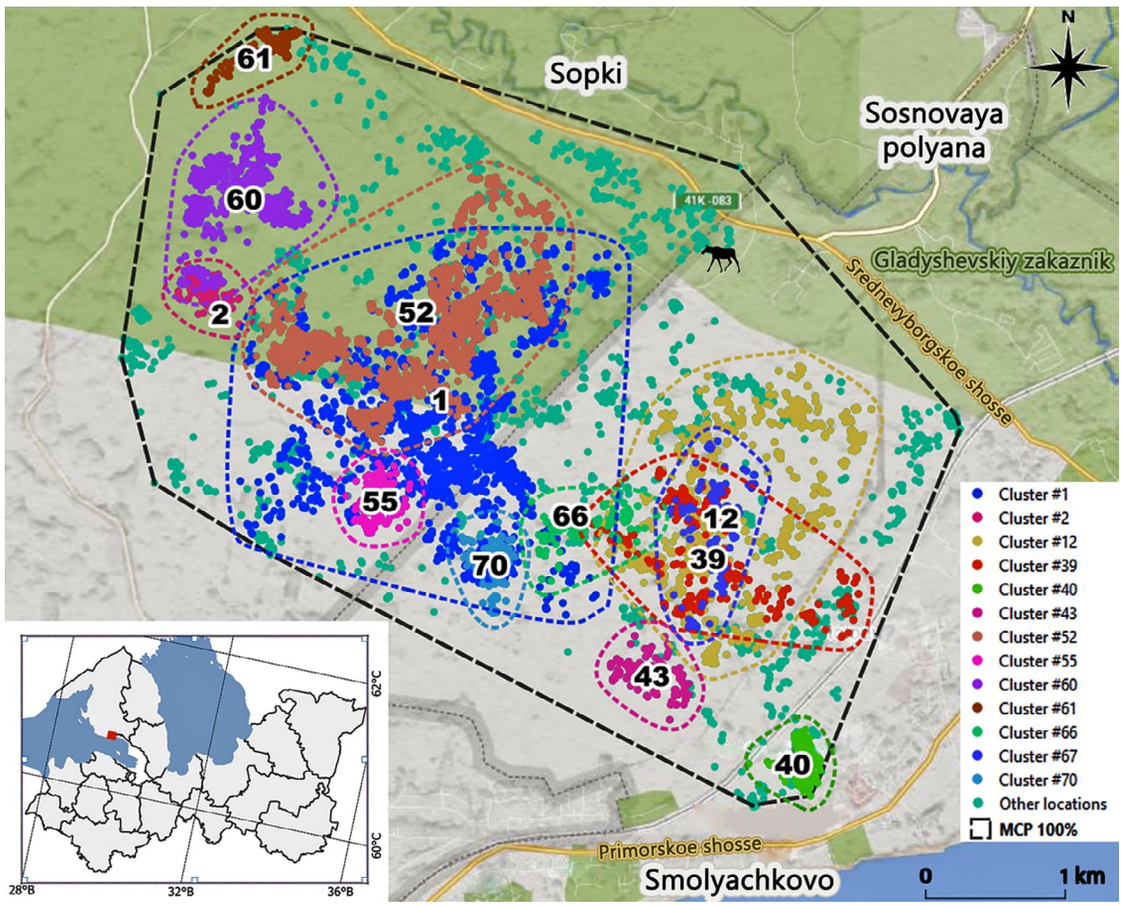

Fig. 2. «Mashka»'s home range, locations, and location clusters, identified by the ST-DBScan method (designated according to Table 2). Criteria for combining locations into clusters — see «Results». The black silhouette of the moose is the place of release.

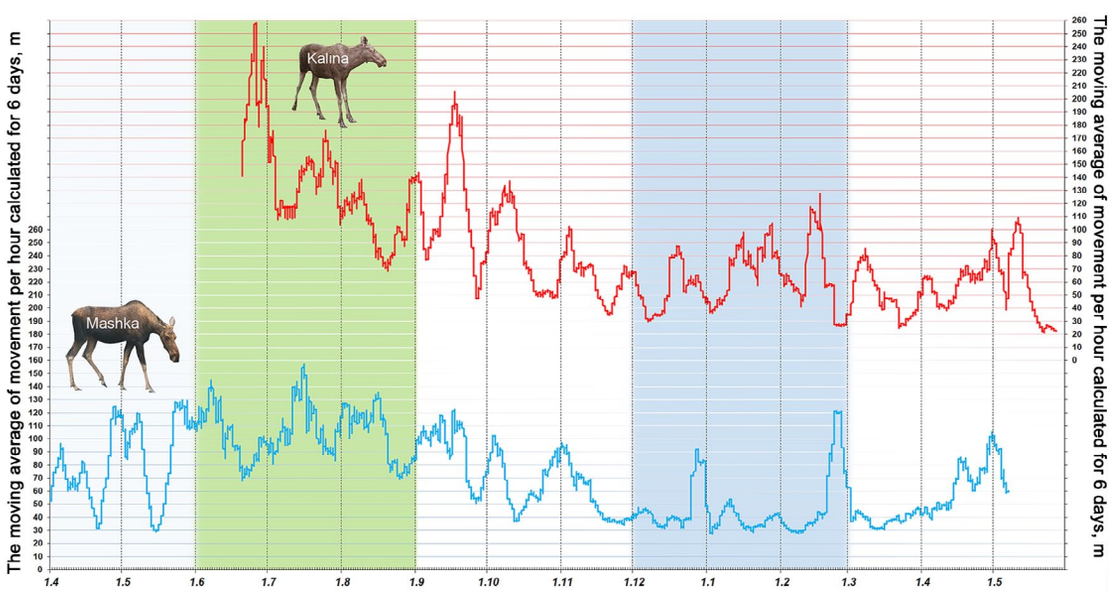

Fig. 3. The dynamics of the moving average of movements per hour (m) over 6 days for the observed individuals over the entire monitoring period.

we observed logical, seasonally distinct movement activity: for both moose movement values during the summer period and the rut were higher than during the demi-seasons and winter. During each season, we observed cyclic phases of rising and falling activity, though these phases varied in both length and intensity. Some phases exhibit a duplicated, recurring peak in activity depending on the moving average calculation period (e.g., for «Mashka» in early May, or for «Kalina» in late July 2024, as shown in Fig. 3). The next frequency level was observed when we identified differences in movement activity throughout the day. In

Table 2. Characteristics of the distribution of «Mashka» locations by month and selected clusters in accordance with the Fig. 2.

#Cluster	Year	Month	Locations in cluster per month, psc	The proportion of locations in the cluster out of all registered locations, %	The proportion of locations in the cluster relative to all registered locations, distributed by month, %
1	2024	3	1	23.2%	0.7%
		4	371		52.6%
		5	597		82.7%
		6	345		52.7%
		7	125		20.3%
		8	315		47.0%
		9	39		6.2%
		10	289		40.6%
		11	41		6.0%
2	2024	3	135	2.3%	99.3%
		4	73		10.4%
12	2024	4	50	9.4%	7.1%
		5	57		7.9%
		6	235		35.9%
		7	285		46.3%
		8	230		34.3%
39	2024	9	37	4.0%	5.9%
		10	243		34.1%
		11	83		12.1%
40	2024	9	127	1.4%	20.3%
43	2024	9	34	1.6%	5.4%
		10	41		5.8%
		11	69		10.1%
52	2024	11	464	21.5%	67.7%
		12	622		89.9%
	2025	1	428		59.3%
		2	449		67.4%
55	2024	12	14	3.3%	2.0%
	2025	1	286		39.6%
60	2025	2	14	8.0%	2.1%
		3	561		77.5%
		4	161		23.1%
61	2025	2	53	2.0%	8.0%
		3	127		17.5%
66	2025	4	87	1.1%	12.5%
		5	15		12.7%
67	2025	4	109	1.5%	15.6%
		5	27		22.9%
70	2025	4	91	1.5%	13.1%
		5	42		35.6%

Table 3. Characteristics of the distribution of «Kalina» locations by month and selected clusters in accordance with the Fig. 1.

#Cluster	Year	Month	Locations in cluster per month, psc	The proportion of locations in the cluster out of all registered locations, %	The proportion of locations in the cluster relative to all registered locations, distributed by month, %
9	2024	7	600	15.7%	88.5%
		8	569		80.1%
		9	82		11.7%
12	2024	7	3	3.7%	0.4%
		8	84		11.8%
		9	212		30.2%
13	2024	7	10	36.4%	1.5%
		8	23		3.2%
		9	330		47.0%
		10	692		95.7%
		11	628		90.5%
		12	709		98.6%
	2025	1	336		45.6%
		2	182		27.5%
26	2025	1	49	9.5%	6.6%
		2	95		14.3%
		3	126		17.2%
		4	330		47.0%
		5	160		23.9%
27	2025	1	55	2.2%	7.5%
		3	121		16.5%
		4	1		0.1%
35	2025	1	83	1.3%	11.3%
		3	18		2.5%
40	2025	2	199	7.9%	30.0%
		3	417		57.0%
		4	12		1.7%
50	2025	4	201	8.2%	28.6%
		5	451		67.4%

summer, the peak activity hours were 4:00–5:00 AM and 7:00–10:00 PM (Fig. 4A, C). In winter, the peak activity hours were 8:00–10:00 AM and 2:00–5:00 PM (Fig. 4B, D). Both periods correspond precisely to dawn and dusk hours according to the season.

We also hypothesized that during the mating season (September), the moose would exhibit higher movement activity. However, movement levels in September did not differ significantly from those in the summer months. We noted that for «Kalina», the mean daily movement distance increased, as did the ratio of movement distance to daily range, which may indicate an increase in directed movements (Fig. 5A). For «Mashka», no changes in movement activity during the rut (September) were identified compared to the summer period in terms of absolute values ($p > 0.01$). However, abrupt movements were observed—visually evident—to new and previously seldom-used habitat areas (Fig. 2, Fig. 5B, Table 2). During the demi-seasons and winter, the movement levels of «Kalina» were significantly higher than those of «Mashka» ($p < 0.01$).

When comparing the current female data with the already available data on males, it was revealed that «Kalina»'s summer daily path did not differ significantly from that of the adult bull during the first year of observation (in 2021). In all other comparisons, the differences were significant (Fig. 6). Nevertheless, it should be noted that after applying the Bonferroni correction for multiple comparisons, the significance of the differences between «Mashka»'s daily path and that of the adult bull during its second observation year (in 2022) decreased. «Mashka»'s winter daily path did not differ significantly from that of the captive-bred young male, nor from that of the adult male during the first observed winter period (in 2022). In contrast, Kalina's winter daily path differed from those of all observed animals, irrespective of the observation period (Fig. 7). The results of the pairwise comparisons for the ana-

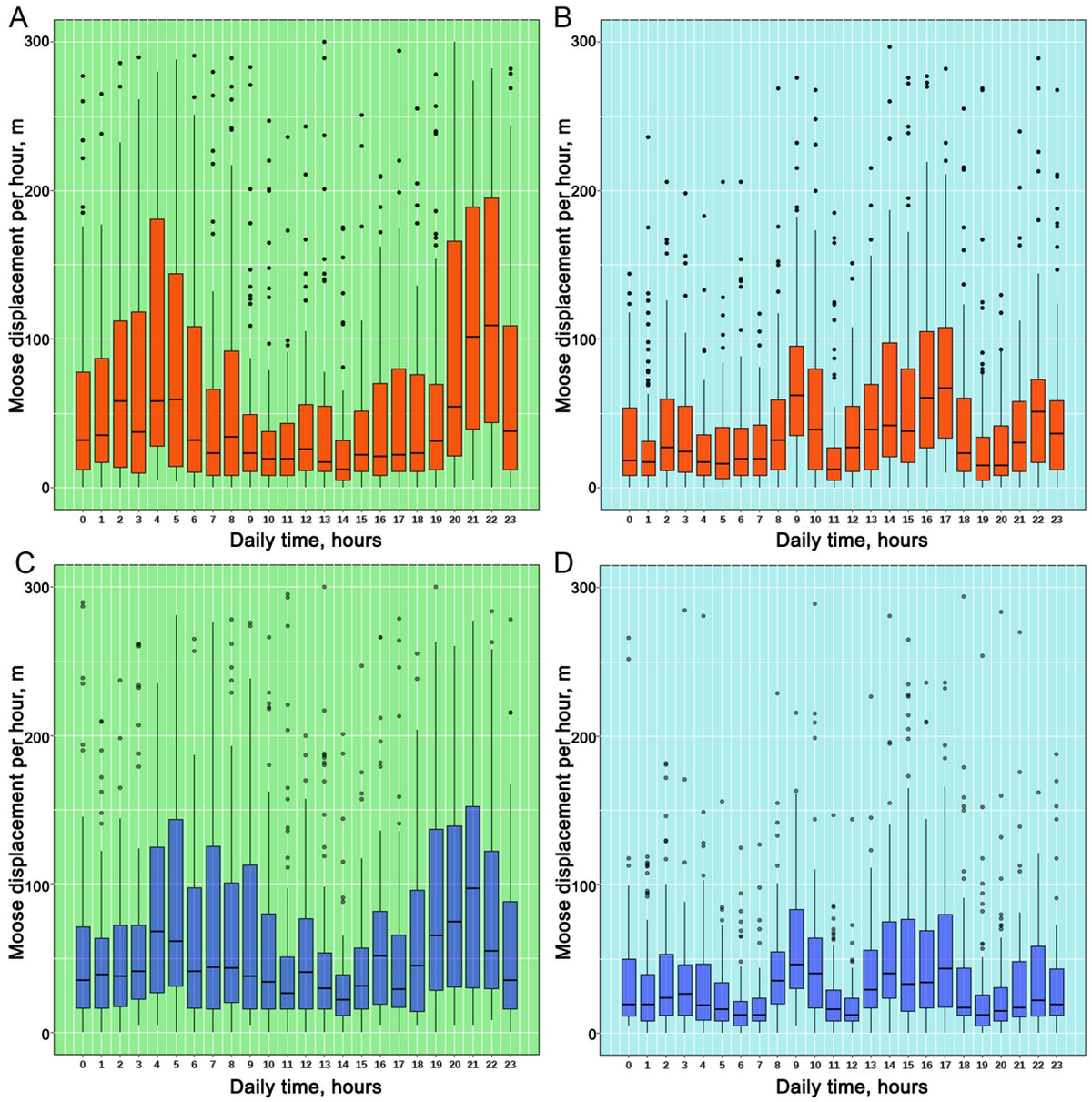

Fig. 4. The dynamics of moose movements per hour during the day for cow «Kalina» in summer (A) and winter (B), and similarly for cow «Mashka» (C–D). The movement values for «winter» and «summer» are taken during periods coinciding with calendar seasons (or periods highlighted with the same color designations in Fig. 3). The lower and upper boxplot boundaries correspond to the interquartile range (IQR) — Q1 to Q3; whiskers –lines extending from both ends of the box indicate variability outside Q1 and Q3. The minimum/maximum whisker values are calculated as Q1/Q3 ± 1.5 * IQR. In the boxplots the old line represents the median. Everything outside is represented as an outlier (circles).

lyzed samples are presented in the supplementary materials (Appendices 1, 2).

Discussion

Our previous attempt to conduct long-term monitoring of an adult female's movements in Leningrad Province was unsuccessful. In 2023, we documented a homing phenomenon during the release into the wild of an adult, two-year-old female (Sedikhin & Minaev, 2024). Instances of homing behavior and philopatry in moose are poorly documented in the literature (Rogers, 1988; Sweanor & Sandegren, 1989). The successful reintroduction of a captive-bred yearling male within the Nizhne-Svirsky Nature Reserve (Sedikhin & Minaev, 2026) raised hopes for a similar outcome with the yearling female under observation. Unfortunately, expectations were not fully met.

Analysis of the collected data yielded notable differences in the behavior of the two females. These differences were observed both in the size of the utilized home range and in the annual movement activity. It is worth noting that the total home range area calculated using the MCP method for «Kalina» is significantly larger than that for «Mashka». At the same time, the home range area calculated using the KDE method was similar for both individuals (1173.2 and 1325.5 ha). This was to be expected. According to Nilsen *et al.* (2008), in many studies the ratio between home range estimates obtained by the MCP and KDE methods is

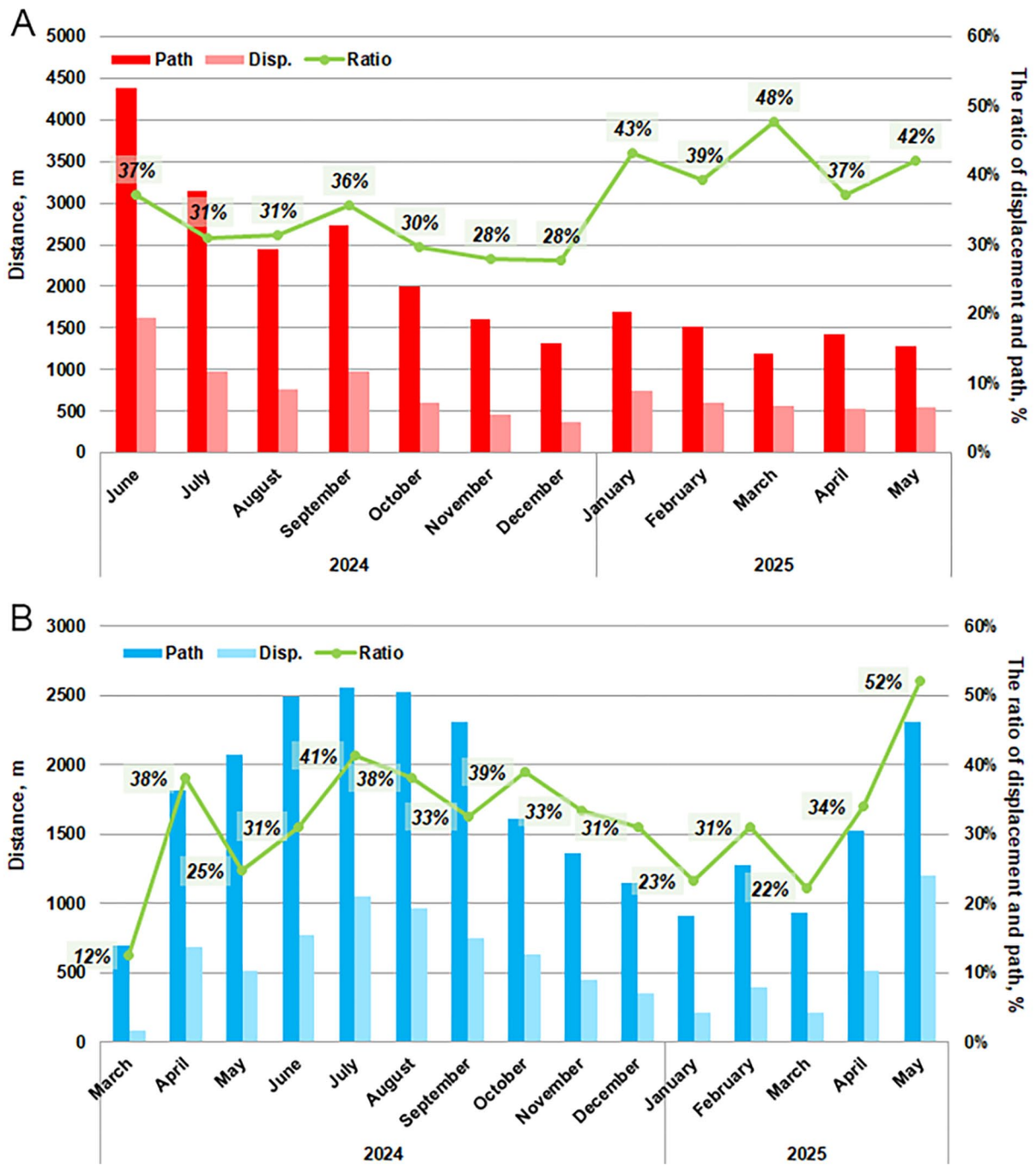

Fig. 5. The values (m) and the ratio (%) of the average daily path and average daily displacement by month for the observed individuals: cow «Kalina» (A) and cow «Mashka» (B). The calculation of the average daily path and average daily displacement is performed for the array of values obtained for each hour for which a location measured 24 hours later is available (see «Material and methods»).

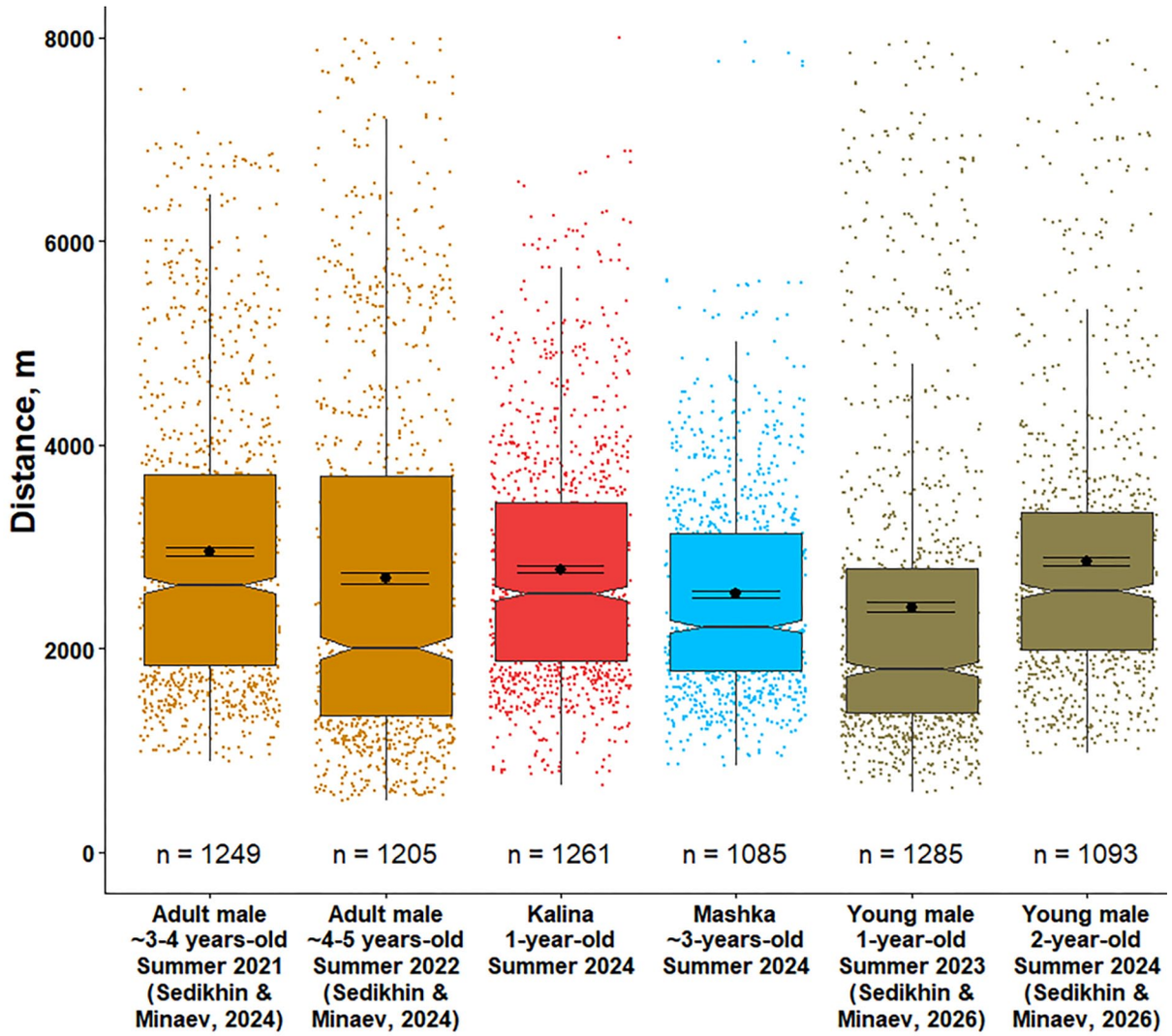

Fig. 6. Daily summer (July–August) path of the observed individuals. The individuals are labelled according to the designations used in the cited papers (Sedikhin & Minaev, 2024, 2026). «*n*» — group sample (number of measurements). The calculation of the daily path is performed for each hour that has a location measured 24 hours later (see «Material and methods»). In the boxplots, the bold line represents the median, while the 95% confidence intervals are shown as notches. The black dot with whiskers — mean value with standard error. Dots are individual observations. Outliers are not presented.

quite large; moreover, the MCP method introduces substantial unpredictable error and bias when estimating mean values from small sample sizes. (Burgman & Fox, 2003; Nilsen *et al*., 2008). In effect, by estimating area sizes using different methods, we obtain information pertaining to different concepts. The area sizes of polygons obtained using the KDE method represent a certain minimum area, necessary for the animal's habitation, to which the animal showed the greatest affinity during the study period (or it's a conditional value with a high probability of being positively correlated with it). Under the specific conditions we observed, the area containing the necessary resources and factors for the annual survival of the moose amounted to approximately 1000 ha. However, the number of habitat patches utilized by each moose differed. By contrast, the home range estimated by the MCP method constitutes a particular area with specific environmental conditions, within which the animal can access the suite of resources necessary to meet its survival requirements. For «Mashka», the use of the ST-DBSCAN method may be excessive for identifying the most preferred zones within the home range boundaries. Moreover, some periods within a single season (e.g., clusters #66, 67, and 70, containing locations from April–May 2025) are separated only by the distance between the utilized sites. Nevertheless, this method confirms that this moose used the same areas across different seasons.

As previously mentioned, all of «Kalina»'s locations were recorded along the periphery of a large ag-

ricultural field area — an open, treeless area (Appendix 3). Undoubtedly, the composition of the available land cover influenced the distribution of the animal's locations, as she clearly avoided these open areas. In contrast, «Mashka»'s territory consisted of mature and overmature mixed forest stands interspersed with forest regeneration sites following selective logging, alternating with areas of raised bogs and swampy pine forests. In addition, a ravine stream with multiple branching channels and tributaries ran through the entire home range, to which the moose also appeared to be closely associated. Furthermore, part of the home range was located within a protected area (Gladyshevskiy Reserve) with a special conservation regime. Although these represent only some of the possible explanations for the observed differences, it cannot be ruled out that these factors may collectively influence animal movements. At present, we lack reliable data on the forage conditions within the study areas, making it impossible to test complex models.

The females did not exhibit a clear division of their utilized territory into summer and winter home ranges, in contrast to the males we had previously observed. No seasonal migrations were recorded. For «Kalina», due to her movements along the periphery of the fields, the areas of prolonged occupancy were more distinctly separated in space and time than for «Mashka». Nevertheless, in the areas where «Kalina» resided during the winter period (January–April 2025), she had also been present in the preceding months, albeit apparently only passing through. The largest cluster of Kalina's locations encompassed positions from July 2024 through February 2025. It is located approximately 1 km from the boundaries of the cluster dominated by locations from July–August 2024. For «Mashka», the largest clusters (#1 and #52),

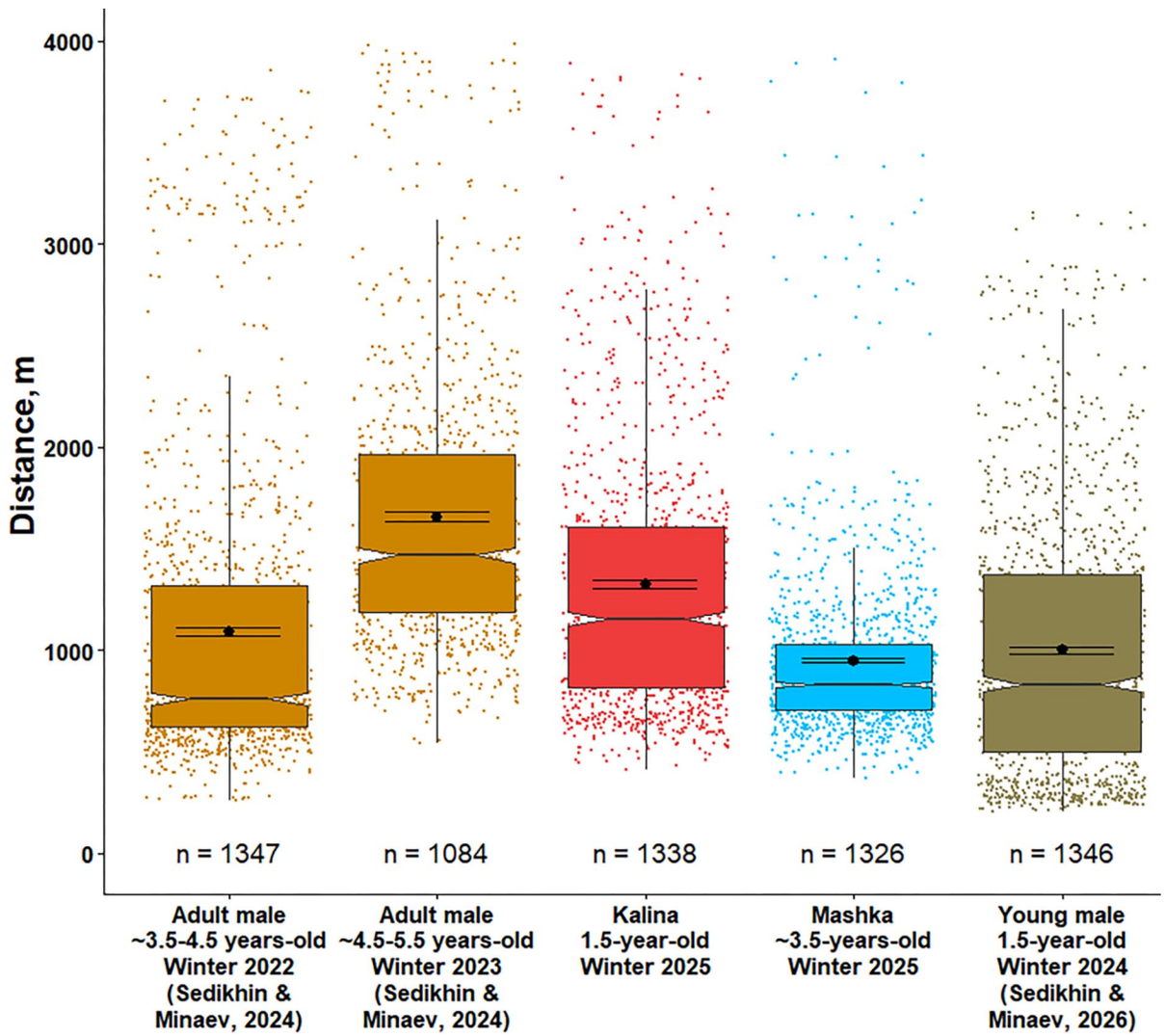

Fig. 7. Daily winter (January–February) path of the observed individuals. Designations as in the Fig. 6.

representing locations from different seasons, almost completely overlapped.

Based on the obtained movement activity graphs, we can clearly observe that «Mashka» generally moved less actively than «Kalina». The frequency of changes in movement activity (peaks in Fig. 3) for «Mashka» was approximately 1.5 times lower than for «Kalina». Peaks in movement activity in Kalina's graph were recorded during periods when such behavior was absent in «Mashka» (from November to March). We do not know with certainty whether «Mashka» was pregnant or whether she may have coexisted with a calf during the season, but this possibility should not be ruled out. Moreover, in mid-May, «Mashka»'s graph shows a period of sharp decline in movement activity (approximately to the level of activity observed during the subsequent winter period), which may in turn be indicative of calving.

According to the literature, females with calves have the smallest home range and do not travel long distances compared to other sex-age groups (Cederlund *et al*., 1987; Bowyer *et al*., 1999; Gilliham & Parker, 2008a, b; van Beest *et al*., 2011). It should be noted that most of Kalina's locations in winter and spring 2025, in each month (Table 3), belonged to several clusters. Moreover, the proportion of locations within these clusters was significantly smaller than in the preceding months of 2024. Thus, while the winter period was relatively calm for «Mashka» (with two peaks in activity), «Kalina» was forced to move more frequently due to factors unknown to us. We tentatively suggest that this may have played a significant role in the early death of the animal. However, according to the specialists who examined the carcass, the moose appeared to be in good body condition. The absence of pregnancy was confirmed upon necropsy.

The relatively higher movement levels of the yearling female during the summer period, particularly immediately after release, were most likely caused not only by biotic factors — such as higher abundance of biting insects (compared to the pen) and changes in forage conditions — but also by the stress of the release itself, as well as by homing behavior, i.e., an attempt to return to the enclosure. Supporting this interpretation are the overall northeastern direction of movement during the first few days and the subsequent prolonged (cluster #9) occurrence of a significant number of locations near the highway in the direction of the captive facility. Due to the absence of fear of anthropogenic factors, the moose likely remained for extended periods near areas of human activity. In our view, captive-bred females become much more habituated to humans than do males. We suggest that to increase the success of reintroduction of captive-bred moose females, it is necessary to develop a rearing and housing methodology that minimizes human contact, following the example for brown bears, *Ursus arctos* (Linnaeus, 1758), of Pazhetnov *et al*. (1999). An opposite example is provided by the spatial behavior of «Mashka». Upon careful examination of her locations, it is evident that very few points occurred in close proximity to roads and settlements. The majority of locations were situated 200 m or more from roads. Only one location of «Mashka» was recorded outside the inhabited forest area bounded by roads and settlements. We hypothesize that this may have been a telemetry error or an isolated, incidental case of the animal moving beyond its home range.

Analysis of the data using the Kruskal-Wallis and Dunn's tests revealed both similarities and differences with previously observed males, and in some cases between certain year periods. «Kalina»'s summer daily movement pattern was similar to that of the captive-bred young male during its second year in the wild and did not differ significantly from the daily path of the adult bull aged ~3–4 years. However, in this study we did not employ tests or criteria specifically designed for comparing data distributions. We suggest that additional tests might confirm the differences between individuals, especially given that confirmed differences exist in the sizes of their seasonal home ranges. Overall, the differences in winter daily path can be largely explained by snow depth and the availability of favourable foraging conditions. All other factors being equal, snow depth and habitat quality are inversely proportional to the extent of daily movement of moose. The winter daily path of the adult female «Mashka» differed only from that of the adult bull during the second winter of observation (in 2022). At the same time, both daily path values for the adult bull differed significantly between seasons and years, which serves as evidence of the combined influence of intrinsic individual characteristics and environmental conditions on animal movements. Seasonal and daily variations in movement activity of moose and other mammals have long been recognized and are relatively well characterized (Bonnefond *et al*., 2022; Wolfson *et al*., 2023). Nevertheless, the variability of these adaptations and their biochemical underpinnings continue to be investigated (Wood *et al*., 2020; Carvalho *et al*., 2024; Li *et al*., 2024). As regards the intermediate periodic fluctuations in locomotor activity (i.e., alternating increases and decreases), these represent, precisely, the unknown level of individual responses to external stimuli. They may be related to forage availability, interactions with conspecifics, other species, predators, humans, biting insects, or other factors not yet identified (Benedict *et al*., 2024; Homstol *et al*., 2024). This level is particularly intriguing to researchers because it is the most difficult to assess and to discern any clear patterns within. Based on the two observed individuals, we see distinct differences in risk-avoidance behavior. Overall, we consider that captive-bred animals, even when released into the wild at one year of age, exhibit a significantly reduced fear response to humans compared to wild-born individuals (Minaev, 2006).

Detailed information on female moose home ranges is not available for the Northwestern region of Russia (Perovsky, 1980; Filonov, 1983). Therefore, the most suitable basis for comparison of the obtained results is data from European Union countries, particularly Fen-

noscandia. Long-term studies of moose indicate that both migratory and sedentary individuals occur within populations (Sweanor *et al*., 1992; Ball *et al*., 2001); however, there is no general agreement on which behavioral pattern females tend to exhibit. According to Finnish data, the size of seasonal individual home ranges for females does not exceed several thousand hectares, with core areas averaging between several hundred and 1500 hectares (Heikkilä *et al*., 1996; Nikula *et al*., 2004; Nikula, 2017). The available data from Sweden and Norway largely confirm these findings. (Cederlund & Okarma, 1988; Cederlund & Sand, 1994; Lykkja *et al*., 2009; Bjørneraas *et al*., 2012). The size of the annual home range, depending on whether the individual exhibits sedentary or migratory behavior, is either similar to the summer home range or increases to several tens of square kilometers, reflecting the distance traveled to the wintering habitats. It should be noted that the methods used to measure home range sizes and moose locations in studies from the 1980s and 1990s have certain limitations and specific characteristics, and may differ significantly from contemporary approaches. The classification and assignment of locations to a given period may vary, and, as previously mentioned, the minimum convex polygon method can introduce unpredictable error when applied to small sample sizes. Therefore, we eagerly await the official material from the long-term study referenced in the Finnish hunting magazine (Melin *et al*., 2023).

Regardless of season, the home range area of females in Fennoscandia is smaller than that of males (Cederlund & Okarma, 1988; Bjørneraas *et al*., 2012), which we, in turn, also observe in the study region. In some other parts of the range, notably North America, the findings are comparable (Gillingham & Parker, 2008b; McLaren *et al*., 2009), although larger home range sizes are documented in certain areas (Courtois *et al*., 2002; Blouin *et al*., 2023). In summary, the results of our observations are quite typical for the Fennoscandian region and can readily be used as a reference for assessing other individuals (or territories) in the Northwestern region of Russia, representing a characteristic example of the sedentary spatial behavior pattern in female moose.

Conclusion

For the first time in the study region, the results of year-round telemetry monitoring of female European moose movements are presented. We venture to conclude that the observed females exhibited a sedentary pattern of habitation. Home range sizes estimated using the KDE method were approximately 1000 ha. Locations recorded during the summer and transitional-winter periods partially overlapped for both females. Clusters of locations identified by the ST-DBSCAN method encompassed periods from different seasons. When assessing core areas of the home range, this method may be excessive for data obtained from individuals inclined to occupy the same territory year-round. Overall, home range sizes were lower in females than in males previously observed in the same region. Seasonal daily paths also differed significantly in most comparisons. The yearling female released from the enclosure moved more actively than the wild adult female. The premature death of the young individual, together with previous reintroduction experience, provides grounds for a more detailed investigation of the characteristics and release sites for young animals.

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Appendix 1. Results of pairwise comparisons (Dunn's test, Holm correction) of summer (July–August) daily path among the observed individuals. * — $p = 0.02 – 0.001$; ** — $p = 2 \cdot 10^{-4} – 6 \cdot 10^{-6}$; *** — $2 \cdot 10^{-7} – 2 \cdot 10^{-9}$, **** — lower, «ns» — not significant, $p > 0.05$.

Group 1	Group 2	Z-statistic	*p*-value	Adj. *p*-value	Signific.
Kalina 1-year-old Summer 2024	Adult male ~3–4 years-old Summer 2021 (Sedikhin & Minaev, 2024)	0.951	0.342	0.342	ns
Kalina 1-year-old Summer 2024	Adult male ~4–5 years-old Summer 2022 (Sedikhin & Minaev, 2024)	–6.860	**0.000**	**0.000**	****
Kalina 1-year-old Summer 2024	Young male 1-year-old Summer 2023 (Sedikhin & Minaev, 2026)	–11.301	**0.000**	**0.000**	****
Kalina 1-year-old Summer 2024	Young male 2-year-old Summer 2024 (Sedikhin & Minaev, 2026)	2.941	**0.003**	**0.013**	*
Kalina 1-year-old Summer 2024	Mashka ~3-years-old Summer 2024	–4.101	**0.000**	**0.000**	***
Mashka ~3-years-old Summer 2024	Adult male ~3–4 years-old Summer 2021 (Sedikhin & Minaev, 2024)	5.007	**0.000**	**0.000**	****
Mashka ~3-years-old Summer 2024	Adult male ~4–5 years-old Summer 2022 (Sedikhin & Minaev, 2024)	–2.545	**0.011**	**0.033**	*
Mashka ~3-years-old Summer 2024	Young male 1-year-old Summer 2023 (Sedikhin & Minaev, 2026)	–6.746	**0.000**	**0.000**	****
Mashka ~3-years-old Summer 2024	Young male 2-year-old Summer 2024 (Sedikhin & Minaev, 2026)	6.799	**0.000**	**0.000**	****

Appendix 2. Results of pairwise comparisons (Dunn's test, Holm correction) of winter (January–February) daily path among the observed individuals. * — p = 0.05–0.001; ** — $p = 2{\cdot}10^{-4} – 6{\cdot}10^{-6}$; *** — $2{\cdot}10^{-7} – 2{\cdot}10^{-9}$, **** — lower, «ns» — not significant, p >0.05.

Group 1	Group 2	Z-statistic	p-value	Adjusted p-value	Signific.
Kalina 1.5-year-old Winter 2024	Adult male ~3.5–4.5 years-old Winter 2022 (Sedikhin & Minaev, 2024)	–13.508	**0.000**	**0.000**	****
Kalina 1.5-year-old Winter 2024	Adult male ~4.5–5.5 years-old Winter 2023 (Sedikhin & Minaev, 2024)	11.325	**0.000**	**0.000**	****
Kalina 1.5-year-old Winter 2024	Young male 1.5-year-old Winter 2024 (Sedikhin & Minaev, 2026)	–17.018	**0.000**	**0.000**	****
Kalina 1.5-year-old Winter 2025	Mashka ~3.5-years-old Winter 2025	–15.284	**0.000**	**0.000**	****
Mashka ~3.5-years-old Winter 2024	Adult male ~3.5–4.5 years-old Winter 2022 (Sedikhin & Minaev, 2024)	1.832	0.067	0.670	ns
Mashka ~3.5-years-old Winter 2024	Adult male ~4.5–5.5 years-old Winter 2023 (Sedikhin & Minaev, 2024)	25.765	**0.000**	**0.000**	****
Mashka ~3.5-years-old Winter 2024	Young male 1.5-year-old Winter 2024 (Sedikhin & Minaev,2026)	–1.673	0.094	0.943	ns

Appendix 3. Map of the female «Kalina»'s home range (Fig. 1) with landscape features of area. Layer «ESRI Satellite» (A) and Layer «OpenTopoMap» (B) for QGis 3.28.10 (Accessed 30.03.2026).

