 

# Some results of telemetry observations of European elk (*Alces alces*) (Artiodactyla, Cervidae) movements in the southern taiga subzone in Northwest Russia

**Nickolai V. Sedikhin* & Alexander N. Minaev**

ABSTRACT. The paper presents the results of telemetry observations of movements of individuals of the European elk *Alces alces* (Linnaeus, 1758) received in the period from 2021 to 2023. Two males were released into the wild after accidentally entering anthropogenic sites in St. Petersburg. Additionally, one female was released into the wild after a prolonged (about two years) existence in captivity. The individuals were equipped with collars containing GPS/GSM transmitters. The calculated values of the individuals' movements for one hour, as well as the values of the diurnal path and diurnal displacement, are presented. In 75% of the cases, the observed individuals did not move more than 200 m per hour. The highest median values of the diurnal path and diurnal displacement for the adult male were observed in June (4369 m/1649 m), and the lowest in February (677 m/195 m). For other individuals, due to the short term of monitoring, values were calculated for the entire observation period and were 2015 m and 619 m for the adult female, respectively, and 4297 m and 1431 m for the yearling male. Movements of the adult male indicate seasonal sedentariness and consistent habitat use in summer. We identified 5 spatially distinct habitat periods associated with the seasonal behaviour of the individuals: the readaptation area after release into the natural environment, summer habitat areas, autumn-winter traveling area, winter habitat area and spring migration. Further, we estimated individual home ranges using different methods: the minimum convex polygon, kernel density estimation, local convex hull and concave polygon alpha shape. Minimum convex polygon home range sizes (100% locations) were: for the adult male — 66692 ha in 22 months; for the adult female elk — 33178 ha in one month; for the yearling male — 6978 ha in 3.5 weeks. A brief literature review summarises previously published similar measurements made in Russia, Scandinavia, Canada and the USA. A comparison of the calculated values with the literature shows territorial and sex-age differences in the aspect of elk movement in space, as well as methodological differences in the assessment of habitat characteristics.

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

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# Некоторые результаты телеметрических наблюдений за перемещениями европейского лося (*Alces alces*) (Artiodactyla, Cervidae) в подзоне южной тайги северо-запада России

**Н.В. Седихин*, А.Н. Минаев**

РЕЗЮМЕ. В статье приведены результаты телеметрических наблюдений за перемещениями особей европейского лося *Alces alces* (Linnaeus, 1758) в период с 2021 по 2023 г. Два самца были выпущены в естественную среду после случайного попадания на территорию антропогенных объектов Санкт-Петербурга. Одна самка была выпущена в естественную среду после продолжительного (около двух лет) существования в неволе. Особи были снабжены ошейниками с GPS/GSM-передатчиками. В статье приведены расчетные значения перемещений особей за 1 час, значения суточного хода и суточ-

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ного перемещения. В 75% случаев наблюдаемые особи не перемещались более чем на 200 м в час. Наибольшие медианные значение суточного хода и дистанции суточного перемещения для взрослого самца отмечены в июне (4369 м/1649 м), наименьшие в феврале (677 м/195 м). Для остальных особей значения были рассчитаны для всего периода наблюдения из-за краткосрочности мониторинга и составили для взрослой самки 2015 м и 619 м соответственно, для годовалого самца 4297 м и 1431 м. Данные о перемещениях взрослого самца свидетельствуют о сезонно-оседлом характере его обитания и постоянстве в использовании летнего участка обитания. На его примере выделены 5 территориально различных периодов обитания, связанных с сезонным поведением особи: участок реадаптации после выпуска в естественную среду, летние участки обитания, участок осенне-зимней кочевки, зимний участок обитания, а также весенняя кочевка. Произведена оценка площади участков обитания различными методами: MCP, KDE, LoCoH и Concave Polygon альфа-формы. Размеры участков обитания (по методу MCP, 100% местоположений) составили: у взрослого самца — 66692 га за 22 месяца, у взрослой лосихи — 33178 га за месяц; у годовалого самца — 6978 га за 3.5 недели. В кратком литературном обзоре приведены ранее опубликованные аналогичные измерения, сделанные в России, Скандинавии, Канаде и США. Сравнение расчетных значений с литературными свидетельствует о территориальных и половозрастных различиях в аспекте перемещения лосей в пространстве, а также методологических различиях в оценке характеристик участков обитания.

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

## Introduction

The European elk, *Alces alces* (Linnaeus, 1758), is the largest and most numerous ungulate species in the North-West of the Russian Federation. In Russia, telemetry observations of wild elk are not widespread so far. The characteristics, size and principles of individual home range formation remain poorly understood against the background of extensive native studies of elk biology (Filonov, 1983; Danilkin, 1999). Moreover, accurate information on seasonal migrations and movements of elk is extremely rare.

From 2021, a group of specialists has conducted single events in St. Petersburg and the Leningrad Region to immobilise, equip with GPS transmitters and release into the wild elk that have entered the anthropogenic environment. The main purpose of telemetry observations is to identify patterns of elk population existence and individual movements in space for subsequent prediction of suitable habitat conditions. The practical long-term goal is to preserve the aforementioned habitat areas, their connectivity ways, and to prevent undesirable human interactions, including traffic accidents. The primary aims of telemetric observations were: 1) to determine quantitative characteristics of movements of individuals in different months and periods of the year; 2) to determine the territorial sizes of individual habitat areas; 3) to compare the measured parameters with similar data for elks *Alces* spp. from other parts of the range.

## Material and methods

### *Observed animals*

Three elk were fitted with GPS+GSM transmitters. The first object, a 4-year-old male, was immobilised on the premises of the Nissan Manufacturing RUS plant and released on the border between St. Petersburg and the Leningrad Region in the Kurortny District. It entered the factory site in September 2020 by breaking through a fence. During the period prior to immobilisation, the elk was located in an undeveloped area of about 100 ha of overgrown young trees. In April 2021, the elk 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 1.2 ml per animal). The estimated mass of the individual was 300 kg. Antidan (0.5% solution of atipamezole hydrochloride in a dose almost equal to the administered meditin or 1 ml) was used as an antidote. During immobilisation, the animal was on the right side to avoid breathing difficulties in case of rumen ballooning.

The second object, a yearling male, immobilised in Pavlovsky Park (St. Petersburg), was released in the Tosnensky District, Leningrad Region, on 19 May 2022. Reliable reasons why the elk went into the park are unknown. The male was also immobilised by remote injection of meditin at a dose of 0.8 ml per animal. The estimated mass of the individual was 150 kg. We did not use an antidote since the elk came out of sedation on its own.

The third object, a two-year-old female, was released from the enclosed area of the tourist village “Mandrogi” (Podporozhsky District, Leningrad Region) on 22 May 2022. The female was in captivity from one month of age together with a male of similar age. They were released together; the male was not observed. Sedation was carried out with the drug “Rometar” at a dose of 5 ml per animal. The cow also came out of anaesthesia on its own.

The capture and immobilisation of the objects were carried out by employees of the Committee for Nature Management, Environmental Protection and Ecological Safety of St. Petersburg, the Committee for Protection, Control and Regulation of the Use of Fauna Objects of the Leningrad Region. Assistance was provided by members of the public organisation "Nature Protection Union", staff of the Zoological Institute of the Russian Academy of Sciences and A.N. Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences.

***Tracking system***

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

***Assessment of movements and habitat areas***

Movements within an hour, the diurnal path and diurnal displacement were calculated for each individual, based on the tracks obtained. The diurnal path was calculated as a sum of all distances (m) from each location to the next location that were recorded during a 24-hour interval from the time of recording the initial location. The diurnal displacement was defined as the distance from the initial location to the location 24 hours later. Due to limitations in the GPS/GLONASS module, some object location information was not available. Data were determined for each measure that had information about the object's location after 24 hours at a similar time. The median, first and third quartiles were calculated for each value.

The area of the habitat site was estimated using the following methods: the minimum convex polygon (MCP) (Hayne, 1949; Nilsen *et al.*, 2008; Adam *et al.*, 2015; Gregory, 2017) (100% and 95% of locations), the concave hull/alpha shape with threshold values 0.3 and 0.1 (where 1 — the convex polygon, i.e. MCP) (Edelsbrunner *et al.*, 1983), point kernel density estimation (Silverman, 1986; Powell, 2000; Kie *et al.*, 2010) (KDE, 95% probability contours, h = 200, method — standard sextant biweight Kernel (w_max=1)) and local convex hull (Getz & Wilmers, 2004; Getz *et al.*, 2007) (LoCoH, 99% probability contours, r = 200). Calculations were performed in QGis 3.16.9, OpenJump (Steiniger & Hunter, 2012) and R (R Core Team, 2024). The assignment of a portion of the total habitat area to seasonal areas was carried out using a plot accounting for changes in home range using the MCP method (adult male only).

## Results

The main quantitative characteristics of object displacements are presented in Tables 1, 2 and 3. Information on the size of individual and seasonal ranges is presented in Table 4. Other results are presented below separately for each individual.

***Adult (4–5 years old) male (Vyborgsky District of the Leningrad Region–St. Petersburg)***

During the period from 8 April 2021 to 18 February 2023, we received 15575 locations (Fig. 1). The first 178 locations were excluded from the analysis because in that period, the elk was in an area of about 50 ha and had little or no movement. After 8 days, the elk started moving randomly. By the end of May 2021, the male had circled most of the future summer habitat area. No major changes to the habitat site occurred between 2 June and October (Fig. 2). All locations during the rutting season (for September) were recorded within the boundaries of the summer habitat areas. On 11 October 2021, the elk began moving from its permanent location within the summer habitat area and purposely left it on 21 October. Based on field observations, within the boundaries of the summer habitat area, the elk preferred overgrown anthropogenic glades and mixed forests with dense undergrowth of European rowan (*Sorbus aucuparia*), willow (*Salix*) and bird cherry (*Prunus padus*).

During the second half of October, November and December 2021, elk moved ~32 km northwest of summer habitat. On 2 January 2022, the male ceased extended movements. For nearly four months, it inhabited a lake-restricted area of 1105 ha (based on MCP 100%) (Fig. 3D).

From 27 April to 5 May 2022, the elk made a crossing in a general southeast direction totalling 57.6 km, with 36.3 km of movement. On 5 May 2022, the elk appeared within the 2021 estimated summer habitat site. The patterns of habitat selection behaviour in 2022 did not change. The elk preferred small foraging staging areas represented by overgrown glades, where its locations were recorded in 2021. On several occasions, the elk moved outside the estimated 2021 summer habitat area, resulting in a 2022 MCP (100% locations) summer habitat area 1.4 times larger than last year (Fig. 3A–B). A minimum convex polygon across 95% of the locations indicates that the zones are identical in size. Other methods also revealed minor differences in the size of summer habitat sites.

The 2022 rutting period, similar to 2021, took place within the boundaries of the summer habitat area. Similarly to 2021, the locations formed 2 plots with a single transition between them (Fig. 4). Locations during the 2022 rut were more concentrated than in 2021. After the rut, the elk did not make any long-distance movements within the summer range for about a month. On 28 October, it moved to the northwest for a few km, but returned to the summer area on 5 November and remained in a relatively small area (0.47 $km^2$ or 47 ha). On 26 November, the bull began purposeful long movements to the northwest. The elk reportedly did not reach the 2022 winter habitat area, but continued to explore its previously visited territories during the 2021 autumn traveling. On 18 February 2023, the battery in the GPS transmitter ran out of charge.

Based on elk movements, several seasonally differentiated habitat areas are reliably distinguished: the

**Table 1.** Quantitative characteristics of elk movements per hour. n — the number of recorded locations. Min/Max — minimum/maximum values.

| Object | Year | Month | Movements within an hour, m | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | *n* | Median | 1st quartile | 3rd quartile | Min | Max |
| No.1 Adult male | 2021 | April | 338 | 30 | 15 | 72 | 0 | 2000 |
| | | May | 663 | 43 | 17 | 110 | 0 | 2000 |
| | | June | 623 | 53 | 20 | 148 | 0 | 2400 |
| | | July | 680 | 46 | 19 | 129 | 0 | 1500 |
| | | August | 633 | 48 | 21 | 111 | 0 | 1300 |
| | | September | 590 | 50 | 18 | 166 | 0 | 1500 |
| | | October | 660 | 47 | 19 | 141 | 0 | 1700 |
| | | November | 684 | 41 | 13 | 123 | 0 | 2000 |
| | | December | 730 | 29 | 8 | 111 | 0 | 2700 |
| | 2022 | January | 738 | 23 | 11 | 68 | 0 | 2100 |
| | | February | 656 | 19 | 11 | 37 | 0 | 361 |
| | | March | 738 | 23 | 11 | 53 | 0 | 2000 |
| | | April | 699 | 34 | 15 | 90 | 0 | 1700 |
| | | May | 665 | 51 | 22 | 124 | 0 | 1200 |
| | | June | 657 | 53 | 19 | 148 | 0 | 2200 |
| | | July | 667 | 39 | 17 | 107 | 0 | 4400 |
| | | August | 690 | 42 | 17 | 111 | 0 | 1800 |
| | | September | 666 | 41 | 19 | 120 | 0 | 2300 |
| | | October | 681 | 42 | 19 | 126 | 0 | 2200 |
| | | November | 700 | 29 | 15 | 62 | 0 | 3200 |
| | | December | 743 | 17 | 5 | 69 | 0 | 2700 |
| | 2023 | January | 733 | 24 | 8 | 93 | 0 | 4000 |
| | | February | 410 | 27 | 8 | 75 | 0 | 677 |
| No.2 Yearling male | 2022 | May–June | 433 | 68.5 | 21 | 171 | 0 | 2400 |
| No.3 Adult female | 2022 | May–June | 669 | 33 | 13 | 99 | 0 | 3500 |

**Table 2.** Quantitative characteristics of the diurnal path of elk (within 24 hours), calculated for each hour. Designations as in Table 1.

| Object | Year | Month | Diurnal path (calculation for each hour), m | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | *n* | Median | 1st quartile | 3rd quartile | Min | Max |
| No.1 Adult male | 2021 | April | 314 | 2073 | 804 | 4194 | 534 | 6910 |
| | 2021 | May | 630 | 2461 | 1245 | 5064 | 688 | 10479 |
| | 2021 | June | 594 | 4369 | 2221 | 6334 | 709 | 13012 |
| | 2021 | July | 649 | 2854 | 1865 | 4657 | 891 | 7493 |
| | 2021 | August | 600 | 2476 | 1775 | 3158 | 974 | 6402 |
| | 2021 | September | 554 | 3635 | 2680 | 4482 | 1138 | 9053 |
| | 2021 | October | 633 | 2910 | 2117 | 3767 | 1099 | 11263 |
| | 2021 | November | 660 | 2268 | 1648 | 3615 | 466 | 6109 |
| | 2021 | December | 708 | 2320 | 1634 | 3527 | 315 | 18705 |
| | 2022 | January | 714 | 1234 | 728 | 2472 | 261 | 10860 |
| | 2022 | February | 633 | 677 | 606 | 849 | 429 | 1742 |
| | 2022 | March | 715 | 976 | 760 | 1252 | 310 | 3774 |
| | 2022 | April | 674 | 1640 | 1292 | 2138 | 716 | 20149 |
| | 2022 | May | 640 | 3171 | 2291 | 4434 | 941 | 12956 |
| | 2022 | June | 627 | 4298 | 2557 | 5705 | 901 | 12041 |
| | 2022 | July | 578 | 2551 | 1425 | 5535 | 509 | 13788 |
| | 2022 | August | 627 | 1798 | 1331 | 2852 | 686 | 8253 |
| | 2022 | September | 606 | 2289 | 1609 | 2781 | 856 | 7130 |
| | 2022 | October | 607 | 2098 | 1673 | 2605 | 982 | 5109 |
| | 2022 | November | 658 | 1036 | 823 | 1621 | 492 | 14697 |
| | 2022 | December | 719 | 1522 | 1098 | 2285 | 254 | 5236 |
| | 2023 | January | 700 | 1592 | 1194 | 2437 | 702 | 12353 |
| | 2023 | February | 384 | 1477 | 1229 | 1776 | 546 | 2974 |
| No.2 Yearling male | 2022 | May–June | 385 | 4297 | 2668 | 5746 | 783 | 10137 |
| No.3 Adult female | 2022 | May–June | 590 | 2015 | 1442 | 3511 | 525 | 18167 |

**Table 3.** Quantitative characteristics of the diurnal displacement of elk (within 24 hours), calculated for each hour. Designations as in Table 1.

| Object | Year | Month | Diurnal displacement (calculation for each hour), m | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | *n* | Median | 1st quartile | 3rd quartile | Min | Max |
| No.1 Adult male | 2021 | April | 337 | 247 | 110 | 2121 | 9 | 5340 |
| | 2021 | May | 653 | 522 | 162 | 1951 | 2 | 6134 |
| | 2021 | June | 614 | 1649 | 264 | 3077 | 5 | 9957 |
| | 2021 | July | 673 | 1027 | 392 | 2149 | 16 | 4921 |
| | 2021 | August | 618 | 912 | 441 | 1652 | 7 | 3134 |
| | 2021 | September | 580 | 1293 | 793 | 1905 | 44 | 5435 |
| | 2021 | October | 656 | 1374 | 436 | 2020 | 10 | 10668 |
| | 2021 | November | 683 | 1057 | 497 | 2168 | 21 | 4927 |
| | 2021 | December | 729 | 1206 | 604 | 1873 | 2 | 20403 |
| | 2022 | January | 737 | 454 | 192 | 1095 | 6 | 9169 |
| | 2022 | February | 656 | 195 | 122 | 322 | 3 | 1009 |
| | 2022 | March | 738 | 221 | 124 | 411 | 8 | 2456 |
| | 2022 | April | 694 | 540 | 314 | 824 | 15 | 18798 |
| | 2022 | May | 661 | 1094 | 590 | 2122 | 6 | 9217 |
| | 2022 | June | 648 | 1604 | 761 | 2471 | 11 | 8247 |
| | 2022 | July | 602 | 1332 | 199 | 3162 | 4 | 6851 |
| | 2022 | August | 638 | 547 | 280 | 1123 | 1 | 3867 |
| | 2022 | September | 620 | 525 | 258 | 924 | 7 | 5117 |
| | 2022 | October | 630 | 910 | 595 | 1289 | 19 | 3735 |
| | 2022 | November | 680 | 156 | 85 | 886 | 1 | 11805 |
| | 2022 | December | 742 | 670 | 324 | 1092 | 15 | 3625 |
| | 2023 | January | 722 | 837 | 477 | 1421 | 40 | 11972 |
| | 2023 | February | 384 | 564 | 314 | 805 | 19 | 1472 |
| No.2 Yearling male | 2022 | May–June | 408 | 1431 | 786 | 3113 | 22 | 8518 |
| No.3 Adult female | 2022 | May–June | 624 | 619 | 252 | 2500 | 11 | 18231 |

**Table 4.** Elk's home range size estimated by different methods. * — where 1 is the convex hull, i.e. MCP; n — the number of recorded locations.

| No. | Sex | Age | *n* | Season | MCP (100%), ha | MCP (95%), ha | Concave hull (alpha shape) coefficient 0.3*, ha | Concave hull (alpha shape) coefficient 0.1*, ha | KDE, 95% (h = 200 m), ha | LoCoH-R, 99% (r = 200 m), ha |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Male | 4–5 years | 15398 | All period (16.04.21–18.02.23) | 66691.9 | 63221.1 | 45558.3 | 27450.7 | 5677.6 | 3014.8 |
| | | | 3146 | Summer 2021 (1.06–21.10.21) | 6652.5 | 5763.6 | 5111.2 | 3392.6 | 1926.4 | 857 |
| | | | 1692 | Autumn-winter 2021 (21.10.21–2.01.22) | 33540.7 | 15931.6 | 14589.3 | 9300.6 | 2055.9 | 340.1 |
| | | | 2753 | Winter 2022 (2.01–27.04.22) | 1105.1 | 927.4 | 719.1 | 274 | 555.1 | 421.4 |
| | | | 3922 | Summer 2022 (4.05–28.10.22) | 9219.4 | 5721.4 | 5949.7 | 3452.5 | 1560.6 | 909.6 |
| | | | 2663 | Autumn-Winter 2022 (28.10.22–18.02.23) | 11468.6 | 11417.9 | 7427.6 | 4240 | 1345.7 | 475.4 |
| 2 | Male | 1 year | 482 | All period (19.05–12.06.22) | 6977.6 | 5287.3 | 1919.8 | 606.7 | 501.6 | 123.3 |
| 3 | Female | 2 years | 720 | All period (21.05–25.06.22) | 33177.7 | 22147.6 | 2819.4 | 865.9 | 556.6 | 105.3 |

readaptation area after release into the natural environment, summer habitat areas, the autumn-winter travelling area, winter habitat area and spring migration. In 2023, after the transmitter was discharged, the elk were captured on a trail camera in May (Fig. 5) and July on the mineral lick within the summer habitat area. The presence of the elk in the same habitats for three years, as well as the vector of their movements, indicates their stable multi-year seasonal residence in the same area, and stable seasonal movement patterns.

***Yearling male (Tosnensky District, Leningrad Region)***

During the period from 19 May 2022 to 12 June 2022, 483 location points were received. On 12 June 2022, an array of data with closely spaced coordinates was received. The state hunting inspector of the Tosnensky District made an on-site inspection of elk locations. A dead individual with characteristic traces of a large bear (prints, body damage from teeth/paws, spine fracture) was found. During the observation period, the elk did not make any long-distance movements, except for one — general northwards in a straight line for 7 km (diurnal path 8518 m) from the area, where most of its locations were recorded. After that, the bull returned to the same area, where at last it was killed. The main station, which the elk preferred, was a mixed hardwood-dominated forest, adjacent to a settlement and railway line and adjacent to a large area of sphagnum pine forest with a hydromelioration system.

***Adult (2 years old) female (Podporozhsky District, Leningrad Region)***

In the period from 22 May 2022 to 24 June 2022, 721 location points were received. On 24 June 2022, the cow returned to the housing place (enclosure of the tourist village "Mandrogi"). On 27 June 2022, the cow gave birth to one calf. It should be noted that the straight line distance from the release location to the Mandrogi Village is 27 kilometres. During its stay in the wilderness, the cow made long journeys in different directions up to 18 km per day (Fig. 6A). A total of 6 long travels were recorded, the last of which ended with a return to Mandrogi. A significant number of locations (about 30%) in the "rest" areas (between the above-mentioned transitions) were observed in close proximity (<200 m) to water bodies (lakes, waterlogged streams).

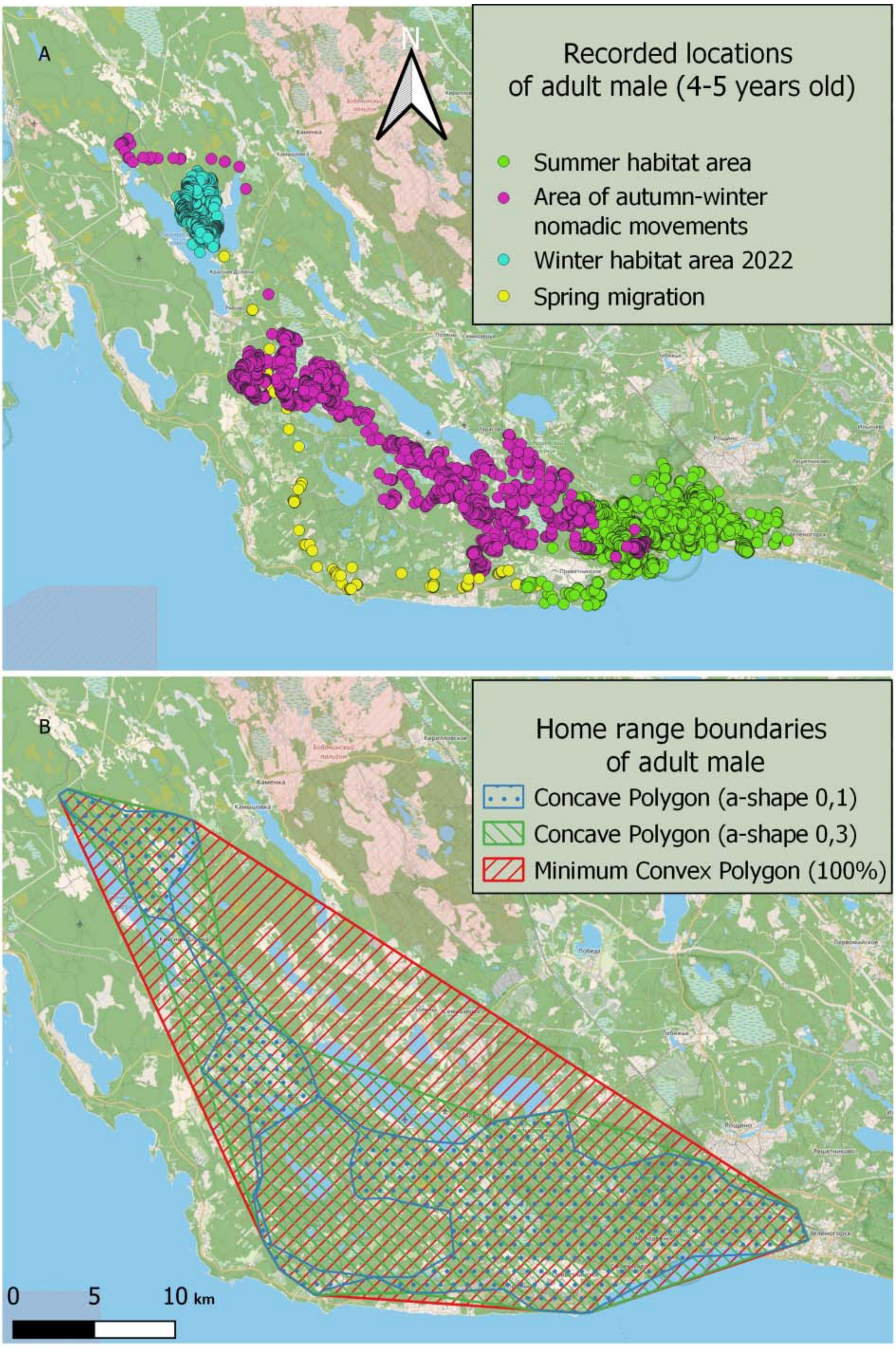


**Fig. 1**. A — Locations of the adult male with gradation by seasonally differentiated habitat areas, for all period of monitoring 16.04.2021 to 18.02.2023; B — Schemes of habitat area with visualization of boundaries measured by MCP and Concave hull method.

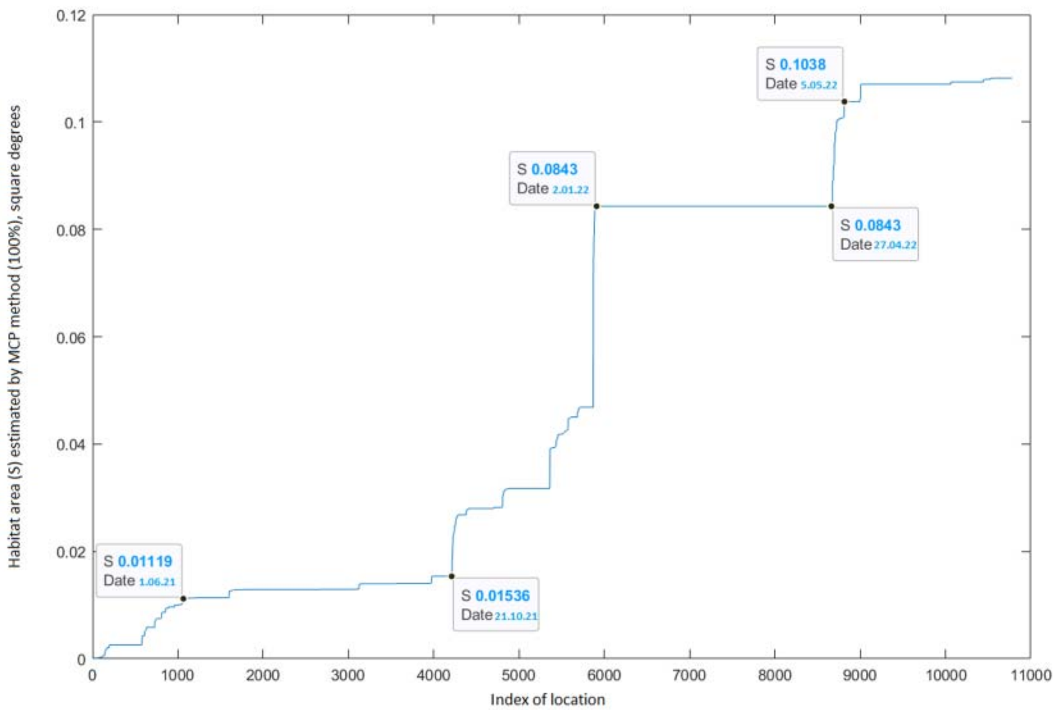


**Fig. 2**. Changes in home range size of the adult male from 2021 to 2022 using the MCP method.

## Discussion

Conclusions about elk's home range size made earlier by scientists in different parts of the range were based on numerous recorded cases of the long-term presence of elk in small areas of space (Filonov, 1983). For example, Knorre (1959) noted that under satisfactory environmental conditions, the home range of individual elk did not exceed 5–10 km$^2$. Many researchers confirmed the statement that "most of life elk move not much" with even smaller values of observed habitat areas. However, it was also noted that seasonal nomadic movements and migrations were quite common for elk (Rusakov, 1967; Timofeeva, 1974; Makridin *et al.*, 1978; Filonov, 1983 and others).

In the Soviet Union in the 1970s, a few attempts were made to mark wild elk in order to clarify their migration. Simple collars with large-format numbers, polyethylene clips or metal ear clips were used (Perovsky, 1980). Marking results outlined in a brief review by Perovsky (1980) indicated the following elk habitat features: 1) the maximum movement of elk was 150 km from the release site; 2) in the Leningrad Region (by the example of an adult cow), movement of 50 km from the marking site was noted; 3) adult animals had a relatively permanent individual habitat area: from 500 to 1500 ha for cows and at least 5500 ha for bulls.

Later, biotelemetric systems, developed in 1981–1988 at A.N. Severtsov Institute of Evolutionary Morphology and Ecology of Animals of the USSR Academy of Sciences, began to be used (Minaev, 1987). Radio-detection systems, consisting of transmitter-radio tags attached to animals and complexes of receiving equipment, made it possible to determine the location of animals by triangulation, as well as to find these animals in the field. They have been applied in the Kostroma, Amur, Belgorod, Bukhara, Moscow, Ryazan, Tver and Krasnodar Regions and in the Republic of Yakutia for tracking roe deer, elk, wild boar and other animals. In elk, the systems have been used to track free-living tame individuals at the "Kostroma Moose Farm" and in the "Losiny Ostrov" Wildlife Refuge. According to the research results, summer habitat areas for cows did not exceed 4000 ha (Bogomolova *et al.*, 2002; Minaev, 2006; Minaev & Purikov, 2015).

There are very few telemetry observations of wild elk in Russia. In 2005, a group of staff of the Federal State Budgetary Institution "Tsentrokhotkontrol" headed by I.K. Lomanov carried out surveys of elk movements during spring migrations using GPS-GSM trackers. Short-term tracking indicated the presence of pronounced sedentary behaviour of captured individuals (Rozhkov *et al.*, 2009). Later studies were carried out in the Tver Region (state experimental hunting farm

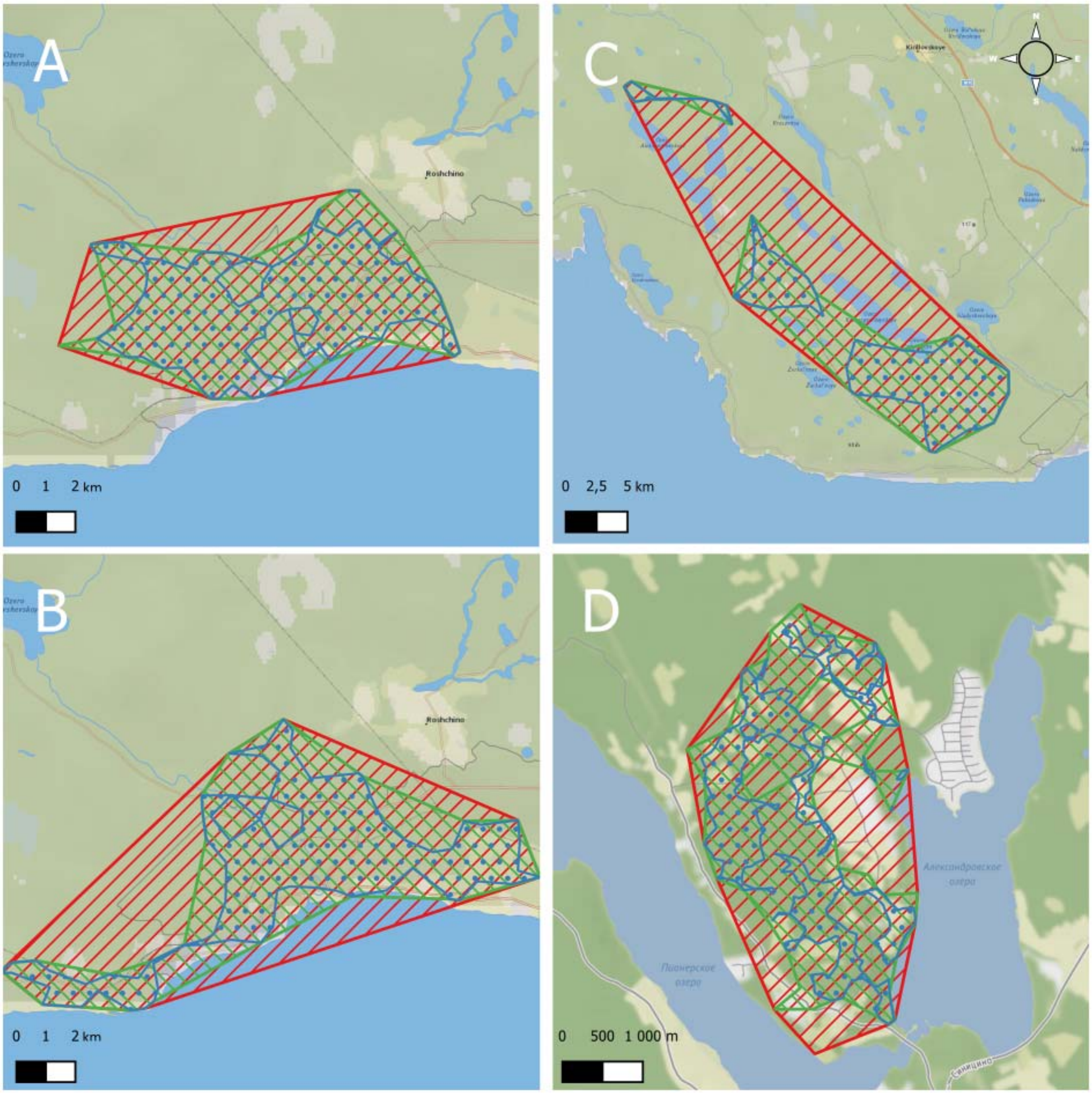


**Fig. 3**. Schemes of seasonal habitat areas of the adult male: A — summer 2021; B — summer 2022; C — autumn-winter nomadic movements 2021; D — winter 2022. Designations as in Fig.1.

"Medveditsa"). Within 7 months after being supplied with a GPS collar, the yearling female explored a territory of 166 km$^2$ and travelled a distance of about 21 km (Pavlov, 2013). The median values of daily movement (1st/3rd quartiles) were 12.08 km (2.6/27.14 km) for May and 10.8 km (5.7/17.6 km) for June. These values strongly exceed the calculated data of actual observations. The general hypothesis of the global pattern of seasonal movements of elk in Russia, which has some confirmation, is represented by the presence of two different elk groups in the population — migratory and sedentary. However, the periods of stable "stationary" habitat in certain areas (and their presence in principle), as well as the quantitative characteristics of the areas occupied by individuals, are not reliably known. Nevertheless, some approximate distances of seasonal migrations have been calculated. The value of the daily movement of elk during seasonal nomadic movements for the middle zone of Russia is about 3–3.5 km, and the total movement between summer and winter stations is in the range of 20–30 km (Rozhkov *et al.*, 2009).

According to our data, the average daily movement of the adult male during autumn nomadic movement ranged from 500 m to 2 km, which is slightly lower

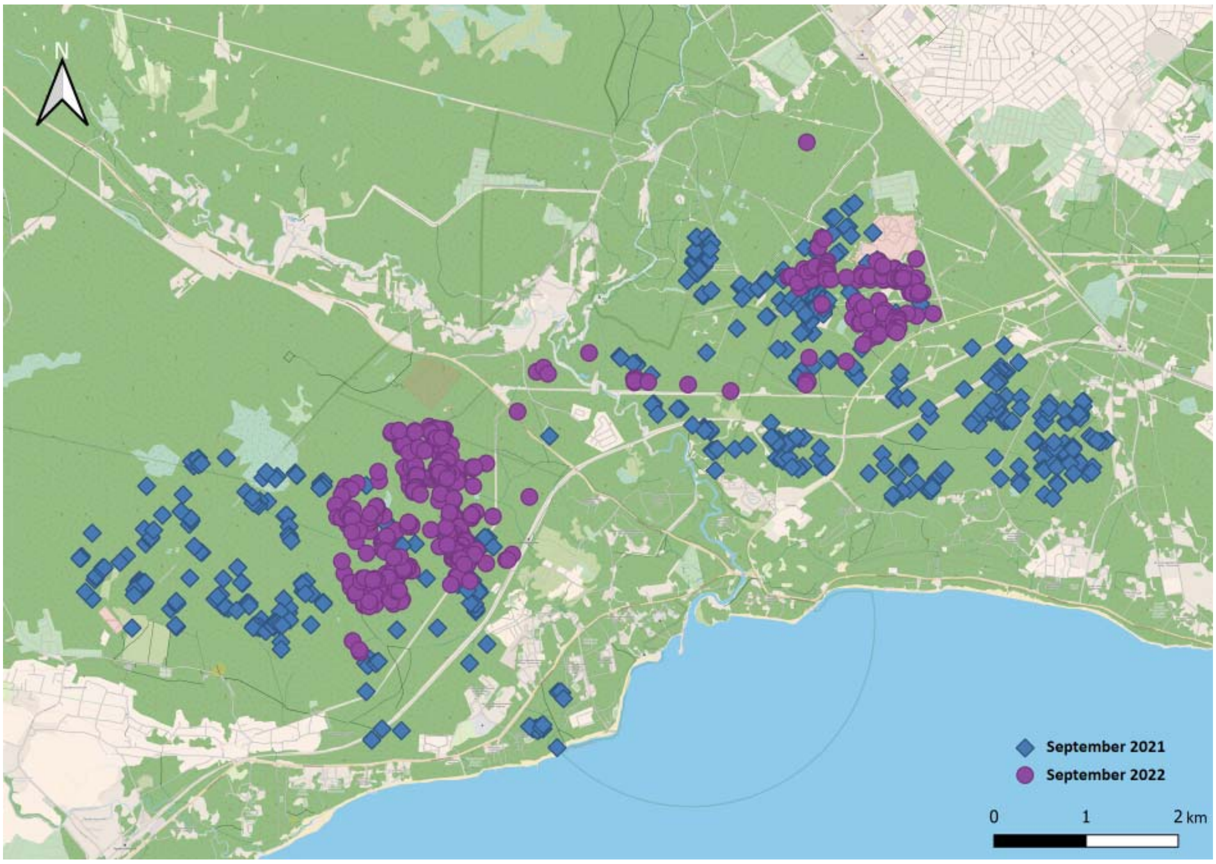


**Fig. 4**. Locations of adult male during rutting periods (September 2021 and 2022).

than the authors' estimates (Rozhkov *et al.*, 2009). In contrast, during spring migration (from winter habitat to summer habitat), the average movement was about 7 km per day. The total movement during the seasonal nomadic movement of elk is slightly higher than expected for the middle part of Russia, falling within the range of 30–50 km. This result may well be explained both by differences in the structure of habitat conditions in different forest zones and by individual preferences of a particular individual. In any case, the order of numbers of measurements is fundamentally similar.

Against the background of the few studies of elk's movements in Russia, in foreign countries — in Scandinavia, Canada and the USA, animal monitoring using satellite telemetry is well developed and telemetry observations in these countries have been carried out continuously for many years. It is convenient to compare the results of these studies with our data because of the similar approach to the method of estimating the size of individual home ranges.

In Norway, there is variability in seasonal movements and individual home range sizes (Ramsrud, 2007; Lykkja *et al.*, 2009; Slangen, 2010; Bjørneraas *et al.*, 2012). According to Lykkja *et al.* (2009), elk rarely go beyond an area of 4–5 km$^2$, as evidenced by long-term observations (over several years). According to Bjørneraas *et al.* (2012), the annual individual male home range averaged 11.0 km$^2$ (SD = 8.7), while females with and without calves used areas of 5.0 km$^2$ (SD = 4.7) and 7.4 km$^2$ (SD = 4.1), respectively (Bjørneraas *et al.*, 2012). In a study by Slangen (2010), the home range size of females using the KDE method ranged from 0.55 to 4.24 km$^2$ (50% of isopleths), and areas of zones with the highest concentration of locations ranged from 0.08 to 0.7 km$^2$ (Slangen, 2010). Slangen also notes that migration typically begins and ends when snow depths are around 30 cm, and defines the end of "winter" for elk as the beginning of migration to summer areas. In the present study, the winter residence period of the adult male was distinguished based on the asymptote of changes in the individual habitat area, so the beginning of migration is also the end of the winter period. It is worth noting that the beginning of the movements also coincides exactly with the time when the ground surface is completely free of snow (end of April). For the male in the present study, the winter habitat area was 550 ha, or 5.5 km$^2$ (KDE method), but we used contours around 95% of locations (95% isopleths), and accordingly, the results were slightly higher. In terms of concentration zones, the winter feeding areas of the single adult male with the highest density of locations did not exceed 20 ha, or 0.2 km$^2$.


**Fig. 5**. The adult male with GPS-collar on the artificial salt lick within the boundaries of the summer habitat in May 2023 after the transmitter has ceased to operate.

In Sweden, the size of seasonal individual female plots varies considerably. Summer habitat areas are almost twice as large as winter areas (9.1 km$^2$ vs. 4.9 km$^2$). Summer habitat areas comprised >70% of the total annual explored area. The annual home range based on survey results was 12.6 km$^2$ and included 2 or fewer core areas (Cederlund & Okarma, 1988). Males, in turn, explore a larger individual habitat area (25.9 km$^2$ ± 3.3 SE) than females (13.7 km$^2$ ± 2.2 SE, $p < 0.01$) during the year (Cederlund & Sand, 1994). At the same time, the size of the habitat area of males is strongly dependent on the age of individuals. According to scientists (Cederlund & Sand, 1994; Mysterud *et al.*, 2001), body size is a major determinant of home range size for species in similar habitats, as body size determines the energy requirements of the organism (McNab, 1963). Differences in home ranges among males have also been attributed to differences in their level of social activity during rutting and hierarchical age dominance.

Studies in North America also mention differences between migratory and conditionally sedentary individuals. As noted by Timmermann & McNicol (1988), migrating moose (*Alces americanus*) in Alaska inhabit up to 300 km$^2$, while adult moose in eastern North America that do not migrate long distances from summer to winter range typically use 20–40 km$^2$. It is worth noting that there is no single term for "animal nomadic movements" in English. It is likely that in foreign literature, the division of animals into migratory and sedentary groups is reduced to one that moves from summer to winter sites and one that stays in a permanent habitat. Based on similar results of Russian authors about the existence of seasonal nomadic movements in part of the population, it seems promising to study the reasons for different territorial behaviour of elk, principles of formation and structure of seasonal habitat areas. In conditions of limited information, the attribution of the observed object (adult bull) to migrating individuals cannot be justified, as migration implies long-term permanence, participation of many individuals and length of movements. Based on the results obtained, the observed object can be attributed to a group of nomadic individuals with a seasonally sedentary lifestyle.

Annual moose home ranges in Canada also lack any consistent value. In British Columbia, habitat areas averaging 195 km$^2$ have been recorded, with a range

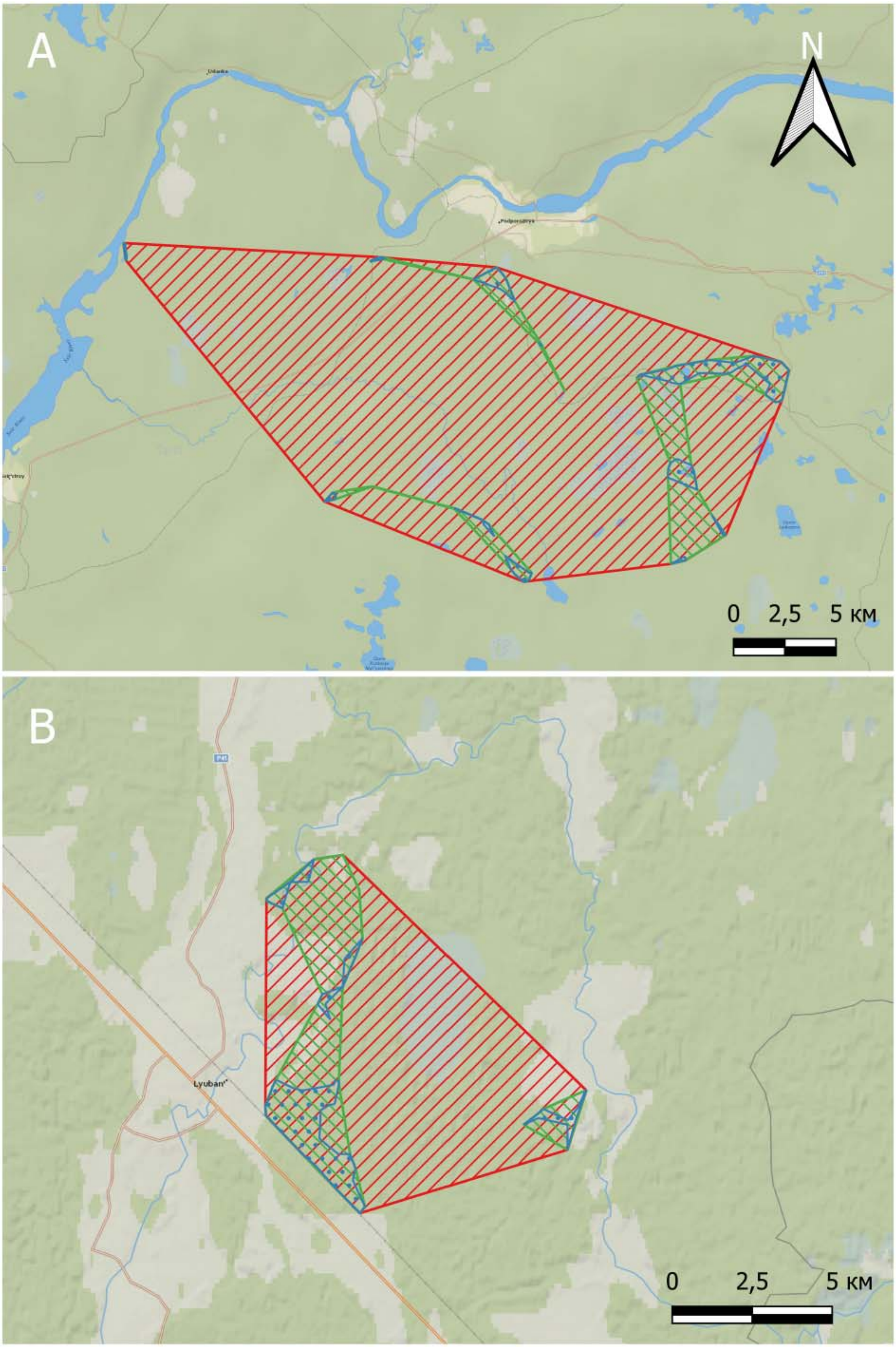


**Fig. 6**. A — Schemes of habitat area of the adult female from 22.05.2022 to 24.06.2022; B — Schemes of habitat area of the yearling male from 19.05.2022 to 12.06.2022. Designations as in Fig.1.

of 39 to 899 km$^2$ and a most-used area of 14–124 km$^2$ (Gillingham & Parker, 2008a). In the Northwest Territories (administrative unit of Canada), individual habitat areas ranged from 40 km$^2$ to 942 km$^2$, with an average of 174 ± 31 km$^2$. It is noted that seasonal home ranges were highly overlapping, indicating that moose were more likely to be sedentary (Stenhouse *et al.*, 1995). In Newfoundland, greater habitat area values were recorded in winter (1200 ± 257 ha, $n$ = 4) than in summer (419 ± 101 ha, $n$ =7) (McLaren *et al.*, 2009). In Quebec, home range values of 87.7 ± 20.3 km$^2$ and 73.7 ± 10.9 km$^2$ are mentioned, depending on the percentage of clear-cutting in the sample territories (Courtois *et al.*, 2002). In the same region, MCP habitat plots ranged within 20–1350 km$^2$ with mean values of 210 km$^2$. The largest range was 125 km$^2$ in summer and the smallest in winter was 3.6 km$^2$. In Alberta, habitat areas equal to 1496–4067 ha were recorded (Osko *et al.*, 2004). During winter in Wyoming, USA, individual a-LoCoH habitat patches were in the range of 83 to 370 ha with mean = 213.8 ha (SD = 81.9) (Baigas *et al.*, 2010).

According to the values mentioned above, our measured data are closest to those recorded in Canada. However, the actual survey sample is extremely small to draw generalised conclusions about movements and habitat areas typical for elk in the Leningrad Region and St. Petersburg. Based on the calculated values, in 75% of cases, all elk in any season of the year did not move more than 200 m from the previous point in an hour. For example, average movement values of moose in British Columbia fall within this range: the minimum speeds during winter and late winter were 35–41 m/h, while summer movement speeds peaked at over 100 m/h, averaging 59 ± 21 m/h (Gillingham & Parker, 2008b). This suggests little or no difference in the movements of European elk (*A. alces*) and American moose (*A. americanus*). It is worth noting that maximum elk movements per hour reached 3500–4400 m, which is more than 17 times higher than most values. We assume that such movements indicate stressful impact on the individual from predators or humans, while the range of movements from 0 to 200 m per hour may characterise normal and calm habitat and movement of the animal.

The adult male was more active in summer than in winter, which is to be expected. Its example shows seasonal nomadic movements and changes in winter and summer habitats. The juxtaposition of autumn-winter movement locations of both periods (Fig. 7) suggests that some stressor occurred in early January 2022 that influenced a short-term habitat shift, causing the elk to move further north, and an attempted purposeful return forced it into the area between the two lakes, where it spent the rest of the winter in 2022. In 2023, no such impact was likely to have occurred, thus the elk remained in an area close to the habitats that it had exploited during the 2021 autumn-winter nomadic movement.

The data on the yearling male and two-year-old female make it possible to clarify some quantitative characteristics of the size of individual home ranges and daily movements of elk. In a fairly short period of time after release, they have explored large territories. Observed individuals “stroll around” several thousand hectares of territory, which significantly exceeds the estimated values from early literature sources (Knorre, 1959; Timofeeva, 1974; Filonov, 1983). It remains to be seen whether this was the result of chaotic movements or a purposeful search for suitable habitat. According to some estimation methods, the size of individual habitat areas is quite similar to the previously reported values, probably characterising zones of “calm” and secured existence. These comparisons suggest that any conclusion about the habitat area will depend on the estimation method and its criteria.

## Conclusion

Telemetry observations of large mammals provide unique information on their life activities, make it possible to identify and suggest areas suitable for use by animals and help to identify migration and nomadic routes and their potentially dangerous places of intersection with transport routes. The data we obtained are the first long-term telemetric observations of elk in Russia, using an adult male as an example to study the animal’s daily movements and habitats over several years.

It should be noted that this article presents the results of primary studies using the most well-known methods of habitat area estimation with subjective input criteria. Several features revealed by the monitoring results are the most interesting: 1) the adult male presented a form of territorial behaviour typical of a seasonally sedentary individual; 2) the “domesticated” cow returned to her permanent enclosure less than a month later and gave birth, despite the fact that the release site was located 27 km away from the housing site and the transfer of the cow to the release site was carried out under sedation; 3) the experience of releasing a yearling male indicates the low adaptability of young individuals to the conditions of the natural environment in the early stage of life without adults and requires the development of specific criteria for the characteristics of the individual to be released and the place of release.

It should be assumed that the behaviour of captive-bred individuals or young animals accustomed to living near humans may differ significantly from that of wild ones, so it seems unhelpful to mark and reintroduce them in order to study the activity of wild relatives. It also seems likely that in the conditions of the southern taiga zone, most elk lead a seasonally sedentary lifestyle, making long-term transitions in autumn and short-term transitions in spring. It should be noted that this may not be true for the whole territory and not for all age and sex groups, since around large urbanised centres, the areas suitable for elk habitat are highly fragmented and differ in their landscape and habitat characteristics, as well as in the level of economic development and the presence of predators. Similarly, individual preferences may determine elk’s movements in space.

Unfortunately, this line of research is limited by the rare possibility of equipping wild elk with satellite trans-

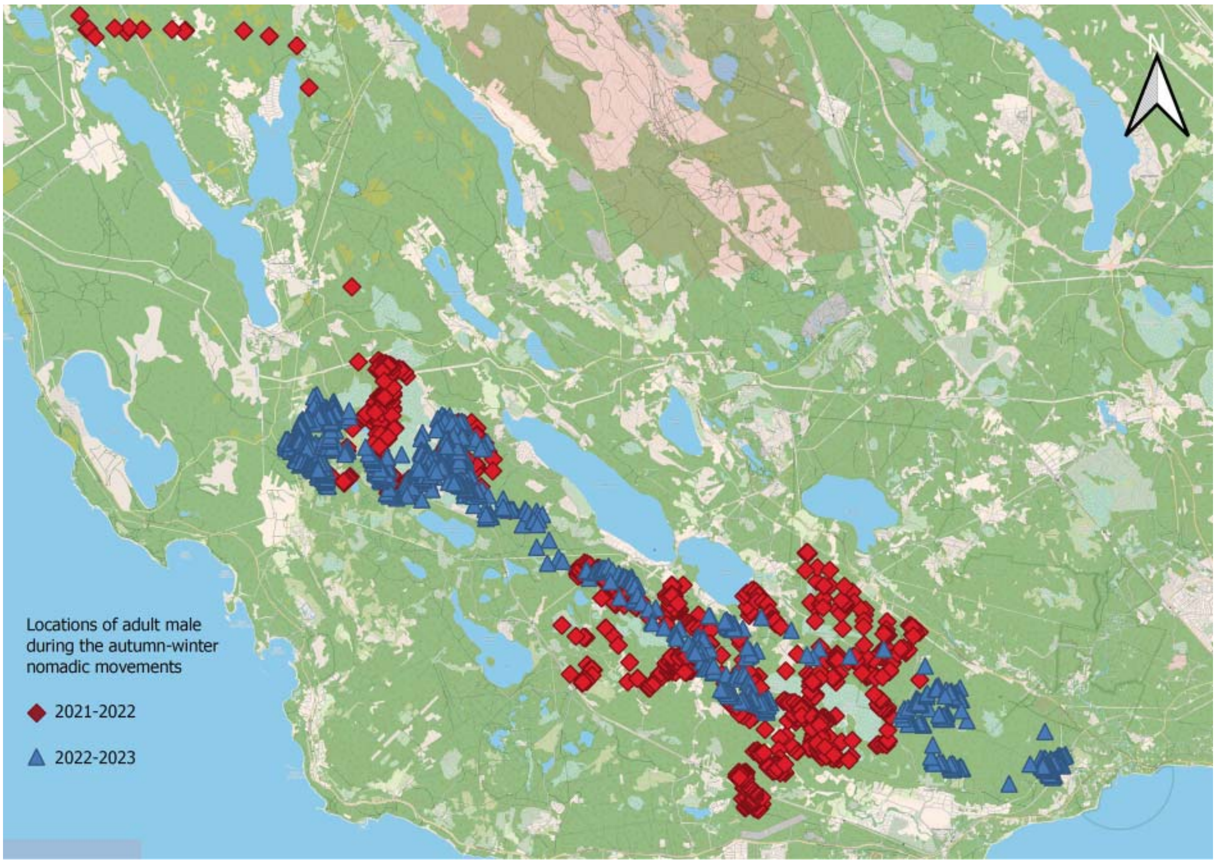


**Fig.7.** Locations of the adult male during autumn–winter habitat periods recorded over two periods.

mitters, as the legislative aspect of issuing permits for this type of activity is not perfect. In this connection, it is possible to equip individuals with satellite transmitters only as a result of accidental occurrence of elk in the anthropogenic environment during direct capture by the competent governmental organisations of the Russian Federation constituent entity. Such cases are extremely limited, and, more often than not, government organisations try to find the easiest way to eliminate the consequences of an animal's presence in an anthropogenic environment. Additional studies to clarify the distribution and movements of different sex and age groups of elk will be continued, as far as possible.

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