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"Coordinated Actions to Improve Wolf-Human Coexistence at the Alpine Population Level"

Action C3

Technical Report

STUDY OF THE RELATIONSHIPS BETWEEN PREDATORS, PREY AND HUMAN ACTIVITIES IN THE ALPS

LOCAL REPORT FOR JELOVICA STUDY AREA, SLOVENIA

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Content

1. Introduction

Project action C3 aimed at investigating spatial responses of wild ungulates (roe deer and red deer) to disturbance/ predation risks in connection with both, anthropogenic mortality and natural predation. The question was posed in four study areas in France, Italy and Slovenia, in order to obtain insights across different anthropogenic, environmental and ecosystemic contexts. Methodology of the study was based on study of movements of both prey and predator by means of tracking GPS locations through live-captures and equipping with telemetry collars (roe deer, red deer, wolf), on systematic camera-trapping, collection of biological samples and similar. We accounted for several environmental and anthropogenic variables, like hunting pressure, livestock presence, co-occurrence of other wild predators and prey. Each study site focused on its characteristics and socio-environmental context. For complete description of study background and protocol refer to Simon et al. 2021.

1.1. Study area

Study area was located in north-west of the country in Julian Alps, which are the vastest and highest mountain massif in Slovenia, culminating at 2864 m a.s.l. at Mount Triglav. The topography of the Julian Alps and the adjacent pre-alpine areas is very diverse and characterised by high peaks and steep slopes exposed to erosion and karstic processes, with the lowest valleys at around 440 m a.s.l. This alpine space is characterised also by two high Alpine plateaus, Jelovica and Pokljuka, where forests are mostly comprised of spruce (*Picea abies*) and beech (*Fagus sylvatica*) in various *Piceetum*, *Fagetum*, *Abieti-fagetum* and *Abietetum* societies, with the conifers prevailing in the tree composition.

Climate is alpine: harsh with cold winters, relatively short summers, and abundant precipitation, especially in autumn. Towards the south of the study area the climate is characterised by a joint influence of alpine and pre-alpine climate, and through the alpine valleys even mediterranean and continental influences can be detected. The amount of precipitation increases from pre-alpine towards alpine space and from east to west, so an average annual precipitation in the pre-alpine space amounts to 1700 - 2000 mm and in the alpine space to 1900 - 2300 mm or 2300 – 3100 mm towards the core of the Julian Alps. The average annual temperature is between 3 and 6°C.

The vast majority of the study area was covered by forests (77,8 %). Meadows represented 14,4 % of the study area's surface, while open areas and agriculture areas in overgrowth comprise for another 3,9 % and arable land for 1,3 % of the area. Urban areas represent only 2,2 % of the study area's surface.

Forests on Jelovica and Pokljuka had been recently, as well as in the last decade, subjected to disturbances due to windbreaks and bark-beetle-outbreaks (see the maps Senf & Seidl, 2021). That's why these forests are interspersed with naturally created clearings of smaller or greater sizes, providing favourable ecotones for roe deer.

1.2. Wild ungulate presence

Potential wolf prey among ungulates in the study area represent five species, namely red deer, roe deer, chamois, mouflon and wild boar. Besides, livestock can be predated, too, and ibex could descend under the forest line in winter on the borders of the study area, thus potentially becoming a wolf prey.

Roe deer is constantly present in the study area, but differences in density occur between larger forest complexes (Pokljuka and Jelovica), where roe deer densities are lower, and the more fragmented landscape of alpine terrain on lower altitudes with mosaic of fragmented forested and anthropogenic areas, where roe deer densities are higher. Roe deer population in the project area is viable and stable.

Red deer was extinct from the territory of Slovenia in the 19th century and reintroduced afterwards in the transition from the 19th to the 20th century. The current trend for red deer in Slovenia indicates spatial expansion of the population, still being in the expansion/ recolonisation process. The hunting bag in the last five years has actually been the largest in the last 20 years[1], as well as in the whole period after the reintroduction. A healthy and stable population has also been formed in the study area in Slovenian Alps.

Chamois is a species that inhabits open rocky areas above the forest line. Generally, chamois stay above the forest line in summer and descend to lower altitudes in winter. Many chamois, however, remain on high mountain pastures all year round. In smaller fragments, chamois is present also in forested, hilly pre-alpine and Dinaric areas in Slovenia. In the study area, chamois habitat is represented mainly by steeper slopes on forested terrains in midlands.

Mouflon is a non-native game species in Slovenia. It was introduced in the 1960s and 1970s. For the most part, its occurrence coincides with human settlements. Individual colonies or local populations became established in or in the vicinity of release sites. Local populations also became established in the midland forests in the study area, where mouflon is regularly present, but showing a decreasing population trend already from before the permanent wolf recolonisation. Wolf predation was expected to have a substantial influence on mouflon numbers in the study area, considering that the mouflon is a non-native species and as such more vulnerable or not adapted to wolf predation. However, data on monitoring of predated ungulates, both wolf- and lynx kills, suggested otherwise, as mouflon kill sites represented a very small percentage of all found wolf or lynx prey (up to a maximum of 2 % of found kills in a certain year; this study and Fležar et al. 2024).

Wild boar, as an extremely adaptable species, is widespread almost all over Slovenia, except in the highlands or some basins, lowlands and hilly areas. Our study area represents a sub-optimal habitat for the wild boar, which is indeed reflected by relatively low densities. In the last 10 years, only a slightly increasing population trend has been detected on the basis of hunting

[1] Source: Annual harvest data, Slovenian Forest Service, Večna pot 2, Ljubljana.

quotas.

1.3. Hunting regime

Wildlife management in Slovenia is based on transparent and sustainable planning, thus all the measures are prepared for ecologically delineated areas and in cooperation with all stakeholders[2]. In game management, hunters and hunting organisations play a very important role. The Slovenian Forest Service (which is under the auspices of the Ministry of Agriculture, Forestry and Food) is the competent wildlife management institution and prepares a proposal of short-term and long-term management plans. These are further validated through the public debate, stakeholders' involvement and contribution of the Institute of the Republic of Slovenia for Nature Conservation, and agricultural holdings operating in neighbouring countries.

Hunting on roe deer is carried out in the following periods: from 1st May to 31st October for adult and yearling males; from 1st September to 31st December for adult females and offspring of both sexes; from 1st May to 31st December for yearling females. Most of the time, hunting cull in open hunting seasons occurs in peaks (not uniformly distributed over the whole open season).
Hunting is carried out by stalking and by waiting on high stands (hunting towers) during the daytime (from morning to dusk). Hunting at night is strictly prohibited. It is possible to hunt roe deer also by drive hunts, but this mode is not commonly used.

As for all game species, also in case of red deer hunting is carried out in accordance with the defined hunting periods, which determine hunting by sex- and age categories: adult males from 16th August to 31st December; adult females and offspring of both sexes from 1st September to 31st December; yearlings of both sexes from 1st July to 31st December. Red deer hunting is carried out by stalking in combination with hunting by waiting (from high stands), in late autumn and in winter also by drive hunts. Hunting is carried out only during the day (from morning to dusk). Exceptions are allowed on the basis of individually issued and time-limited culling permits due to local increase in damage to agriculture and forestry, which also allows nocturnal deer hunting.

Wild boar can also be hunted by all three hunting modes - waiting on high stands, stalking and driving. In autumn and winter drive hunts are the most represented. From October to January wild boar can be hunted by night, as well.
Chamois and mouflon are hunted by stalking, in lesser extent by waiting on high stands.

Northern and to a lesser degree also western part of the study area lies in the Triglav National Park, where hunting is not performed by hunting clubs, but by professional hunters – park rangers. The park territory is also hierarchically divided in zones, hunting being permitted only in the most external zones, while being forbidden in the core zones.

[2] https://www.gov.si/en/policies/agriculture-forestry-and-food/hunting/

1.4. Wolf status overview

An intensive systematic monitoring on the abundance and distribution of wolves in Slovenia has been established in 2010, when the LIFE SloWolf project started. Methods for collection of data on wolf presence and reproduction like collection and analysis of non-invasive genetic samples, photo-trapping, telemetric monitoring, snow-tracking and wolf-howling have been implemented.

In the period between 2011 and 2018, dispersing wolves (so-called dispersers) and individual wolves were detected only occasionally in Slovenian Alps. Finally, we confirmed the establishment of the first packs (pack Jelovica and pack Pokljuka) in 2018, during the monitoring season 2018/2019 (Bartol et al. 2019) with uniquely admixed ancestry (pack Pokljuka; Konec et al. 2024).

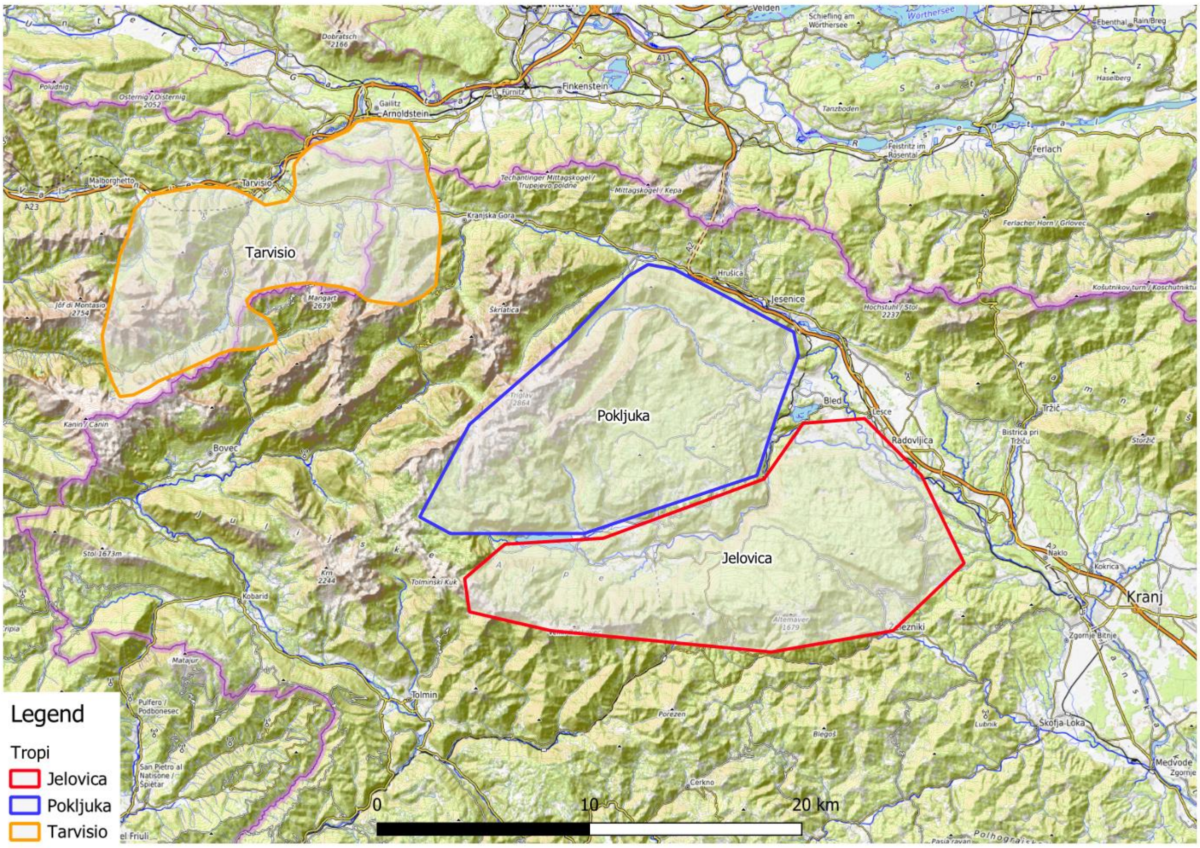


Figure 1 : Wolf packs distribution in SE Alps in Slovenia.

Pokljuka pack

Home range of the Pokljuka pack mainly covers the area of Triglav National Park. In the season 2018/19, the pack was established by a female wolf, which was an immigrant to the Dinaric population (originated from areas further south on the Balkan Peninsula) and a male which originated from the Lessinia Nature Park near Verona in Italy (Konec et al.2024). This male was a direct offspring of the famous Dinaric wolf Slavc, that dispersed from the area in south

Slovenia to Italy in 2012 and mated with a female wolf from the Italian Alpine population, initiating recolonization of the eastern Italian Alps (Ražen et al. 2016, Konec et al.2024). The new Pokljuka couple had a litter of five pups in 2019, one of which had dispersed 300 km of aerial distance to Bavaria, Germany in 2020 (Konec et al.2024).
From the summer of 2019, the reproductive male was no longer detected, and no pups were detected in the following 2020 season, which was only a further indication that the pack, which was formed by the aforementioned pair, had disintegrated.

In the 2020/21 season, the female was joined by a new male, originating from the Italian Alpine population, with whom she had a litter of five pups in 2021. All the offspring left the pack (dispersed) or died till the end of first half of 2022. One of them was hit by a car near the Austrian-German border. In 2022, the same pair had four pups, which were constantly detected throughout the winter of 2022/23. In the spring and summer 2023, we still detected a reproductive pair and one female in the area, most probably their offspring from 2022. In the spring 2023, interestingly, we only detected two offspring in the pack. In addition, there was one other male in the wider area, which we assume to be a temporary disperser looking for its own territory, as it has never been recorded with the pack and will be probably pushed out of the area sooner rather than later. In September 2023, following a permit issued due to local damages on livestock, a young female wolf which we assume to be the aforementioned offspring of the previous year, was legally shot on a pasture near a village.

Jelovica Pack

The Jelovica pack was established by a female originating from Trnovo Forest Plateau (W Slovenia) and a male from the Vremščica pack (SE Slovenia) in 2019. Reproduction was confirmed already in the first season (2019). Reproduction was also confirmed in 2020, 2021 and 2022. At least 6 wolves (maximum 10) were detected in the pack in each season. Beside residential wolves, two individual wolves unrelated to the Jelovica pack were detected in the 2022/23 season. They had not moved with the pack and were probably transient wolves. One wolf from each litter from 2020 to 2022 was captured, equipped with a collar and tracked by means of GPS telemetry during project duration. The first (Jelko, litter 2020) went into dispersion towards Italy in 2021 and settled in the wider area of Resia, where he was killed in a traffic accident (run over by a truck) in February 2022. The second (Mojmir, litter 2021) either disappeared in the Jelovica area either his collar broke. Also, the male has not been detected since then. The third (Neža, 2022) dispersed south to the Polhov Gradec pre-alpine area and had been monitored till December 2023.

Tarvisio Pack

In June 2020, a hybrid wolf (originating from a hybrid pack from Savinjska valley, N Slovenia) came to the area and paired with a female wolf (originating from Slovenia), already present in the area. The first litter of 7 pups was detected in summer 2021. They had obvious phenotypic signs of hybridization. The responsible Ministry in Slovenia issued a decision to cull the entire pack, while the competent Italian institutions only allowed the sterilization of the animals in the event of their potential capture. In April 2022, one of the male offspring was legally shot near Rateče (Slovenia). In May 2022, colleagues from Progetto Lince Italia captured a young female. She had to be subjected to sterilization, but died during the surgery. In 2022, there were 10 animals in the hybrid pack: reproductive pair, one young male from 2021 litter and 7 new pups. By March 2023, the reproductive female and two offspring had been removed from the wild. There were no signs of the reproductive male or of new litter within the pack area in 2023.

Photo 2: Tarvisio hybrid wolf pups 2021 (photo: Progetto Lince Italia).

1.5. Lynx status overview

In the frame of LIFE Lynx project (LIFE16 NAT/SI/000634; 2017 – 2024; https://www.lifelynx.eu) there has been 5 lynx (3 females and 2 males) translocated to the Slovenian Alps in 2021: a male and two females to Pokljuka plateau and a male and a female to the Jelovica Plateau. They reproduced and every year there were litters detected in the area.

A male lynx from Jelovica plateau has been assumed dead in 2022, so there was an additional male lynx translocated to this area in April 2023. However, he left the area immediately after the release and established a home range in Karawanks Mountains along the Slovenian-Austrian border, where we later lost track of him. At the end of 2023, there were 3 lynxes present in Jelovica plateau (the translocated female and pressumably 2 of her offspring).

In winter 2022/2023, all four kittens from the Pokljuka plateau (one female had 3 kittens and the other 1 kitten), were captured and radio-collared. We tracked their dispersal and establishment of their own territories in the wider area of Triglav National Park, mostly on its western side (Fležar et.al. 2024). On Pokljuka, there were all of the three translocated lynxes still present in the area at the end of 2023.

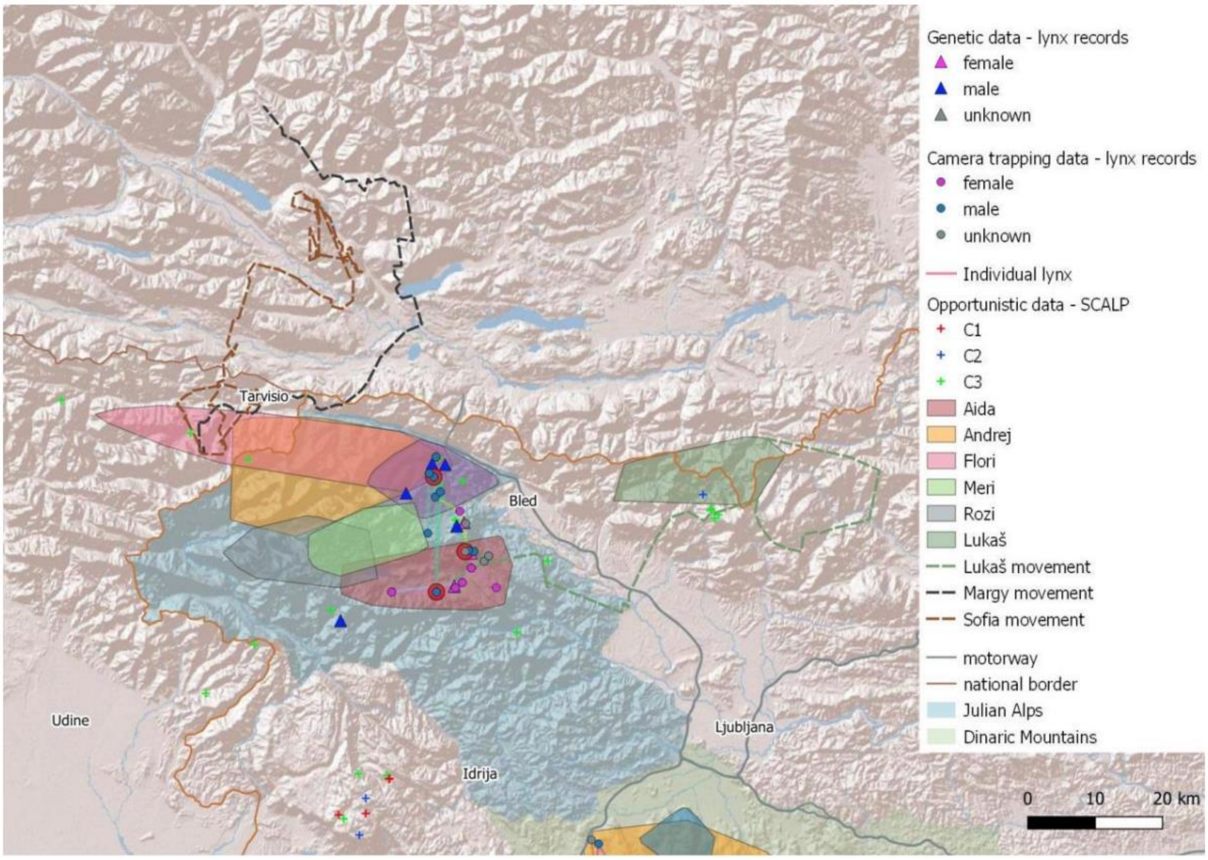


Figure 3: Overview of all confirmed records of Eurasian lynx collected during the 2022-2023 monitoring year in Julian Alps, Slovenia, Italy and Austria in the frame of LIFE Lynx Project (Fležar et.al. 2024).

2. Involvement and support of hunters

As hunters were main stakeholders in this project action, we have put every effort in building a mutual trust from the very beginning. After our initial approach towards their managing boards and leaders of target hunting clubs, inviting them to participate in the study, they have become our indispensable partners in executing field work.

Interested leaders of 6 local hunting clubs, as well as local hunters, were taking part in our field activities regarding roe deer (Photos 4 and 5): choosing sites for box-traps and camera traps, placing them in the field, baiting and maintaining traps, live-captures, observations of marked individuals, measuring carcasses of culled roe deer and providing long bones for bone-marrow analyses. They were also offering logistic support during capture sessions and in recovering monitored animals or collars from the field.

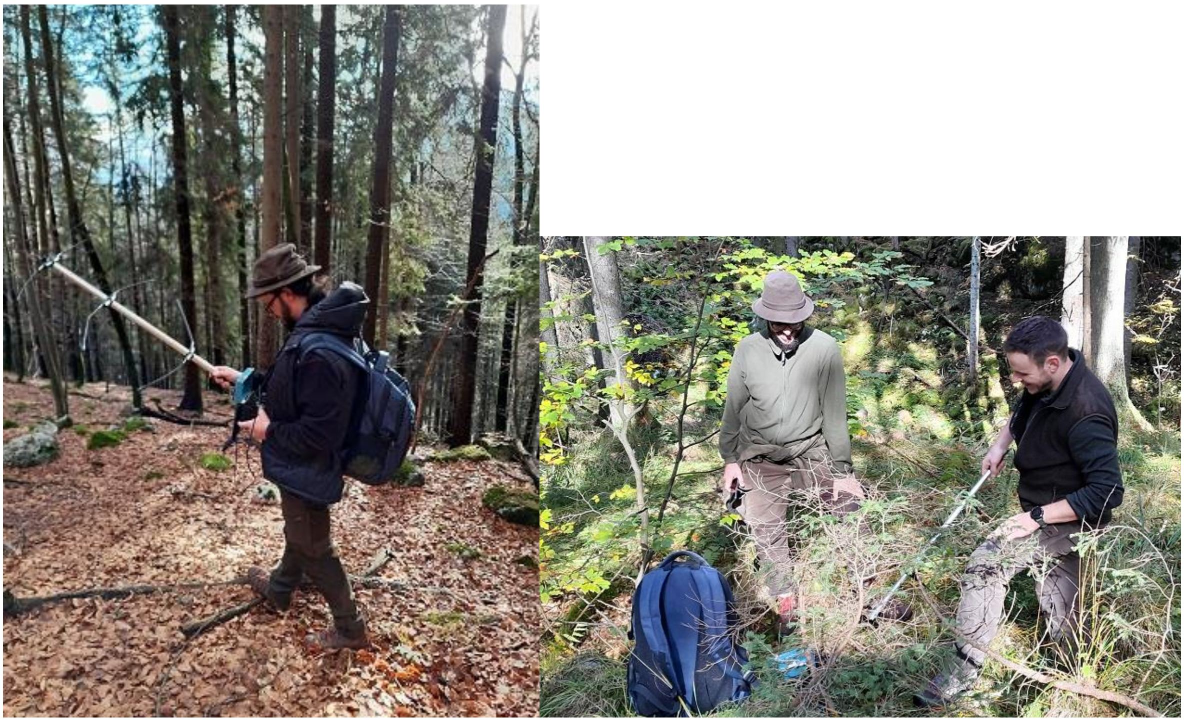


Photo 4: Hunters participated in the field work, like here searching for the VHF-signal from the animal--borne telemetry collars.

Many local hunters and Triglav National Park rangers/ professional hunters participated also in field work regarding wolf: participating in wolf captures, maintaining camera-traps, collecting records of wolf presence and biological samples, searching for kill sites, snow-tracking and similar.


Photo 5: A local hunter is taking part in the search of a dead roe deer, whose GPS-collar had sent a mortality signal (left); hunters, participating in the roe deer capture event (right).

Cooperation with hunters needed to be constant, reciprocal and trust-building. We maintained our cooperation through frequent phone calls and e-mail updates on the progress of fieldwork. Apart from personal one-to-one communication, we organised also larger informative meetings, inviting hunting clubs' leaders and management boards to participate. We organised eight meetings for management boards during the project. Additionally, two workshops for hunters were organised on the site in 2021 and 2022 (Photo 6), where we discussed the study design, its implementation, cooperation in data collection, the methods used, obtained results, experience and challenges from the field.

Photo 6: Workshop with hunters in November 2022 in Sorica, on-site in the Jelovica study area.

Due to a fruitful and trustful cooperation, hunting club Bohinjska Bistrica decided to become a steward of the project. By undersigning the stewardship agreement in December 2021, both institutions reciprocally increased project and institutional visibility through local and project media channels. Two popular articles were published in local newspaper about roe deer captures and monitoring of radio-collared animals to inform local inhabitants about the ongoing study. Additionally, they organised a "School Hunting Day", where they presented project activities to Primary School pupils during a field trip in their hunting ground.

To stay up-to-date with our field activities, field protocols and adjust the methodologies, when needed, project partners gathered also in-person during the project. Not only, we shared experience and knowledge also among other LIFE projects and beyond, when international groups of experts on wildlife conservation visited us during networking events (Photo 7). Local hunters were willingly participating in such field visits of visiting groups in their hunting grounds, too.

Photo 7: In June 2022, when an international group of experts on large carnivore conservation from 8 countries was hosted in Slovenia on a networking event to exchange LIFE best practices, we discussed also field methodology and project results, accompanied by local hunters in the field.

We also reached out to general public with publishing updates on our work on project web-page and social media. We published 24 news on the web-page, all of which were also shared within the hunters' and foresters' networks in the study area, as well as in wider regions of the Alpine and pre-Alpine region. We emphasised the appreciated role of hunters and other external collaborators that enabled our work to be successfully concluded.

3. Live-captures of roe deer

Ministry of Agriculture, Forestry and Food granted our request with issued permission (Nr. 341-5/2021/3) to set roe deer traps in the environment, handle captured animals and mark them with ear-tags and telemetry collars.

3.1. Setting up box-traps

We chose 6 hunting grounds from the Jelovica plateau for executing roe deer captures (see Figure 20 on page 24): Bohinjska Bistrica, Sorica, Železniki, Selca, Jošt – Kranj, and Ribno - Jelovica. We set altogether six wooden box-traps on carefully chosen microlocations. Based on hunters' knowledge of and experience in their hunting grounds, we chose microlocations with high probability of roe deer presence and at the same time accounting for harsh winter conditions, thus avoiding areas, where fast access on snow-plowed forest roads could not be guaranteed during the whole winter.

After having chosen the microlocations, we followed several phases, in order to enhance our probability of a capture. At first, the box-traps needed to be present on a location in advance, in order to give the animals some time to habituate on their presence. We baited the surroundings of the traps with food items (corn, apples, apple remains after fermentation for odor) in order to attract roe deer in the vicinity. At the same time, we set also camera-traps nearby to record the frequency of the visits to the box-traps (Photo 8). All cameras and box-traps were equipped with a notice for the near-by walkers (hikers, locals, mushroom-pickers, hunters, foresters…) to be aware of the visually-supervised area, the motives for the live-trapping and providing contact details in case they had further questions.

Photo 8: Camera-traps were used near and next to box-traps to monitor roe deer habituation and visiting frequency around the box-trap. Cameras were accompanied on the site or at the beginning of a path by a notice for the people, who found themselves in the supervised area.

The traps needed to be set up firmly on the ground, requiring to dig an appropriate size of a flat terrain, in order to ensure firm anchoring and flatness for closing doors (Photo 9). The bottom of a trap was covered with ground material found around the trap. In winter conditions, hunters cleaned accumulated snow from the trap, thus defrosting the triggering mechanism, and shovelled the entrance of the trap.

Photo 9: Hunters and capture team setting up box-traps at the beginning of the capture season.

In presence and by means of camera-traps we monitored roe deer presence around the box-traps (Photo 10). We were interested into the time of the arrivals, whether roe deer visited traps alone or in groups, into the age, sex or family groups of the approaching roe deer, and ultimately if they already entered the traps or not. We activated the box-traps only when the roe deer was completely habituated on entering to feed every night without fear.

Photo 10: We monitored the frequency of roe deer visits to the box-traps with automatic cameras.

Wooden box-traps had an automatically-triggered sliding doors on the front side and a feeder for baiting food items on the opposite side (Photo 11). Just above the feeder there was a line of a transparent fishing thread, attached to a rope under the top of the box, which connected a triggering mechanism, connected to the sliding doors by a wire (Photo 12). Box-trap was big enough that the animal had to enter properly, if wanting to reach the feeder at the back side of the trap. If decided to lower its head into the feeder, it touched the thread above the feeder, which in turn triggered the mechanism and the sliding doors closed by its gravitational force.

Photo 11: Box-trap with sliding doors on one side and feeder on the other side for capturing roe deer. Left: Deactivated box-trap in the field, so the animals can get used to its presence; middle: Activating the mechanism for automatic closure of the sliding doors in the box-trap; right: Activated box-traps were always equipped with satellite trap transmitters, which received a signal upon closing doors and transmitted it over the satellite network.

Photo 12: Attaching the upper part of a triggering mechanism of a box-trap to the sliding doors. (Photo: Janez Tarman.)

It was not only roe deer interested into the baited box, but we also photographed or tracked many other visitors in or around the traps, depending on a specific location: forest-dwelling mice, jay, robin and other small birds, marten, hare, badger, fox, cat, dog and red deer. Rare events were also by-passing lynx and curious bears that played with the box-trap (Photo 12a). On one occasion, a local tornado lifted the anchored box-trap and smashed it upside-down on the ground (Photo 12a).

Photo 12a: Local heavy winds lifted and crashed an anchored box-trap (left). A by-passing bear taking his time to thoroughly inspect a box-trap (right).

3.2. Roe deer captures

Although the preparations and field work for captures took place throughout the year, roe deer captures themselves were executed during winter season, namely in three consecutive seasons, starting in winter 2020/21 and finishing in winter 2022/23.

Beforehand, a capture team of five operators attended simulation trainings for the first two capture seasons to be well-prepared and coordinated during capture events. During capture sessions, the capture team was located nearby, usually in a hunting hut, to be ready to depart immediately upon the triggered alarm/ capture event.

When a triggering alarm of a closed sliding door arrived to our e-mails and/ or mobile numbers, the capture team departed immediately with all the equipment prepared, sorted and loaded beforehand. The meeting point with the hunters was at the last possible parking spot before entering hilly forest roads on foot. That was also the point of the team’s last coordination arrangements and last possibility to talk loudly. Then we set on foot till the closed box-trap in total silence, which lasted till the end of the capture event, so that we prevented adding additional stress to the captured animal with our voices. Well trained and coordinated capture team was able to perform the whole action in silence, acting very fast so as not to allow for an animal to build up its stress chemicals in the body. First, we extracted trapped animal by holding its hind legs, thoracic area and ears. Immediately upon extraction we blindfolded it with a black face mask to help it calm down, then we laid it down on its right side, in order to help keep the digestive tract in its natural position, preserving eased digestive and respiratory processes. Animal was then immediately physically immobilized, in accordance to thorough handling protocol; no anaesthetics were used. We then proceeded with fitting a GPS-collar and ear-tags to the animal (Photo 13), measuring (biometric measurements of various body lengths and circumferences), sexing, aging, weighing (lifting it up in for this purpose specially sown net) and taking hair samples. Afterwards, we released the handled animal immediately on spot, observing its run-away (Photo 14).

The time needed to reach the box trap varied substantially and depended on the circumstances of that particular capture session and combination of activated box traps and team's logistics. The shortest time to reach the box trap after a roe deer was captured was 4 minutes, the longest was 97 minutes. Median time was 40.5 minutes and the average time was 49.4 minutes (n= 22).

The handling process – time from reaching the box-trap until releasing a marked animal – on the other hand, lasted a minimum of 7 minutes and 1st quartile 10 minutes to median of 11 minutes and 3rd quartile of 12 minutes (n= 21 or n= 20). The maximum time was 15 minutes (n= 20), if we exclude one outlier of maximum handling time of 22 minutes due to a treatment of a cut on the front left leg (n= 21).

After each handling, we followed the animal's GPS-movements especially carefully for an initial period and monitored it by means of automatic camera-traps photos in the area or at the box-trap location, in order to make sure the animal resumed its normal behavior and movements (Photo 15).

Photo 13: Fitting a telemetry collar to a physically immobilized and blindfolded roe deer.

Photo 14: After being equipped with the GPS-collar and ear-tags, roe deer were immediately released on site.

Photo 15: Previously captured and marked roe deer approached the capture site, where it was photographed by a camera-trap.

Having had 22 roe deer capture events, Slovenian roe deer capture team executed altogether 21 roe deer extractions from the box-traps in three consecutive capture seasons (1 individual was released without extraction due to being already newly collared). Out of 21 extractions and physical immobilizations, 3 were recaptures of two already marked individuals (two times in the same box-trap and once in a trap on a different location). Thus, we marked altogether 18 individuals, out of which one was captured as a fawn and was therefore marked only with ear-tags. The remaining 17 individuals were marked both by ear-tags and GPS-collars (Table 1).

We started our work with twelve roe deer GPS-collars at our disposition, but during the three-year study period we managed to restitute some collared-roe deer mortalities and provide for one collar refurbishment. Altogether, 5 animals were collared with Lotek collars and 12 with Vectronic collars (9 males and 8 females; Table 1).

We weighed 14 collared roe deer during the capture events and on average they weighed 21.8 kg (range from 18.2 to 24.7 kg, median 22.3 kg). Their telemetry-collars represented on average 2.0 % of their body mass (range from 1.6 to 2.7 % of body mass, median 2.1 %; n= 14; see the data on collar weight below).

3.2.1 Technical specifications of GPS-collars

Purchased GPS collars were produced by two manufacturers: 9 by Vectronic Aerospace (model VERTEX Lite-1D GSM either with incorporated manufacturer's SIM chip either with customer provided national mobile operator's SIM) and 3 by Lotek (model LiteTrack 360 Iridium). Comparing their performance through our experience, both products exhibited quite different characteristics in terms of reliability of hard-ware (chips, sensors, batteries) and in terms of accuracy of location receivers.

Seven Vectronic collars weighed from minimum 486 grams to maximum 495 g (median 491 g), depending on the various circumferences of the belt. Two Vectronic collars had a 4-layer cotton "belt break-away" piece incorporated into the belt, which increased their weight to 511 and 520 g. Three Lotek collars were lighter, they weighed 362, 363 and 364 g, respectively. All collars were equipped with a standard set of sensors – temperature, mortality and accelerometer/ activity sensor – and they all had a VHF beacon, so we were able to locate collars in the field with a hand-held 3-element Yagi antenna and a VHF receiver. All collars were also equipped with a drop-off system. Vectronic model had an internally mounted drop-off system, triggered both automatically (pre-programmed timer release) and manually from the proximity in the field, while Lotek had it externally mounted and triggered automatically and remotely on a command. We pre-programmed different drop-off release times (110, 80, 71, 70 or 40 weeks), depending on a certain deployment's needs and battery conditions. Eleven collars had black colours of the belt and two belts were beige.

We preferentially chose data transfer via GSM mobile network, when possible (in all Vectronic collars), otherwise the data transfer was carried out via Iridium satellite communication (all Lotek collars). Anyhow, our priority was always to recollect collars from the field after each deployment, in order to download all GPS data, which were stored in the collars' electronics, even if the data transfer was priorly disabled due to field conditions. Besides, this was also the only way to obtain the activity or accelerometer data. We succeeded to recollect all collars from the field except one.

Table 1: Description of captures and life-history traits of seventeen roe deer individuals, equipped with GPS-collars in Slovenian study area on Jelovica plateau in the period 2021-2023.

Animal ID	Animal name	Sex	Date and time of (first-collaring) capture	Hunting ground at capture	Body mass [kg]	Age class estimate at capture date
SI01M	Andraž	m	2021-02-16 19:15	Selca	-	Subadult (<1 years <2)
SI02M	Jule	m	2021-02-16 21:02	Železniki	-	Adult (>= 2 years)
SI03M	Forti	m	2021-12-20 16:15	Selca	22.2	Adult (>= 2 years)
SI04M	Miro	m	2021-12-21 02:10	Selca	22.2	Adult (>= 2 years)
SI01F	Vesna	f	2021-12-21 16:10	Jošt-Kranj	20.2	Subadult (<1 years <2) or adult (2 years)
SI02F	Frula	f	2021-12-22 04:22	Jošt-Kranj	18.2	Subadult (<1 years <2)
SI03F	Ida	f	2022-01-10 14:11	Bohinjska Bistrica	22.3	Adult (>= 6 years)
SI05M	Matic	m	2022-01-10 16:34	Bohinjska Bistrica	22.7	Adult (>= 6 years)
SI04F	Luna	f	2022-01-10 22:10	Železniki	21.7	Adult (>= 2 years)
SI07M	Matjaž	m	2022-01-12 19:56	Železniki	23.4	Adult (>= 2 years)
SI05F	Gora	f	2022-02-02 23:54	Jošt-Kranj	22.8	Adult (>= 2 years)
SI08M	Tevž	m	2022-02-04 17:29	Bohinjska Bistrica	24.7	Adult (>= 2 years)
SI06F	Tereza	f	2022-03-09 15:08	Bohinjska Bistrica	23.7	Subadult (<1 years <2) or adult (2 years)
SI07F	Zala	f	2023-01-30 19:13	Železniki	18.8	Adult (>= 6 years)
SI09M	Draže	m	2023-01-31 03:35	Selca	19.9	Adult (>= 2 years)
SI10M	Borči	m	2023-02-09 15:55	Železniki	-	Adult (>= 2 years)
SI08F	Maja	f	2023-02-09 21:04	Železniki	-	Subadult (<1 years <2)

4. Monitoring of GPS-collared roe deer

4.1. Monitoring time and survival of individuals

First capture sessions were carried out in February 2021 with 2 male roe deer being equipped with telemetry collar. In the next winter (2021/22) 11 roe deer were equipped and in the third winter (2022/23) further 4 individuals (Fig. 16).

On average, we tracked animals for 50.6 weeks (11.6 months), with a median tracking time amounting to 48.9 weeks. The shortest time we have tracked a collared individual was 6.0 weeks (1.4 month) and the longest was 120.3 weeks (27.7 months; Table 2; Fig. 16).

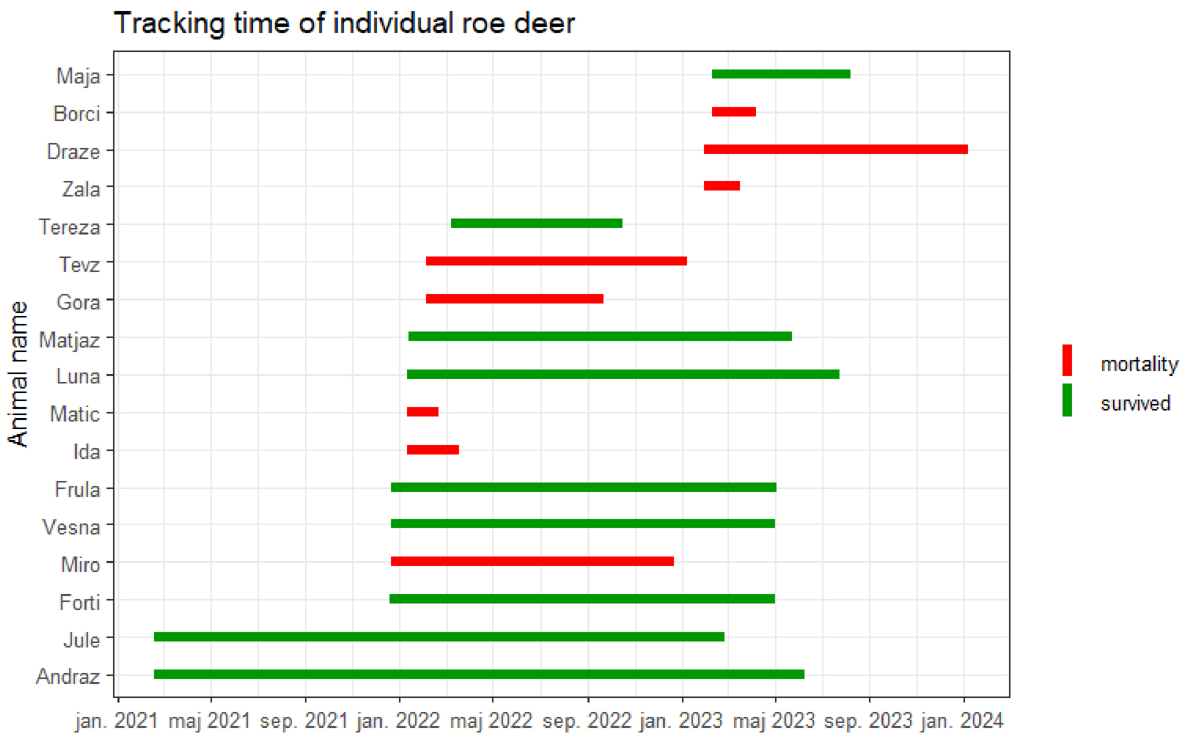


Figure 16: Tracking periods of seventeen collared roe deer from Jelovica plateau, Slovenia, monitored by means of GPS-telemetry from February 2021 till January 2024.

Out of 17 collared individuals, 9 (52.9 %) survived till after the end of monitoring period and 8 (47.1 %) died before the programmed end of deployment (Table 2, Fig. 17).
Average tracking time for those that survived till after the end of monitoring period was 71.9 weeks, and those that died during the monitoring period were tracked for 26.6 weeks on average (Table 2, Fig. 16).

Table 2: Tracking time (in weeks) of seventeen GPS-collared roe deer in the period 2021-2024. Individuals are separated by sex and if they survived the whole monitoring period or not.

	Sex	Animal name	Tracking time [weeks]
Survived after the end of monitoring period	Males	Andraz	120.3
		Jule	105.5
		Forti	71
		Matjaz	71
	Females	Vesna	71
		Frula	71
		Luna	80
		Tereza	31.7
		Maja	25.7
Mortality before the end of monitoring period	Males	Miro	52.4
		Matic	6
		Tevz	48
		Draze	48.9
		Borci	8.1
	Females	Ida	9.6
		Gora	32.9
		Zala	6.6

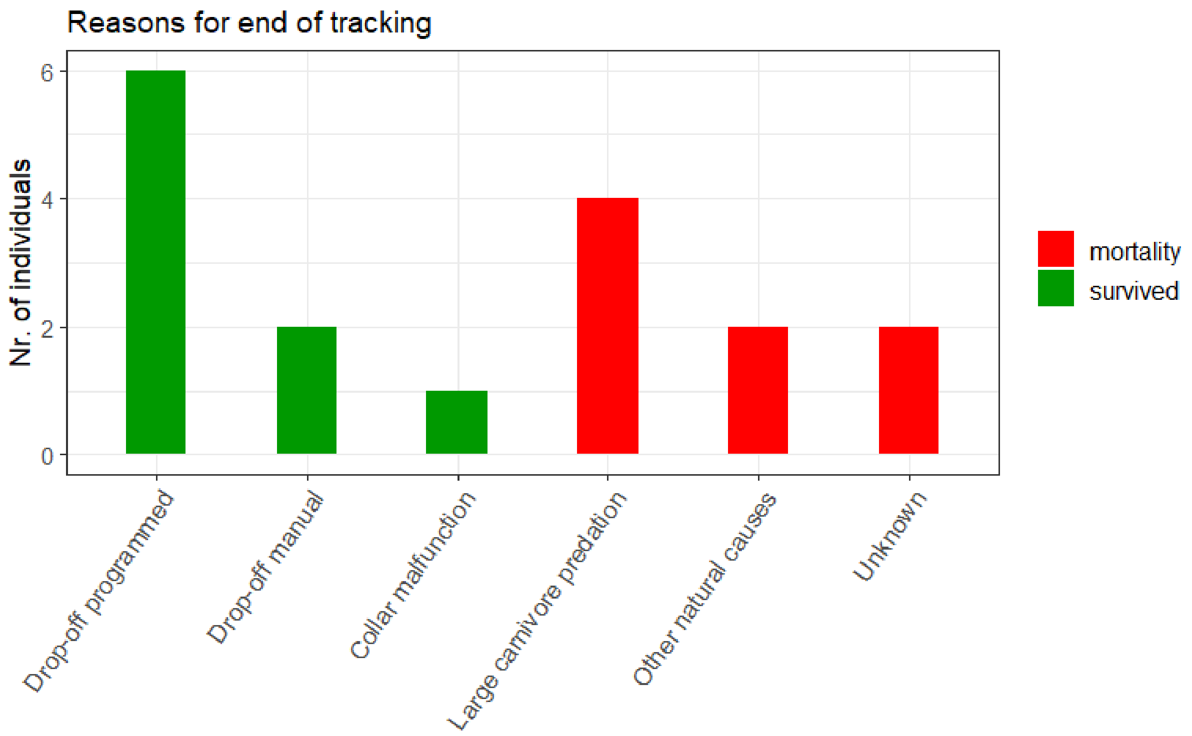


Figure 17: Count of roe deer individuals that survived the whole monitoring period (in green; see text on pg. 24 for explanation of categories) and those that died before the end of monitoring period (in red) with specified reasons for monitoring termination. Important to note, hunting cull is otherwise the primary cause of roe deer mortality in the area, but hunters were asked to spare the marked animals for the purpose of the study.

Out of 8 mortalities, 4 individuals were predated by a large carnivore (lynx or wolf; 23.5 %), 2 died from other natural causes (11.8 %; disease and dying under a cliff) and 2 animals (11.8 %) finished with an unknown fate (only their collars were recuperated on the ground; in one case also its ear tags; Figs. 17 and 18).
Out of 9 survivors (Fig. 17 in green), six (35.3 %) terminated their deployment period by means of pre-programmed automatic drop-off after 70 to 80 weeks of deployment (Photo 19) and 3 (17.6 %) experienced hard-ware or soft-ware malfunctions (for 2 of them we manually fired a drop-off system to release their collars, and for the third one we lost track of the animal; all three were Vectronic collars).
Importantly to note, hunters were asked to spare marked animals (i.e., not to cull them) whenever possible, for the purpose of executing the study. Otherwise, hunting cull is the most frequent cause of roe deer mortality in the area.

Photo 18: Three examples of collared roe deer mortality during the monitoring time: predation by lynx (upper left), predation by wolf (upper right) and mortality due to other, undefined natural causes (lower left; buck was found at the bottom of a deep cliff).

Photo 19: Two examples of retrieval of automatically opened collar on the ground after the end of monitoring period, when drop-off system enabled collar to open and be shaken off by the roe deer.

4.2. GPS locations

GPS schedule for each collared roe deer was not uniform during the whole monitoring period. Before the common protocol among all study areas was applied, we programmed fixes every 4 hours, afterwards the GPS locating took place every 6 hours. We applied a more frequent GPS schedule during the periods of potential highest vulnerability of roe deer to predation risk, in order to track precise movements during such periods. Thus, in 2021 roe deer were located every 30 minutes for 6 consecutive weeks in winter period (January/ February – vulnerability to natural predators due to winter conditions) and during the peak of hunting season in summer period (July/ August for males and August/ September for females – peak of number of hunted roe deer in the study area hunting grounds). From summer 2022 onward, we harmonized this intensive GPS schedule with the Italian study area to fixes every 15 minutes for 4 consecutive weeks (same periods as above).

Altogether, we collected 81.367 fixes from 12 animals with Vectronic GPS-collars. The highest number of collected fixes for a single animal was 10.983, the lowest was 1.743 (average amounting to 6.781 and median being 7.086).
5 animals were collared with Lotek GPS-collars and from them we collected 27.502 fixes altogether. The animal, monitored for the longest period, provided 10.507 fixes, the lowest number of fixes was 2.117 (average 5.500 fixes, median 4.494 fixes).

Data from Vectronic collars contained very few missing locations, altogether only 118 (0,15 %). The highest number of empty fixes from a single animal was 64 and the lowest 0, with the average and median amounting to 10 and 3 fixes, respectively.

On the other hand, Lotek data contained a large number of empty fixes, altogether 3.899 (14,2 %). The highest number of empty fixes from a single animal was 1.394 and the lowest 74 (average 780 and median 748 of empty fixes).

After data cleaning process, when we removed fixes without location, fixes with the "DOP" variable equal to or higher than 3, and fixes with less than 3 satellites (in this order), 80.280 fixes from Vectronic collars and 15.895 fixes from Lotek collars remained for further calculations and analyses (Figs. 20a and 20b).

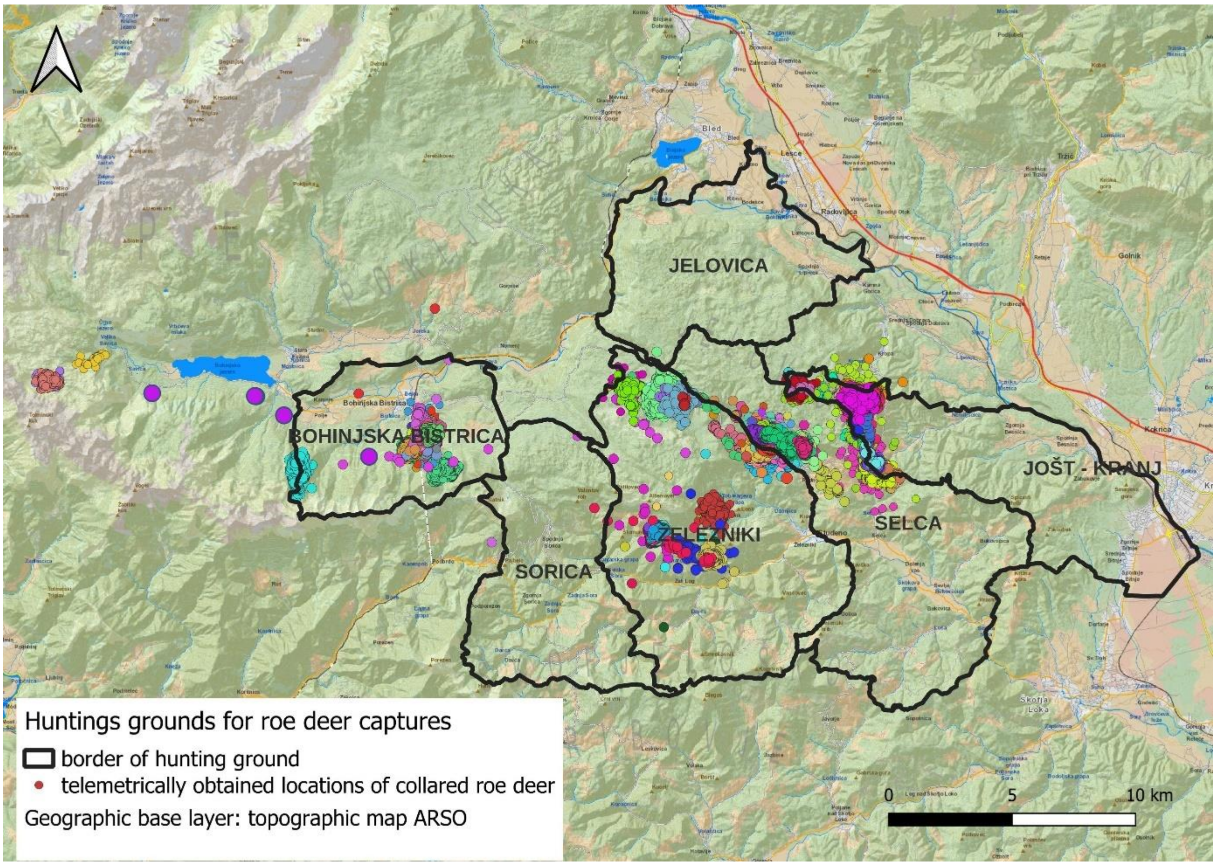


Figure 20a: Julian Alps in north-west Slovenia with 6 hunting grounds marked as polygons (black lines), where roe deer captures took place. Coloured points are collected GPS locations of collared roe deer.

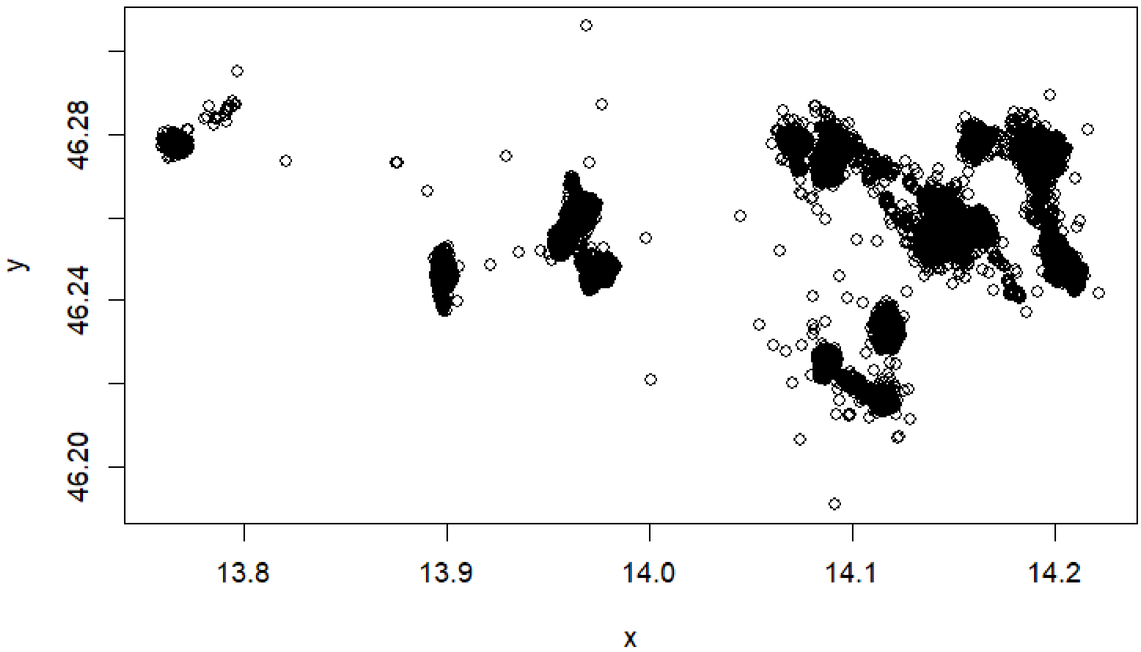


Figure 20b: Plot of coordinates of all GPS fixes of 17 GPS-collared roe deer in Slovenian study area. Coordinates are labelled in EPSG 4326 (WGS84) coordinate system.

4.2.1. Bounding box of roe deer GPS locations

After the data cleaning process, remaining roe deer GPS locations encompassed a bounding box of 455 km^2 (see Fig. 20c for reference).

Available range of altitude within the bounding box ranged between 440 m a.s.l. (pre-alpine valleys encircling Jelovica plateau in the east and south) and 2086 m (Mount Tolminski Kuk on the west side of the study area). Roe deer GPS points were located at the minimum of 495 m a.s.l. and at the maximum of 1576 m (altitude of GPS points was extracted from the digital relief model). Average altitude of roe deer GPS points was 920 m (median 885 m).

4.2.2. Land use and habitat use

For the land use calculations, we enlarged the bounding box for a buffer of 1500 m (the most frequently exhibited approximate distance between roe deer seasonal home ranges), acquiring an area of 607 km^2 (Fig. 20c). For this area we calculated land use percentages from the GIS layer of Ministry of Agriculture, Forestry and Food from 2024 (*Inventory of actual agricultural and forestry land use, 2024*). The area was almost in its entirety forested; forests covered 80% of the area. Meadows represented 11% of the area, open areas in higher altitudes 4 %, while urban areas only 2 %.

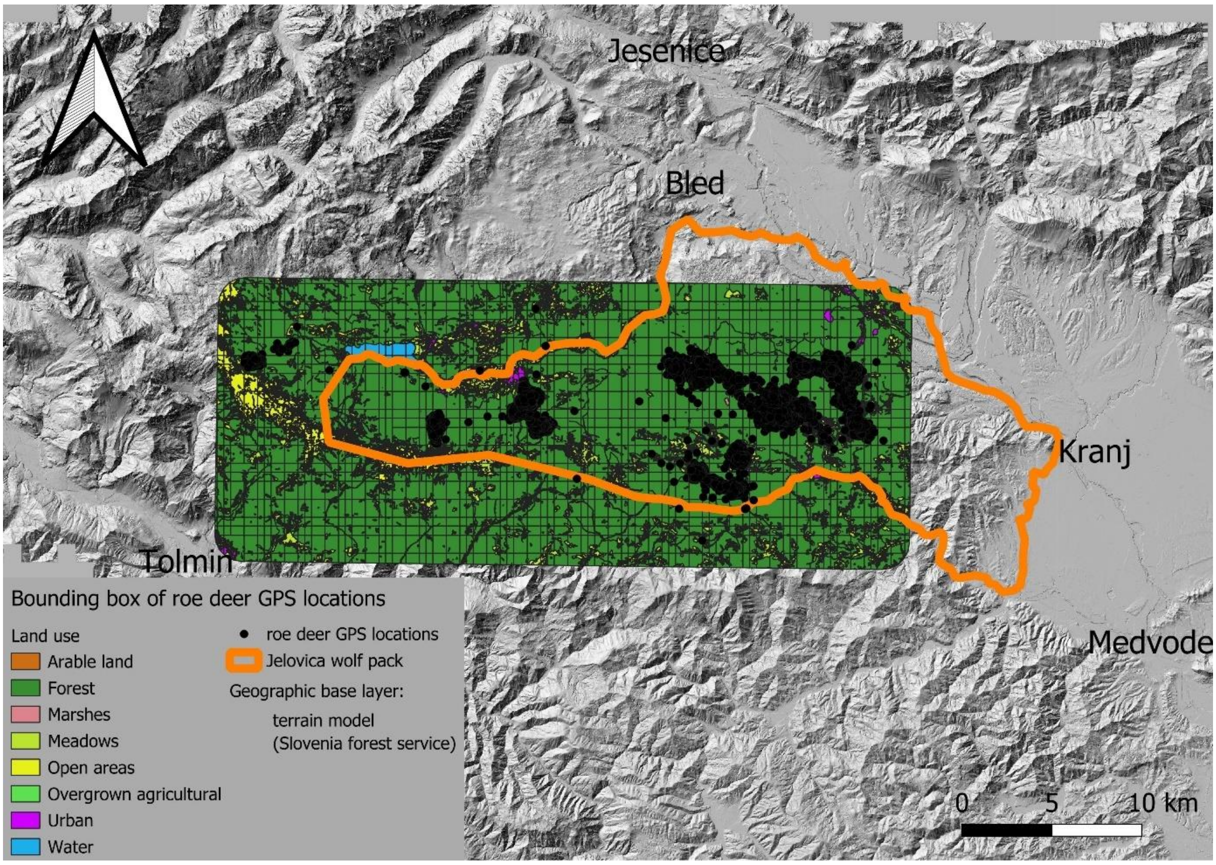


Figure 20c: North-west part of Slovenia, encompassing the entire study area as described initially in project Action A4, but illustrating final bounding box (green rectangle) of all roe deer GPS locations (black dots), coloured by the land use type (legend on the map). An approximated outline of the "Jelovica" wolf pack territory (orange polygon) is added for clarity.

When inspecting habitat use of roe deer (attributing land use to roe deer GPS locations both with QGIS "Point sampling tool" and R package "sf"), we found out that most of the roe deer fix were located in the forest. 84 % of GPS locations were in the forest, 12 % were in the meadows, 2 % in the overgrown/ abandoned agricultural areas and 1 % in the agricultural areas (Fig. 20d).

When preliminarily checking, if such a distribution of fixes held true for all individuals or if there were rather certain individuals that would spend the majority of time out of the forest, we found out that almost all individuals predominantly used forest and that almost half of the individuals were never located in agricultural or urban areas (Fig. 20e). To further inspect this issue, we need to compare the space use (occurrence of fix in different land use types) of individuals during their periods of intensive tracking (15-min or 30-min fix rate) to their periods with 4- or 6-hour fix rate. In such a way we will get a better insight into the validity of the above-mentioned habitat use on the basis of fix percentages, given that we did not use a "roll-over" rule in GPS schedules (this would otherwise enable to schedule fixes at different hours of the day).

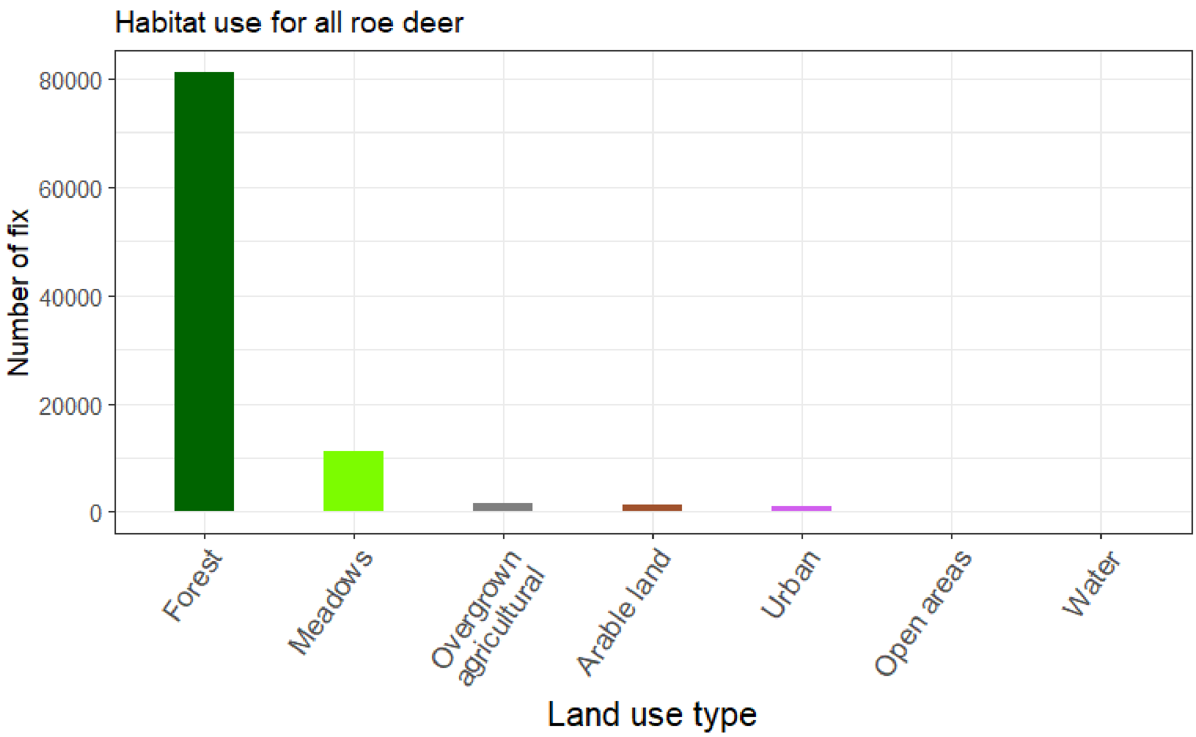


Figure 20d: Occurrence of roe deer fix in different "land use" types (the latter calculated on the base of "*Inventory of actual agricultural and forestry land use 2024*" of Ministry of Agriculture, Forestry and Food).

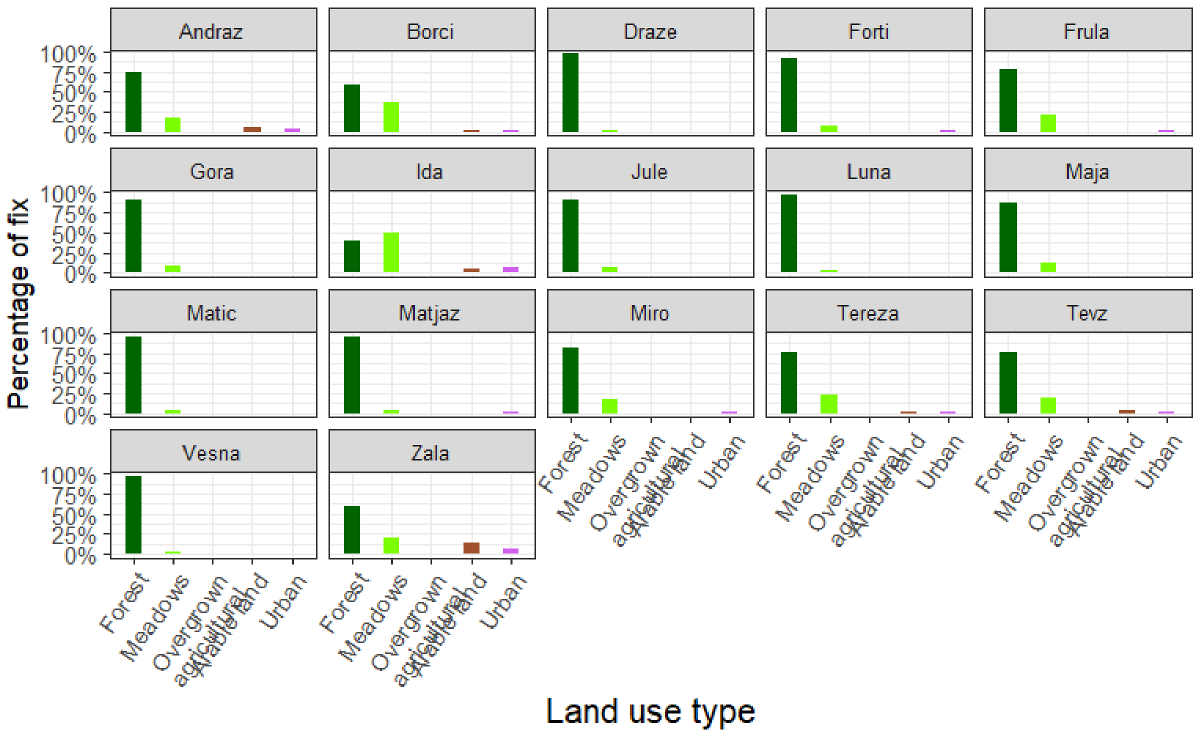


Figure 20e: Percentage of fix for individual animals in different land use types.

4.3. Spatial behaviour

4.3.1. Partial migration

The most obvious feature of our sample's spatial behaviour were pronounced seasonal movements (Fig. 21 and 22), that other study areas within C.3 action of LWA EU project (see "Local reports" from Italy and France for Action C.3) did not record or to a much lesser degree. Partial migration concept that is nowadays widely recognised in a vast array of species, also ungulates, describes the cases when one part of a population is migratory, while the other remains resident. It supports the view of a migration as a continuous phenomenon, where the "resident" and "migratory" tactics are merely the end points of a behavioural gradient. Viewed as such, migration is a behavioural continuum with one-trip migration and residence as its end points, and commuting and multi-trip migration with short residence times in seasonal ranges being the intermediate tactics (Cagnacci et al. 2011; Cagnacci et al. 2015).

We identified different types of extra-territorial movements or movements outside the stable home ranges: seasonal migration from winter to summer home ranges and vice-versa by migratory individuals, excursions by males in late winter period or at the beginning of territory-establishment phase, summer excursions by females and males (Figs. 25 and 29), explorative movements before onset of the migratory phase, movements to the stable home range after capturing and extra-seasonal movement between seasonal home ranges.

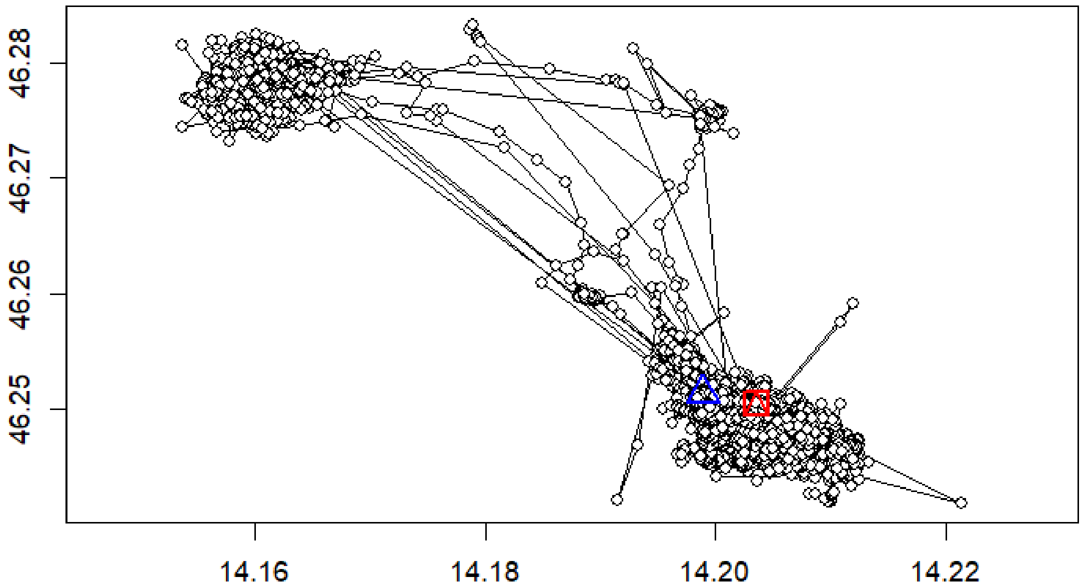


Figure 21: Example of a movement trajectory of a migratory roe deer (case of female "Frula") during its whole monitoring period (December 2021 – May 2023). When migrating from winter home range (south-east of the plot) to summer home range (north-west of the plot) in spring and vice-versa in early winter, the female underwent several, more or less direct trips "back and forth", before settling on the following seasonal home range.
*Longitude of the fixes is plotted on the x axis and latitude on the y axis; coordinates are labelled in EPSG 4326 (WGS84) coordinate system.

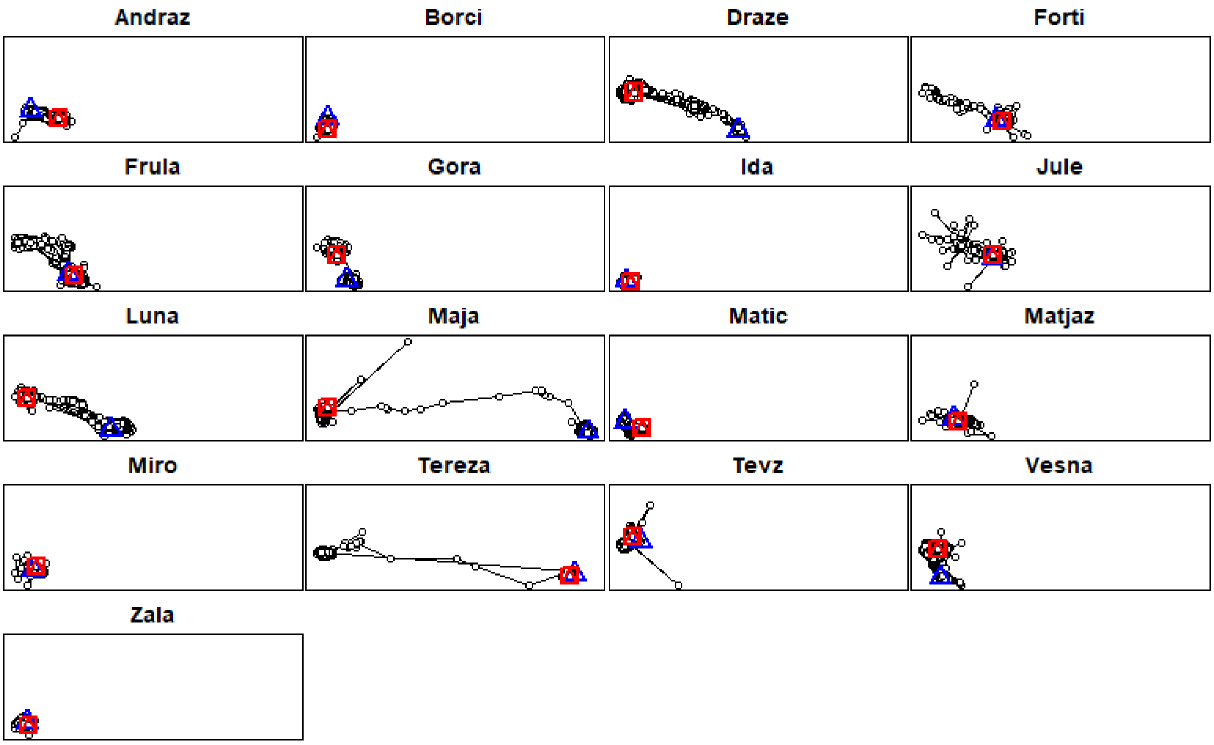


Figure 22: A schematic illustration of 17 individual roe deer movement trajectories (movement in space and time) during their complete monitoring periods.

Out of 17 roe deer, four were monitored for too short period to observe their seasonal home range patterns throughout the year. Out of 13, which were monitored for long enough to observe their seasonal spatial pattern, only three were "residents" (all of them males) and other 10 were "migratory" (6 females, 4 males); marked brown and light-blue, respectively, on Figures 23 and 24.

As "migratory" we described those roe deer, which exhibited such shifts in their space use, that there was almost no overlap between their respective summer and winter home ranges. As "resident" we marked those individuals, that stayed at the same place during the entire year, meaning that their respective annual or seasonal home ranges overlapped substantially.

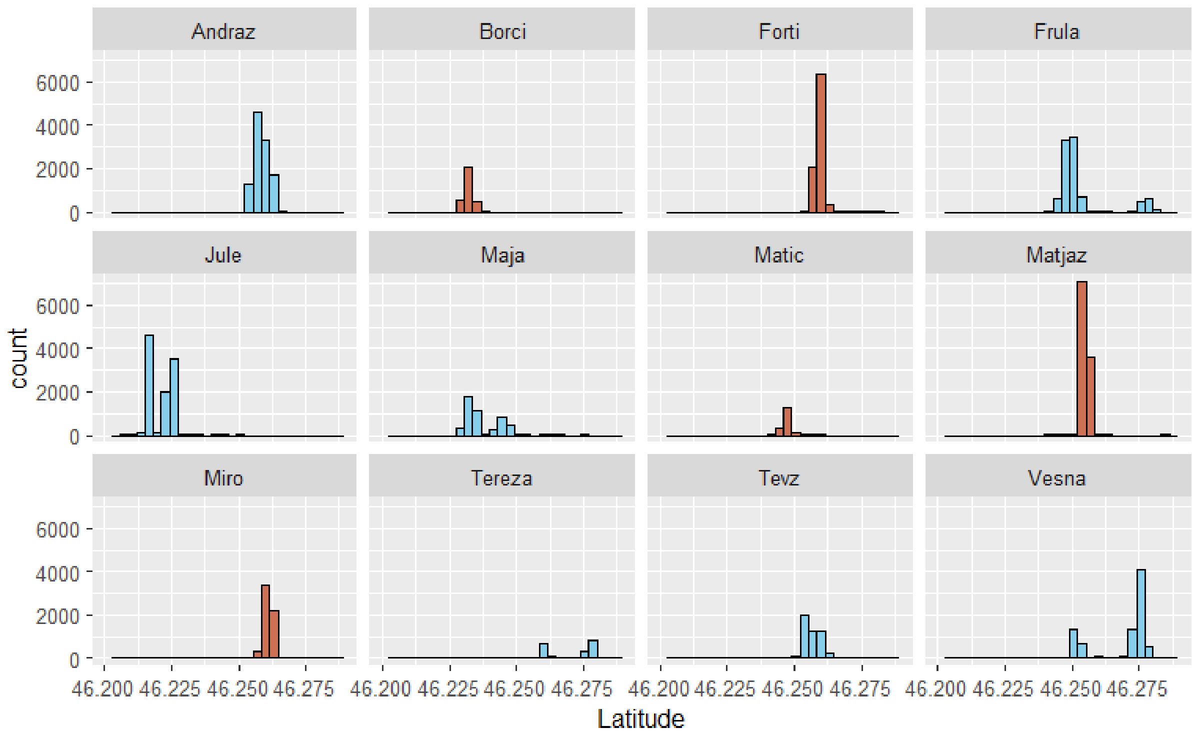


Figure 23: Frequency of GPS fixes distribution in space (referring to latitude) for roe deer, collared with Vectronic collars. In blue are marked “migratory” individuals (see text for explanation) and in brown “resident” individuals (but note that two of the latter – Borči and Matic – were monitored for too short time to define their annual spatial patterns).

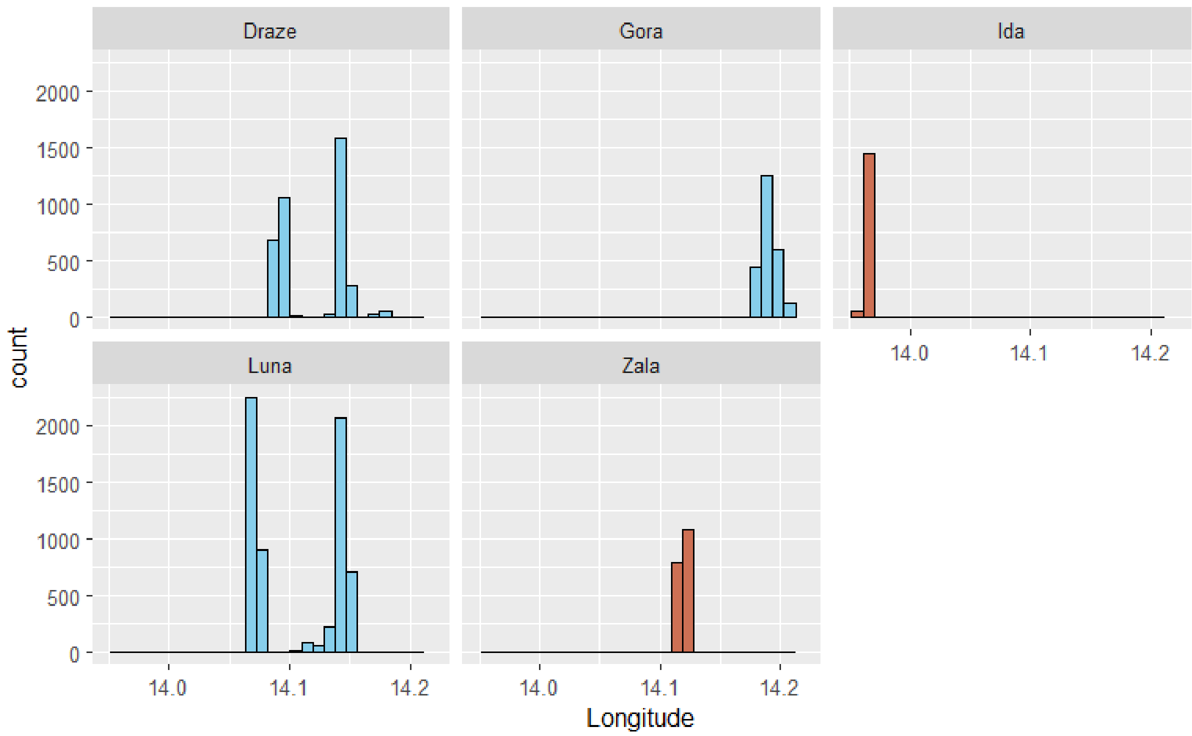


Figure 24: Frequency of GPS fixes distribution in space (referring to longitude) for roe deer, collared with Lotek collars. In blue are marked “migratory” individuals (see text for explanation) and in brown the two individuals – Ida and Zala – that were monitored for too short time to define their annual spatial patterns.

Migratory animals differed to a large degree in the pattern of their migratory behaviour between seasonal home ranges, as well as the same individual differed in its migratory pattern among different years or seasons (examples Figs. 28 and 29). Some individuals took a fast and a direct path for transition to other seasonal home range, while the others underwent a shorter or longer transition period (from few weeks to few months), in which they were moving regularly and frequently (back and forth) in the area between their two seasonal home ranges and using both seasonal home ranges before finally settling on a stable summer or winter home range. The third pattern was a "mixture" of previous two: a roe deer travelled more directly and straight between both seasonal home ranges, but repeated the journeys several times before abandoning previous seasonal home range completely (example Fig. 21). Cagnacci et al. (2011) showed that performing numerous trips between winter and summer ranges vs. single, one-hop trip depended on factors influencing the costs of movement, in their case on between-range distance, slope and habitat openness.

On the other hand, roe deer express very high site fidelity, which in our study held true both for residents - occupying the same home range between the years - and for migratory individuals, expressing very high site fidelity to their seasonal home ranges, returning to roughly the same area in respective seasons (see Fig. 22 for illustration).

* This holds true for those animals, which we tracked for longer than one year, so we could verify their migration cycles (or residency) with their actual GPS locations (refer to Fig. 16 on page 22). However, several indices supported our post hoc assumption that we neither had cases of dispersal among our monitored roe deer (also, we didn't collar fawns) neither that the same animal could be migratory one year and resident the other. Such indices included hunters' field observations of marked individuals or hunters' camera trap imagery, while importantly accounting for both, date and location of the observation (e.g., in some cases also absence of observations in certain area during certain timeframe was considered helpful indices, as sometimes the animal would be expected to be observed or camera-trapped, if still present in the area).

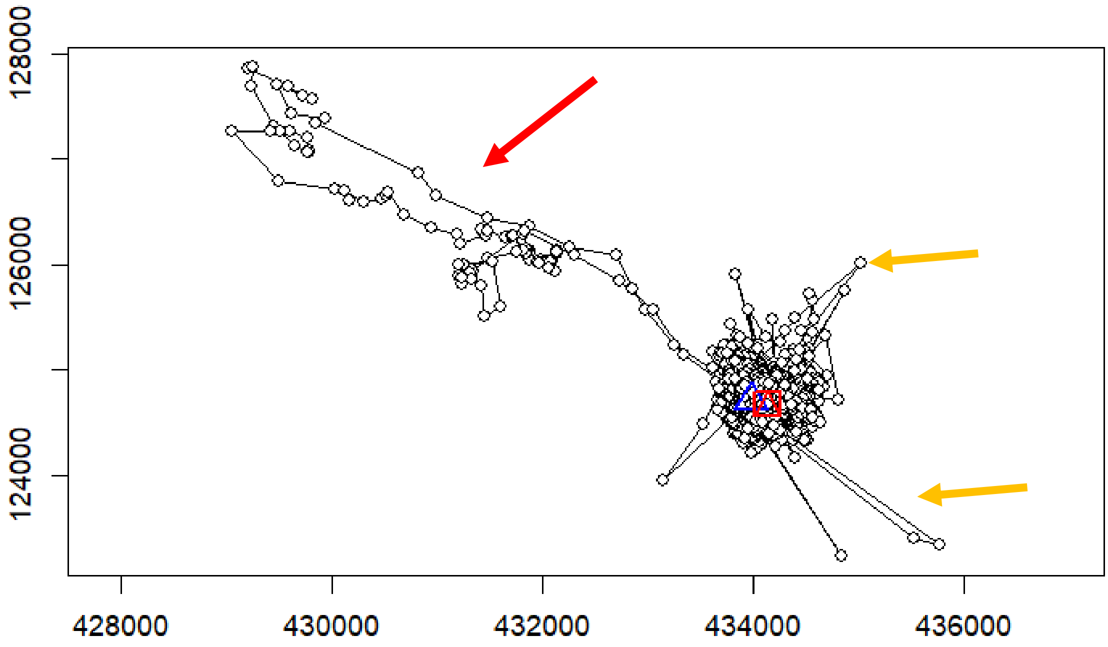


Figure 25: Movement trajectory of a resident male "Forti", whose seasonal home ranges overlapped substantially within and between years (his resident home range is on the right side of the plot). His quick excursions during the reproductive period (July/ August) are clearly recognisable on the left side of the plot (red arrow) and as separate points to the south and north of the home range (orange arrows).
*Longitude of the fixes is plotted on the x axis and latitude on the y axis; coordinates are labelled in EPSG 3794 coordinate system.

4.3.2. Altitudinal partial migration

Most, if not all, of the migratory animals expressed altitudinal migratory paths (Figs. 26 and 27), meaning that they endured the winters in lower altitudes (700-800 m a.s.l.), under the edge of the alpine plateau, and thus closer to human settlements. During the summer, they moved to higher altitudes, usually to the plateau (1000 – 1200 m a.s.l. in average). The transition period from winter to summer home ranges was usually February – April, although two females, that migrated the longest, did so in the period around 1st May (of different years). The transition period from summer to winter home ranges usually took place in November (or from October to December).

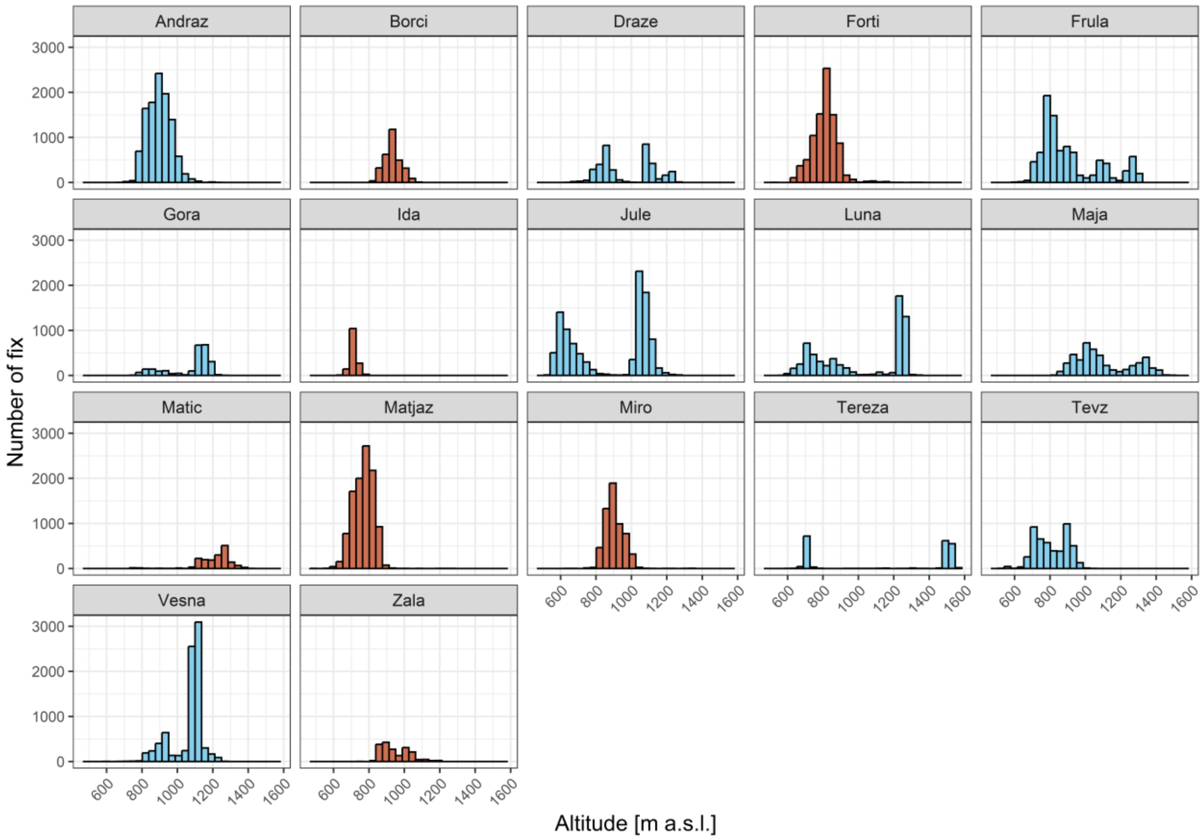


Figure 26: Distribution of altitude of GPS fixes for marked roe deer. The colours - blue for "migratory" and brown for "resident" individuals – are retained the same as in Figures 23 and 24. * Altitude of fixes was extracted from the digital relief model.

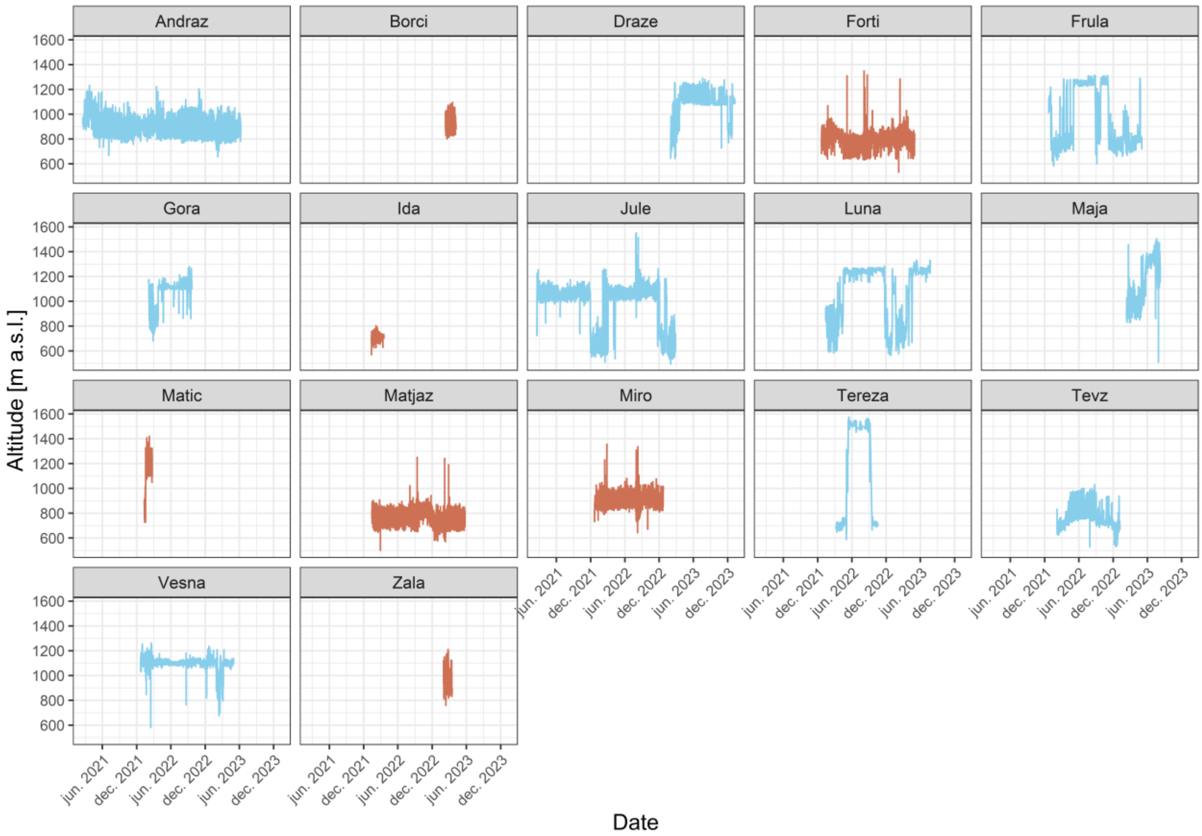


Figure 27: Plots of altitudinal movements for individual roe deer in time. The colours (blue for "migratory" and brown for "resident" individuals) are retained the same as in Figures 23 and 24; altitude of fixes was extracted from the digital relief model. Almost all migratory roe deer (blue plots) migrated altitudinally, except buck "Andraž", who primarily migrated east-west.

Another interesting feature while observing their seasonal migratory movements was something, that speculatively might be connected to a prompt response to an unusually late start of the winter in the season 2022/23. In Slovenia, December 2022 was unusually dry and warm, with the first abundant snow arriving as late as mid January. High plateau Jelovica was no exception and was snow-free till mid January. Some roe deer, that already showed very late onset of their autumn transition downwards to winter home ranges under the edge of the plateau (some as late as December), suddenly headed back to higher altitudes at the end of December/ beginning of January.

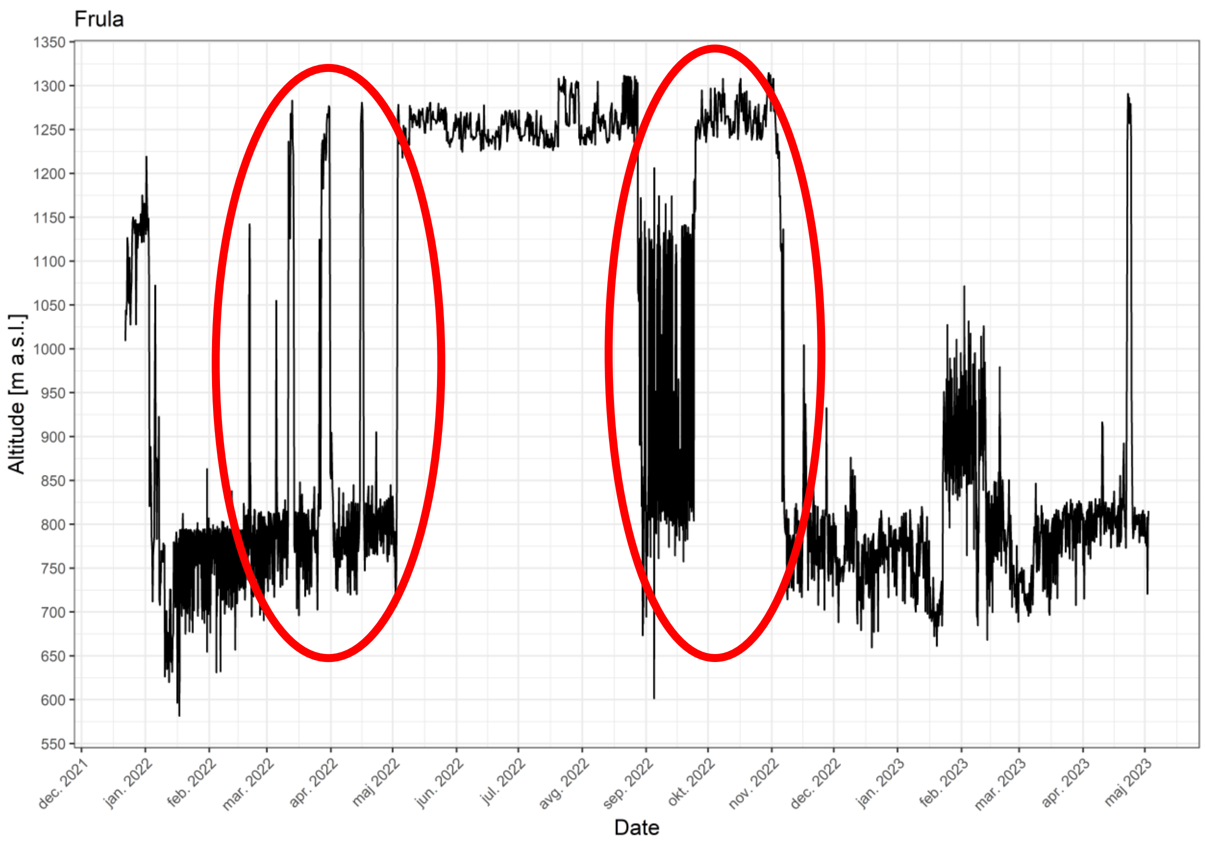


Figure 28: Altitudinal movement in time of a female "Frula" as an example of individual, whose transition periods between seasonal home ranges took several months, when the individual was moving back and forth (marked with red ellipses) between the winter (lower altitude) and summer home range (higher altitude).

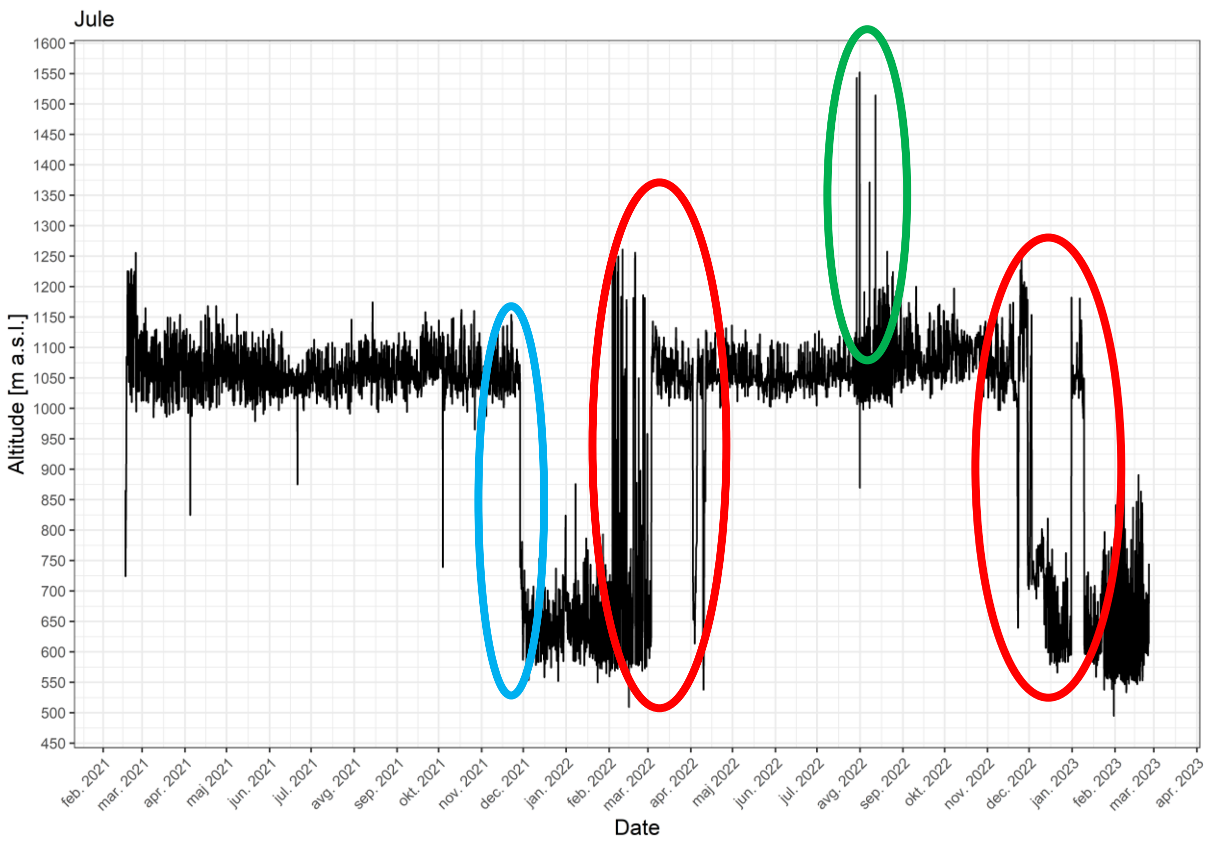


Figure 29: Altitudinal movement in time of a male "Jule" as an example of individual, which sometimes took a fast and one-time-only path for transition to other seasonal home range (at the end of November 2021 - from summer to winter home range; marked with blue ellipse), while the transitions in 2022 took him several weeks or months, before finally settling in one area only (spring 2022 and winter 2022/23; marked with red ellipses). This graph also illustrates some excursions outside of his usual summer home range in July and August 2022, which might had been attributed to summer reproductive excursions (marked with green ellipse).

4.3.3. Quantifying home ranges

Estimating the home range is a main step for many telemetry studies. Different estimators are suitable to answer different research questions related to animal space use.

Estimating home range sizes for (partially) migrating populations (or in our case samples) with high inter- and intra-individual variability in timing of migration, seasonal residence time, migration distance and migratory tactics (one-hop vs. multiple trips for varying periods of time) needs additional caution and should be preferably based on specific research questions (as opposed to pure descriptive purposes).

A specific research question enables us to appropriately choose among the many commonly used methods, to provide correct time frame of the data collected and to appropriately subset the data in accordance to a specific prediction. In such case, the spatial calculations of an area occupied by an individual in certain time frame can be meaningful and biologically or management-wise justifiable. E.g., if animals may be monitored in nonstationary phases of their life cycle, over too short time spans or with inadequate fix rate, the resulting inferences can lead to imprecise and incomplete insights (like missing the site fidelity. extra-territorial excursions, complete area during the entire life cycle…). In many cases, home range analysis may not be the appropriate analytical method, whereas movement models may be more suitable. Often movement analyses are needed prior to calculating home range sizes, e.g., net squared displacement, Brownian Bridge methods, step lengths between different types of spatial movements, density utilization estimates (kernels) etc.

As in our case, simple uniform seasonal or annual home range sizes could not be informative, as the results either would not be representative of the reality or not comparable between the individuals in overall, due to different spatial and temporal patterns of transient migratory periods. However, concerning the communication with hunters it might be of key importance to meet their expectations and inform them about the home range estimates.

To illustrate this issue, we can take a look at an example first. The already mentioned adult buck "Jule" exhibited a spatial pattern of a migrating male, defending his summer territory on an altitude of approximately 1000 m, but aggregating in a group with other roe deer (imagery from camera-traps) on a winter home range on an altitude of around 700 m (Fig. 30). He was travelling between these two seasonal home ranges in the periods February-April and November-December. But not only, he was taking excursions outside his summer territory, mostly in spring and in summer (end July/ 1st half of August).
When calculating his home range with all fixes (without subseting), MCP 95% method estimates his complete area to 392 ha and Kernel DE 95% method to half less – 197 ha, because it of course already attributed his occupied area to two distinct polygons – summer and winter area (Fig. 31). Kernel DE 90%, for example, estimated the home range size of 77 ha for summer polygon and 73 ha for the winter polygon. Centroids between these two seasonal home ranges were 2,4 km distant.
Finally, when subseting his GPS data into temporally distinctive periods, thus distinguishing his residence times on spatially distinctive areas, extra-territorial excursions and transitional periods on his migration area, we estimated the size of his summer territories to an average of 26 ha and winter home ranges to an average of 16 ha with MCP 95% or alternatively to 27 ha for summer and 16 ha for winter averages with Kernel DE 95%. Thus, excluding spring and autumn transition periods and extra-territorial excursions brought us to an estimate of his residence areas. However, to complete his annual migratory cycle the buck needed more than 43 ha of space, as migratory paths and extra-territorial excursions were a crucial part of his life-cycle, though lasting for shorter time than residence periods. For instance, another buck, "Andraž", who migrated for an approximately the same/ comparable distance between summer and winter ranges as "Jule" and had a comparable size of residence ranges (24 ha for summer and 25 ha for winter ranges on average; Kernel 95%), utilised an area of 107 ha during his autumn 2022 transitional period and an area of 130 ha during his spring 2023 transitional period (Kernel 95%; these two transitional periods lasted from 7 to 8 weeks each).

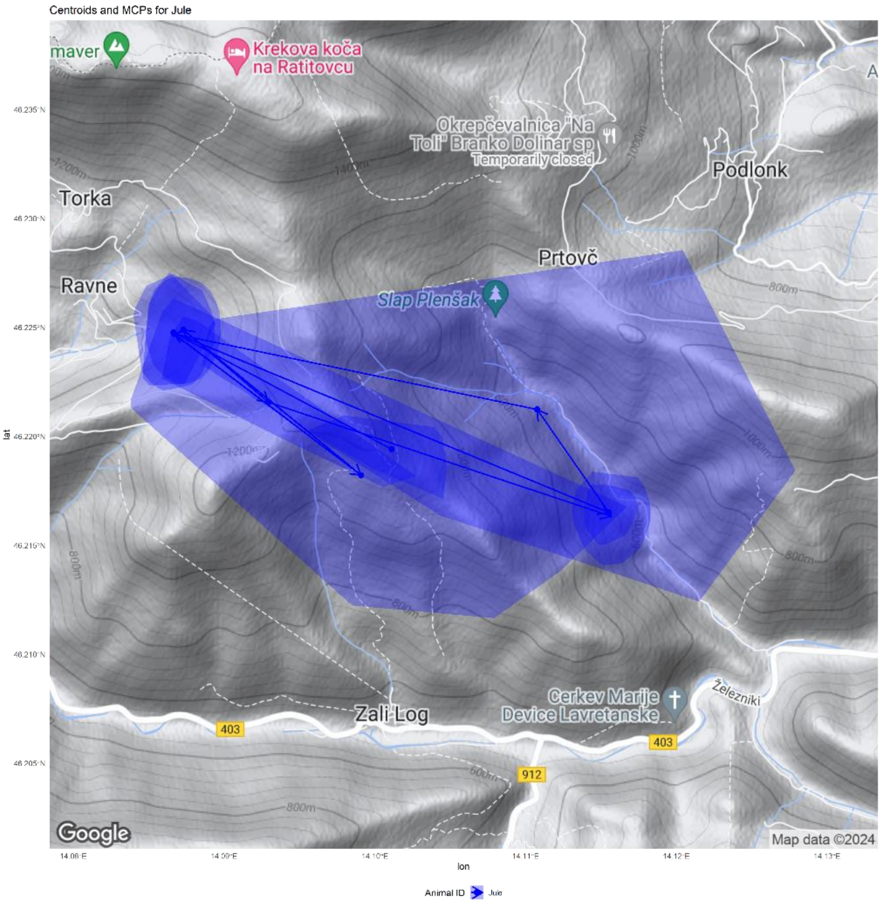


Figure 30: Illustration of MCP 95% polygons for home range size of buck's "Jule" temporally distinctive periods in his annual spatial (migratory/ transitional and residence) cycle. Darker blue circular polygons on the right side of the map are his winter home ranges (2021/22 and 2022/23), and on the opposite side on the left are his summer territories (2021 and 2022). All the other polygons in-between represent his spring and autumn transitional periods, when he was moving back and forth between the two seasonal ranges. Centroids between summer and winter home ranges are 2,4 km apart.

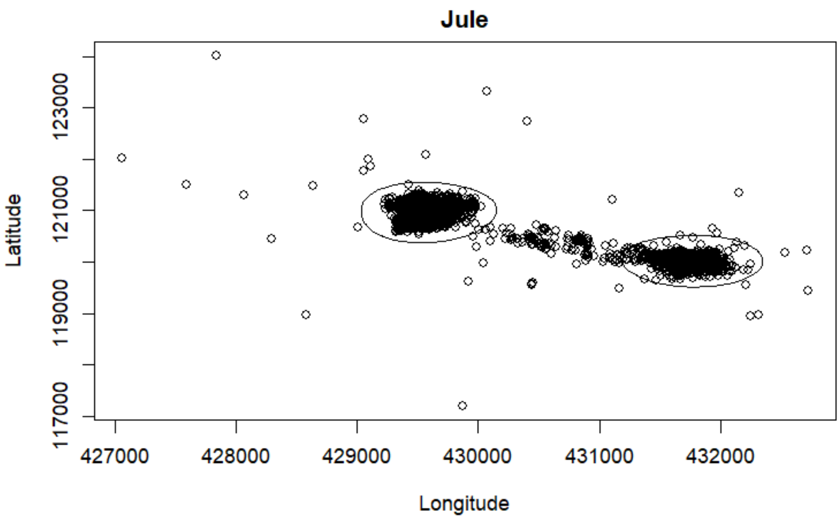


Figure 31: Illustration of Kernel DE 95% polygons for estimating the home range size of buck "Jule" on all fixes. The estimate still inflated the summer and winter areas due to his extra-territorial excursions and the transient migratory area between the summer and winter home ranges.

Thus, when plotting the complete utilised area by collared individuals, we get by expectations too inflated estimates for migratory individuals. Inflating is faster proportionately with the migratory distance and number of other extra-territorial fixes, to the degree that for the farthest migrating individuals such estimates are completely wrong, both with the MCP and Kernel DE estimate (see examples on figures from 32 to 35).

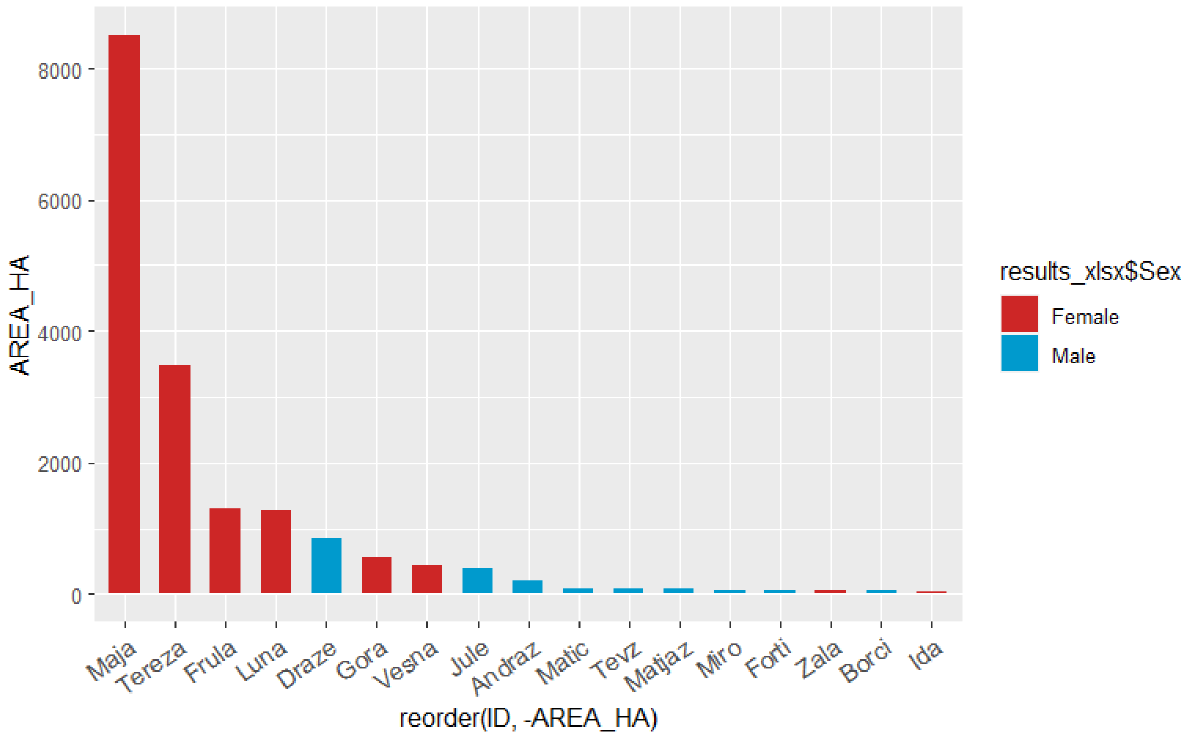


Figure 32: Calculation of “home range” sizes with MCP 95% method with included all fixes (regardless of the transient or resident phase). Bars are coloured according to sex (females red, males blue). On the left side of the plot there are the migratory individuals, for which the estimate is wrong, and on the right side there are the stationary ones or those that were tracked for short periods of time only (see the close-up view for those on Fig. 33).

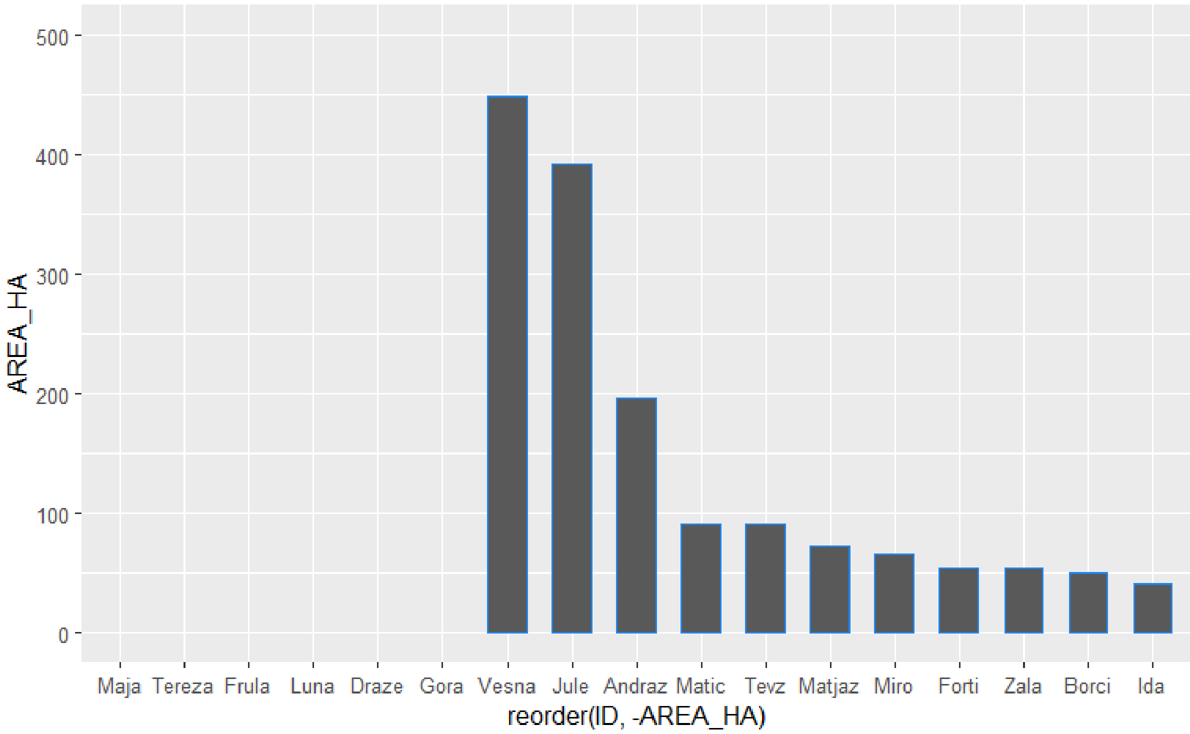


Figure 33: A close-up view of the home range size axis for “home range” sizes with MCP 95% method with included all fixes. The last six animals on the y axis are either resident ones or those that were tracked for a short period only. The average home range size of the resident three males (Matjaž, Miro and Forti) with MCP 95% is 64 ha (± 9 SD).

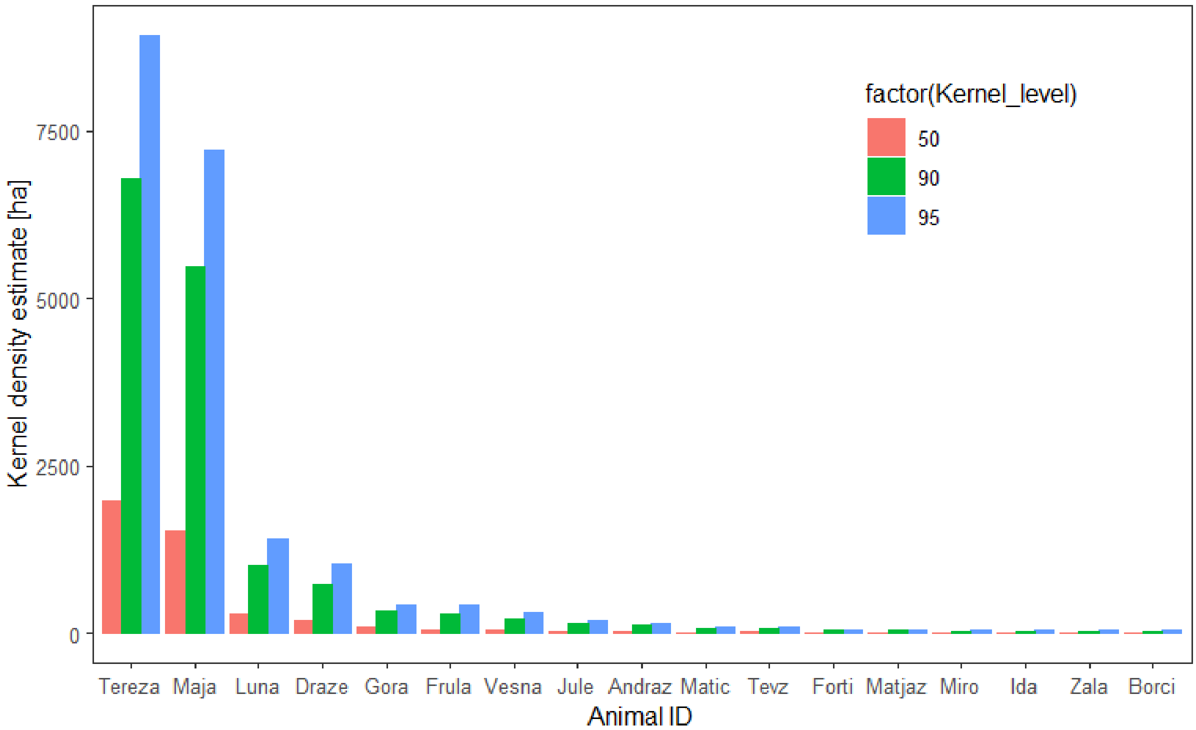


Figure 34: Calculation of “home range” sizes with Kernel DE “href” method (blue bars Kernel 95%, green bars Kernel 90%, red bars Kernel 50%) with included all fixes (regardless of the transient or resident phase). On the left side of the plot there are the migratory individuals, for which the

estimates are wrong, and on the right side there are the stationary ones or those that were tracked for a short period only (see the close-up view on Fig. 35).

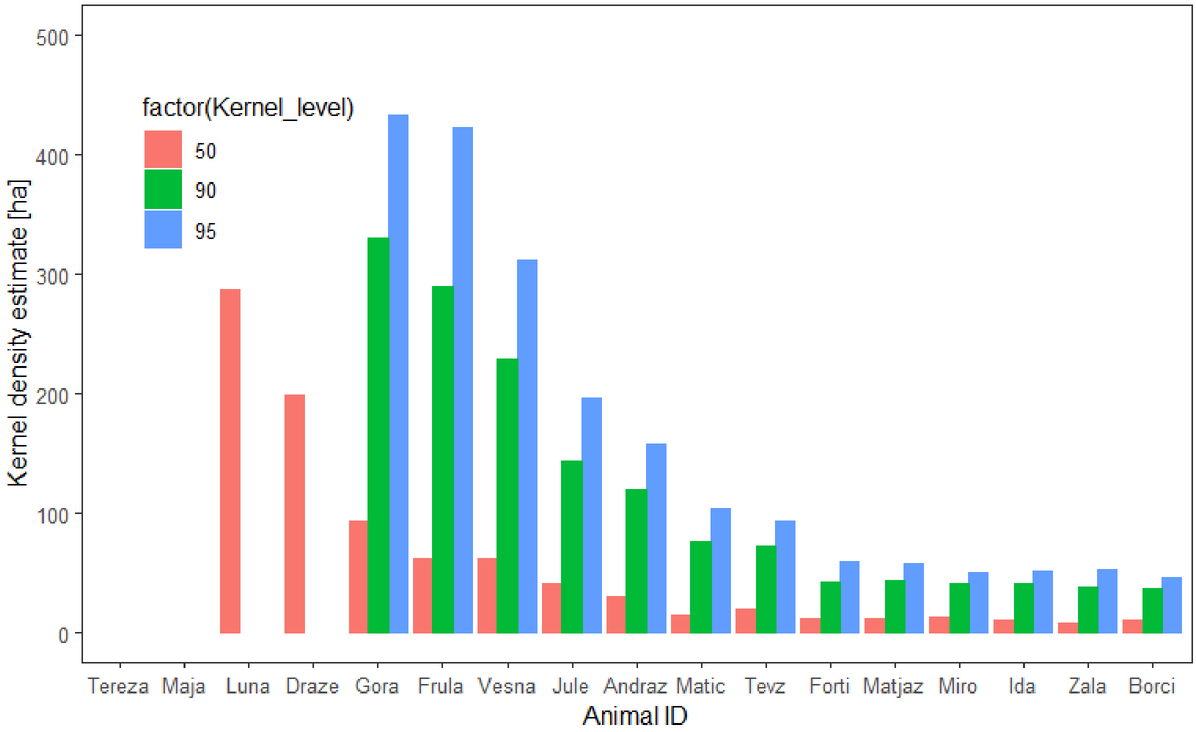


Figure 35: A close-up view of the home range size axis for "home range" sizes with Kernel DE "href" method (blue bars Kernel 95%, green bars Kernel 90%, red bars Kernel 50%) with included all fixes. The last six animals on the y axis are either resident ones or those that were tracked for a short period only. The average home range size of the resident three males (Matjaž, Miro and Forti) with Kernel 95% is 56 ha (± 5 SD).

This highlights the importance of movement analysis prior to home range size estimates. The descriptives should thus be individual-based, taking into account individual variability in space use, as well as its temporal variability of spatial patterns.

For this reason, we handled the data on an individual basis to subset them manually to individually attributed time periods, like stable residence, transitory/ migration periods, extra-territorial excursions and paths between ranges. To illustrate one example, Fig. 36 shows, how acquired fixes of a migratory male "Andraž", collected from February 2021 to June 2023, were divided into 11 subsequent temporal periods, each one characterised with what we thought was a uniform and distinctive spatial pattern. He migrated on an approximate distance 1.8 km between the summer and winter ranges, with his spring and autumn transition phases of different onset, different duration and different spatial patterns. For instance, the movement trajectory of a migratory female "Frula" from Fig. 21 on page 30 was divided into 16 subsequent temporal periods (or 10, if we excluded the shortest excursions outside her stable ranges). This individual-based subseting into spatially distinct temporal periods will be upgraded with appropriate movement analysis (Brownian bridges, net squared displacement, step lengths for intensive sampling…).

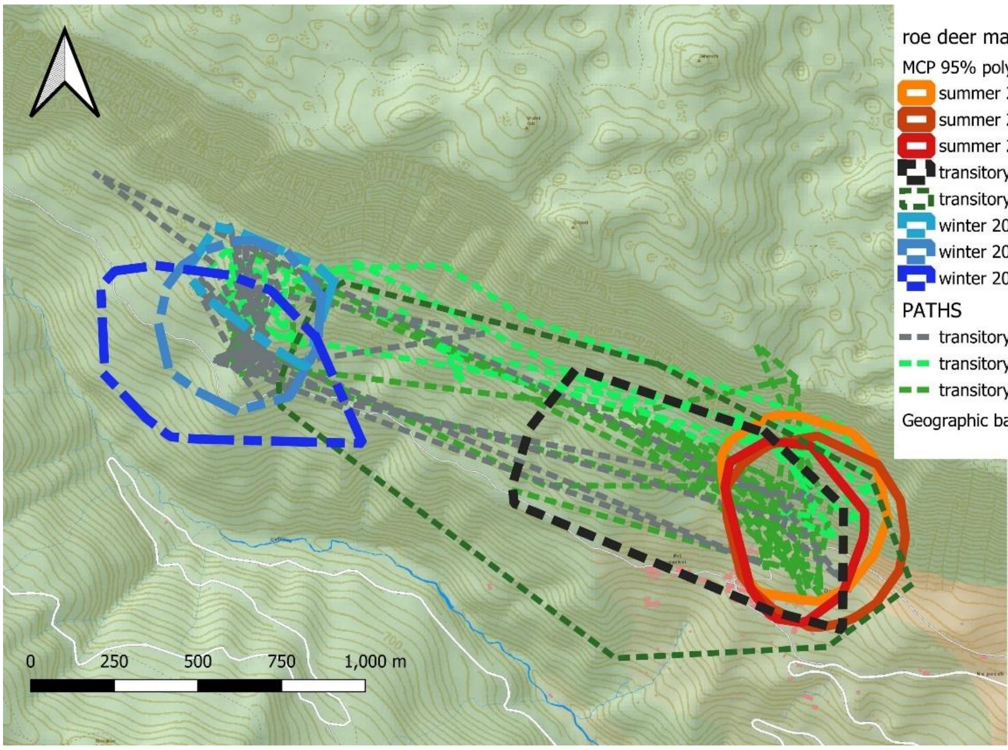


Figure 36: Illustration of consecutive temporal periods with consistent spatial movement pattern, manually attributed to a migratory male “Andraž” trajectory from February 2021 to June 2023. On the east (right) side of the map there are his summer territories (orange to reddish shades of the MCP 95% polygons with solid line), on the west (left) side there are his winter home ranges (blue shaded MCP 95% polygons with dash-and-dotted lines) and in-between there are dotted polygons or trajectories for his spring and autumn transition periods (green-shaded for spring movements and grey- to black- shaded for autumn movements).

Altogether we attributed 96 such distinctive and subsequent spatial patterns to fixes of 17 roe deer individuals. Out of these, we filtered 46 home range areas, meaning that these areas were consistently used for a prolonged period of time, as opposed to quicker extra-territorial excursions, shorter trips into the transitional zone between the seasonal home ranges or one-hop or few-hops migrations.

With two basic home range estimators, MCP 95% and Kernel 95% ‘href’, we calculated size of these spatially and temporally distinctive areas (Figs. 37 and 38), expecting of course much smaller estimates, given that only consistently used areas were considered and all excursions and migration trips excluded.

MCP 95% method thus produced 46 polygons with a minimum of 10 ha, median of 48 ha, mean of 52 ha and a maximum of 144 hectares. Kernel 95% method gave a minimum estimate of 13 ha, median of 52 ha, mean of 64 ha and a maximum of 204 ha. Kernel polygons were still inflated for those individuals that included some spatially distant fixes in these pre-defined periods, thus different Kernel estimator should be used in the future handlings of this dataset.

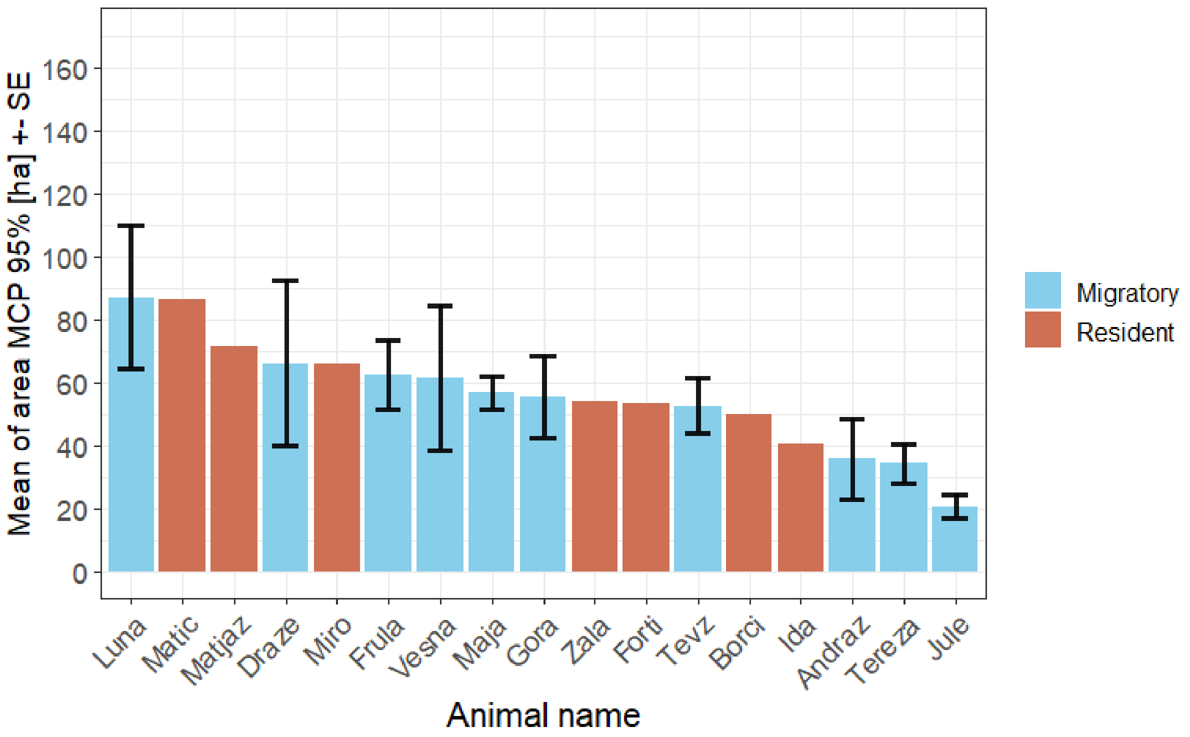


Figure 37: One of the possible representations of average home range sizes for 17 roe deer (migratory individuals blue bars, resident or short-time-tracked individuals brown bars), here presented as mean (± SE) of MCP 95% areas of consistent and distinctive use in space and time for each individual, excluding their extra-territorial excursions and migratory paths (see text for explanation).

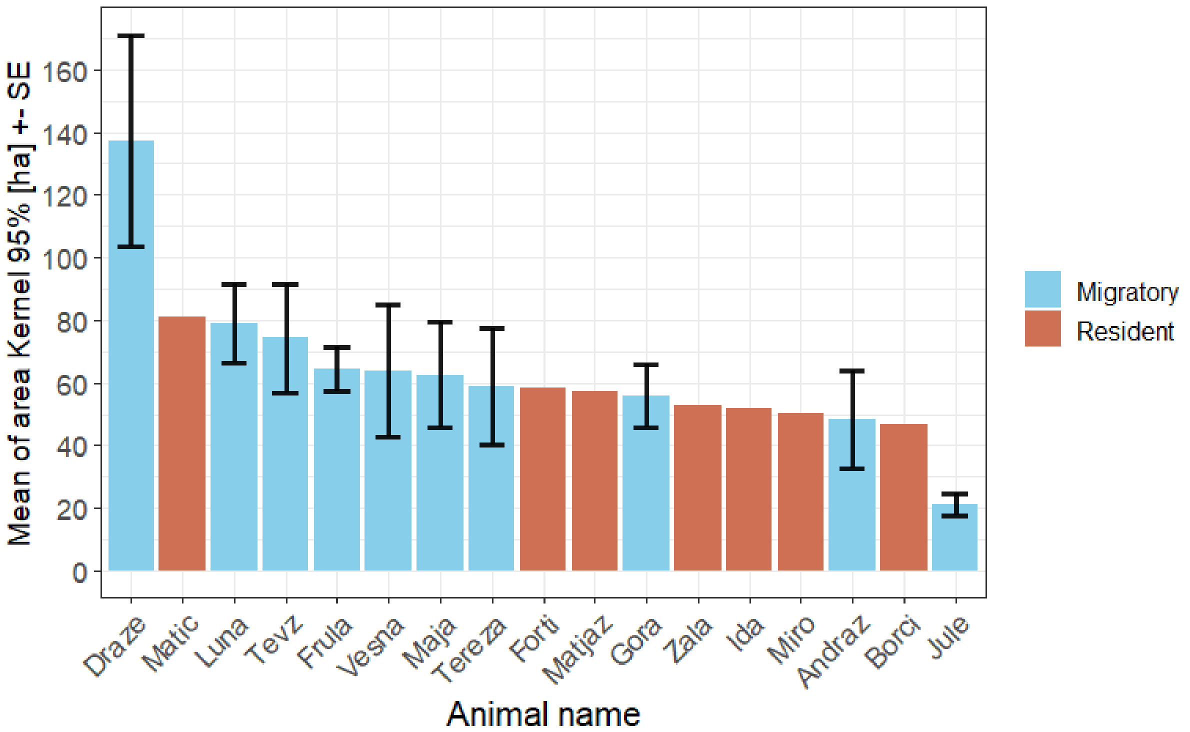


Figure 38: One of the possible representations of average home range sizes for 17 roe deer (migratory individuals blue bars, resident or short-time-tracked individuals brown bars): mean (± SE) of Kernel 95% 'href' areas of consistent and distinctive use in space and time for each individual, excluding their extra-territorial excursions and migratory paths (see text for explanat.).

In general, roe deer from "Jelovica" study area utilized stable seasonal (migratory individuals) or annual (resident individuals) home ranges of 20 to 80 hectares in average. Including the transient home ranges or transition space or migratory paths between the summer territory and winter home range, the complete annual space required by a roe deer could amount up to 800 hectares.

4.3.4. Spatial distances

Range of distances between centroids of summer and winter home ranges for migratory individuals was between 700 m and 19 km, with most animals migrating from 1.5 to 7 km between their summer and winter home ranges. Given that we marked 18 animals on 6 different microlocations, it was of our great interest also to find out, how the spatial distribution of the individuals that were captured together (distances between their home ranges) could relate to their (genetic) relatedness.

Luckily, we captured three females in the same season on the same spot. While all three of them had winter home ranges under the plateau, which overlapped considerably (Fig. 39), they all migrated seasonally to higher altitudes. Their respective summer and winter home ranges were 2.4, 3.1 and 4.7 km apart, respectively.

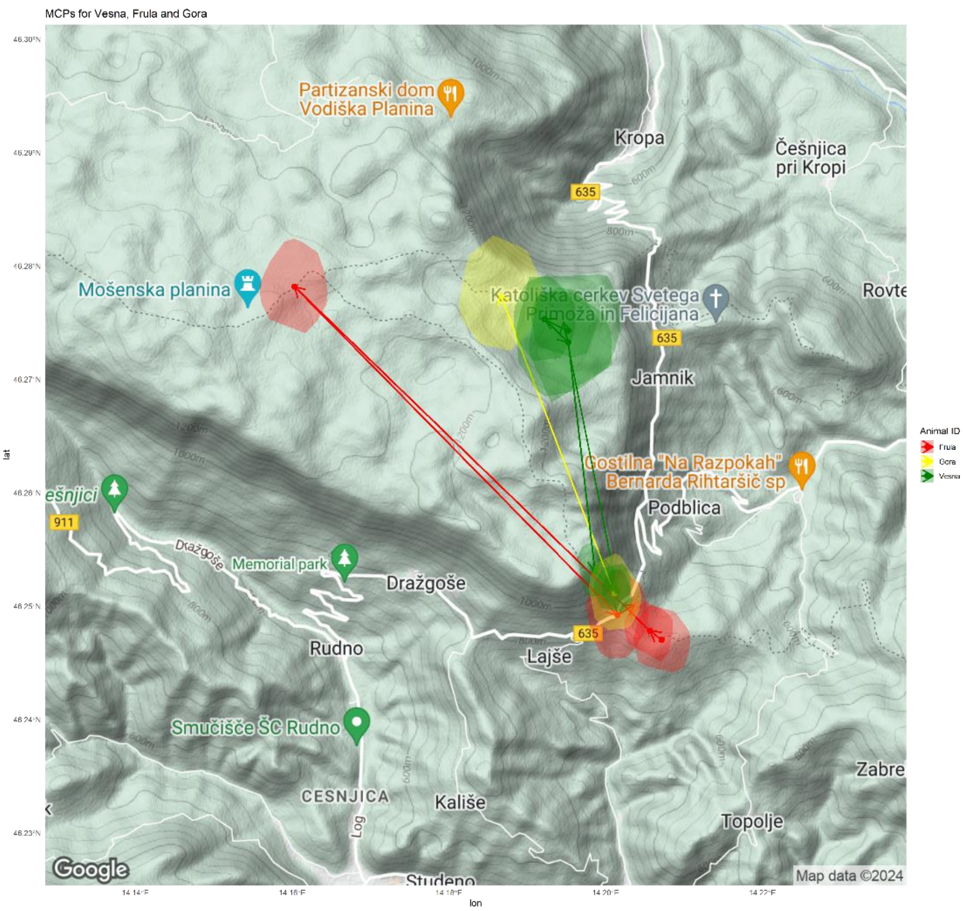


Figure 39: MCP 95% seasonal home ranges for three migratory female roe deer. Their winter home

ranges are in the lower part of the map (south), overlapping considerably, while their summer home ranges are northwards, on the top of the plateau Jelovica. Centroids for the green female ("Vesna") are 2,4 km distant and for the red female ("Frula") 4,7 km.

The summer home ranges of the three females did not overlap anymore, or only to a smaller degree (Fig. 39). For the case of two females (Vesna – green, and Frula – red), Fig. 40 demonstrates, that in the summer they didn't have contacts anymore, as their daily minimal distance between their simultaneously recorded fixes was mostly longer than 2 km. Daily distances between the females shortened to approximately 500 to 1500 m only on separate occasions during spring and summer 2022, reflecting transitory migration period, when females were travelling between the seasonal home ranges. It was only in the next winter, when they aggregated again (February – March 2023; Fig. 40).

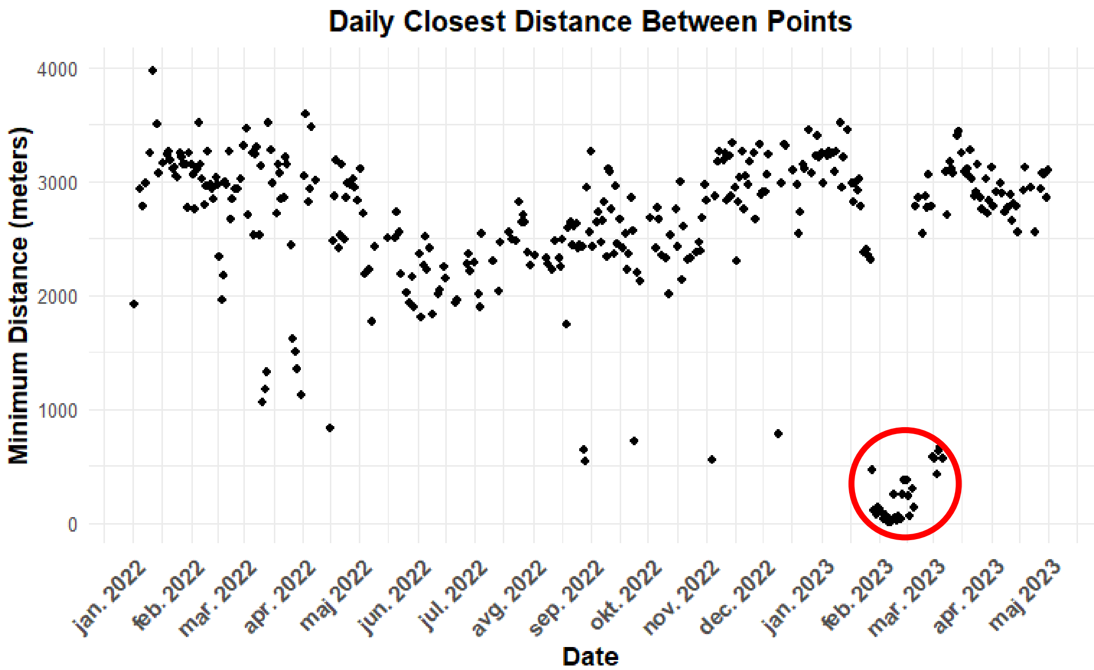


Figure 40: Minimal daily distances between two migratory females (Vesna – green on Fig. 39, and Frula – red on Fig. 39) that were captured on the same spot. The females aggregated only on their winter home ranges (marked with red circle), but kept their summer home ranges separated.
* Minimal distance between two individuals was chosen as the shortest distance between their simultaneous fixes in a day.

The outcome of the genetic analyses of their relatedness showed that two of these females, namely Frula and Gora (red and yellow on Fig. 39, respectively), could be half-siblings with a probability > 55%.

On another spot, also three males were captured in the same season. Interestingly, only one of them was migratory, the other two were residents (occupying the same area throughout the year). Their home ranges were overlapping to a high degree in winter. However, during the territorial period all three of them showed distinctively spatially separated movement patterns. The migratory male "Andraž" left its winter home ranges between February and March each spring (in 2022 and 2023), thus increasing the distance to the resident two males to approximately 1,5 km (Fig. 41). As expected, he was faithful to both, his winter and summer home ranges, thus returning to his winter home range each winter and decreasing the distance to the resident males to less than 250 m again.

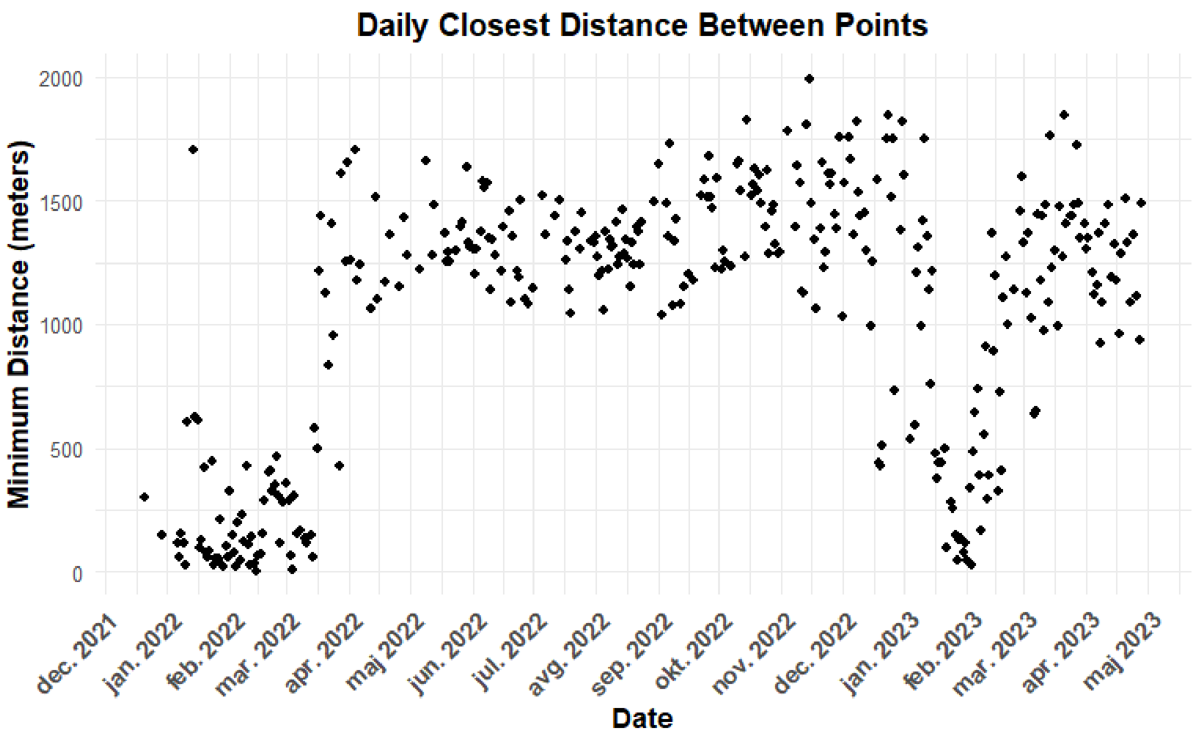


Figure 41: Minimal daily distances between a resident male "Forti" and a migratory male "Andraž", which were captured on the same spot. Their winter home ranges overlapped (daily distances between them mostly shorter than 250 m during winter), but during the territorial period "Andraž" migrated approximately 1.5 km away.
* Minimal distance between two individuals was chosen as the shortest distance between their simultaneous fixes in a day.

During the territorial period, also the two resident males changed their spatial use (Fig. 42). Before the territorial establishment phase, their monthly home ranges in February overlapped for 63 % of Forti's home range (February MCP 95% for Forti = 32 ha, for Miro = 44 ha), but through progressing territorial period toward the reproductive period, the overlap disappeared until June (monthly territory size MCP 95% in June for Forti = 20 ha, for Miro = 26 ha; overlap 1,7% of Forti's territory).

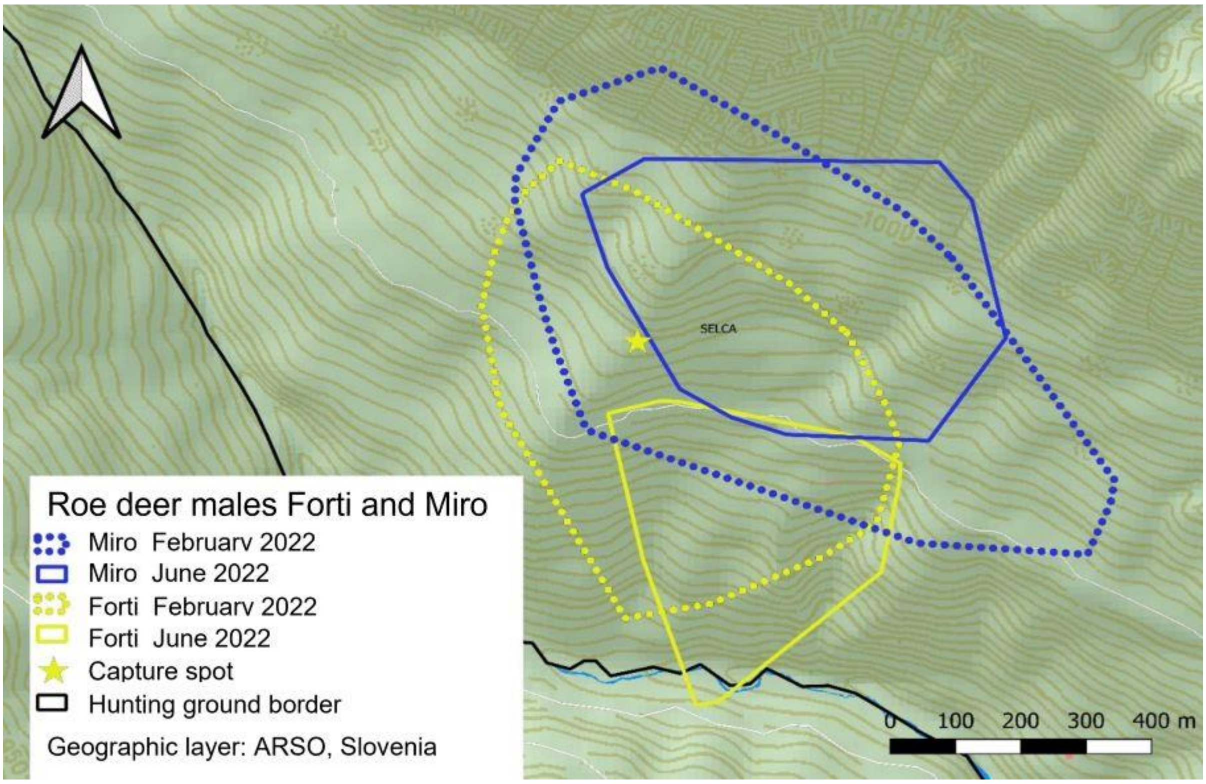


Figure 42: Monthly MCP 95% polygons for two resident roe deer bucks (blue "Miro", yellow "Forti") in February (dotted lines) and June 2022 (solid lines), indicating how overlap between territories disappeared until June, illustrating territoriality of roe deer males.

Genetic analysis for these three males did not detect any sign of their possible relatedness (in the frame from parent-offspring to siblings or half-sibling relatedness). However, buck "Forti" was possibly a sibling to another marked male "Draže" (probability > 40 %), which was captured twice during our study. Unfortunately, he was not collared upon his first capture on the same spot as Forti, but could be tracked only from the next season on, being captured at another spot. "Draže" was a migratory male.
"Forti" was found to possibly be also a half-sibling to another marked buck, "Borči", with an estimated probability for half-sibling relatedness > 55 %. Their home ranges were located in different areas.

The genetic analysis of relatedness found otherwise a reliable (> 99 % probability) parent - offspring relationship for two pairs of marked animals.
A mother – daughter relationship was found for "Zala" (the mother) and "Maja" (the daughter). "Zala" was an old female, who died of natural causes (diarrhoea) at the end of the winter and was monitored only for a month and a half before she died. "Maja" was a yearling (captured in the same trap as "Zala") that performed the longest migration in this study (see description below) at the end of April 2023. Unfortunately, we were not able to monitor her for the whole year, so we can not be absolutely sure, whether her relocation was dispersal or migration (given her age). However, we were monitoring the area for the whole winter by camera traps and she was never photographed, until the next summer (2024), when only then a local hunter photo-trapped her with a fawn. Thus, there might be a possibility, that she returned to the natal area

in the preceding winter, thus exhibiting a migratory behaviour rather than a natal dispersal.

The other parent - offspring pair were female "Luna" (the mother) and a male fawn "Javor" (the son), who was too small at the time of the capture to be collared and was thus marked only with ear-tags. The box-trap was actually visited by at least four individuals during that winter (2021/22): a female with two fawns and a buck. Three of them were then captured that winter (female "Luna", male "Matjaž, and one of the twin fawns – "Javor"). "Luna" was a migratory female, returning to her winter home range the subsequent winter, where she was photo-trapped by a local hunter, still in the company of "Javor" and the resident buck "Matjaž" (together with other unmarked roe deer). The fawn "Javor" thus didn't disperse in spring 2022, but remained in his natal area at least until the next spring (2023). The DNA extraction unfortunately didn't work on a hair sample of buck "Matjaž", but given that "Luna" was a migratory female, we could assume that "Javor" was not his son.

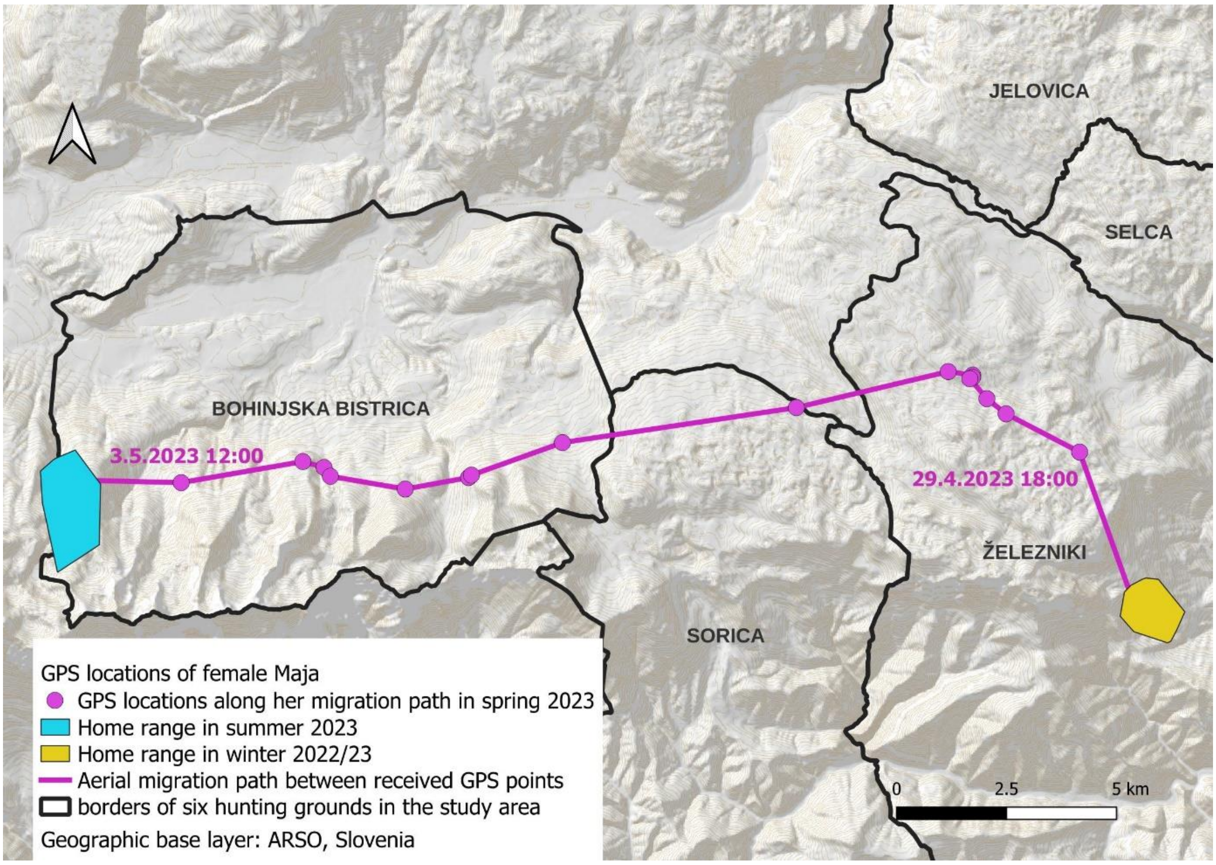


Figure 43: Female "Maja" migrated (alternatively dispersed, see text) from her winter home range (yellow polygon on the right) to her summer home range (turquoise polygon on the left), covering roughly 19-km distance between received GPS points on her path (pink dots and line) in four days (from 29.4.2023 to 3.5.2023).

The largest migration distances in our sample were performed by two young females, both heading in the direction from East to West, towards Julian Alps, and both arriving to their transient or stable summer home range on 3rd of May (in 2022 and 2023, respectively).

Female "Maja" covered 19 km of air distance between points along her movement path in 4 days (Fig. 43).

Female "Tereza" (Fig. 44) migrated 15 km of straight distance between her available locations on the way in one day and a half. She settled for nine days on the transient home range (40 ha, MCP 95%), until moving to the stable summer home range (33 ha, MCP 95%). She returned back to her winter home range in the first half of September (Fig. 45).

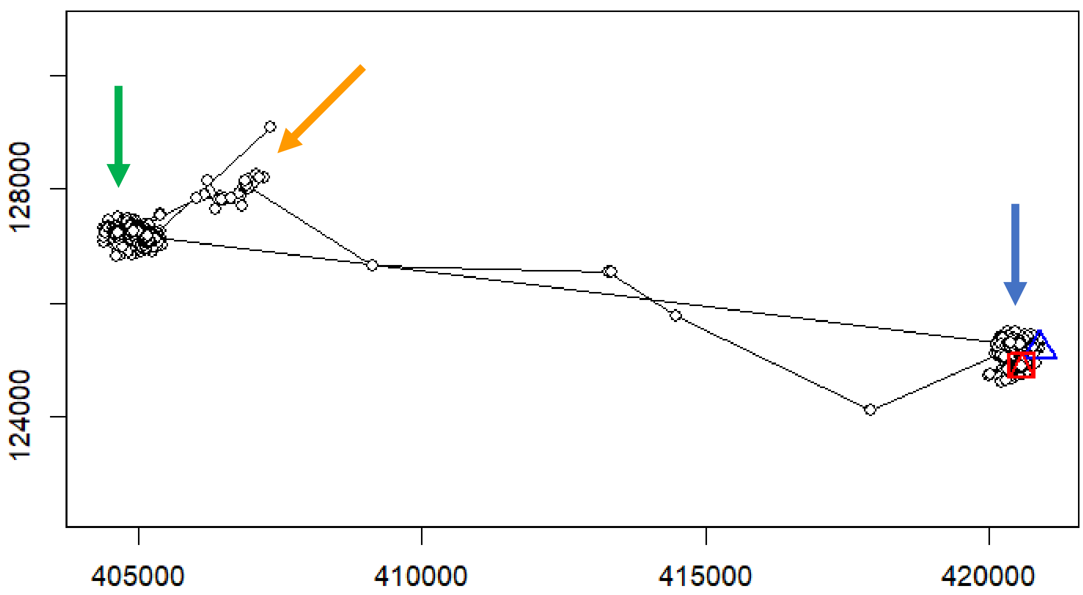


Figure 44: Movement trajectory of a migratory female "Tereza", migrating for 15 km between her summer and winter home ranges. Her winter home range is marked with blue arrow, the transient summer home range with orange arrow and the summer home range with green arrow. Her exact way back from the summer to winter home range was not documented, as the data were not transmitted at that time, but in the middle of September 2022 she was already back in her winter area.
*Longitude of the fixes is plotted on the x axis and latitude on the y axis; coordinates are labelled in EPSG 3794 coordinate system.

She also expressed the largest altitudinal change during her migration among all monitored individuals (Fig. 45). The average (± SD) altitude of her winter fixes was 712 m a.s.l. (± 13), the average altitude of fixes within the transient summer home range was 1193 m (± 113) and the average altitude for summer fixes was 1507 m (± 22).

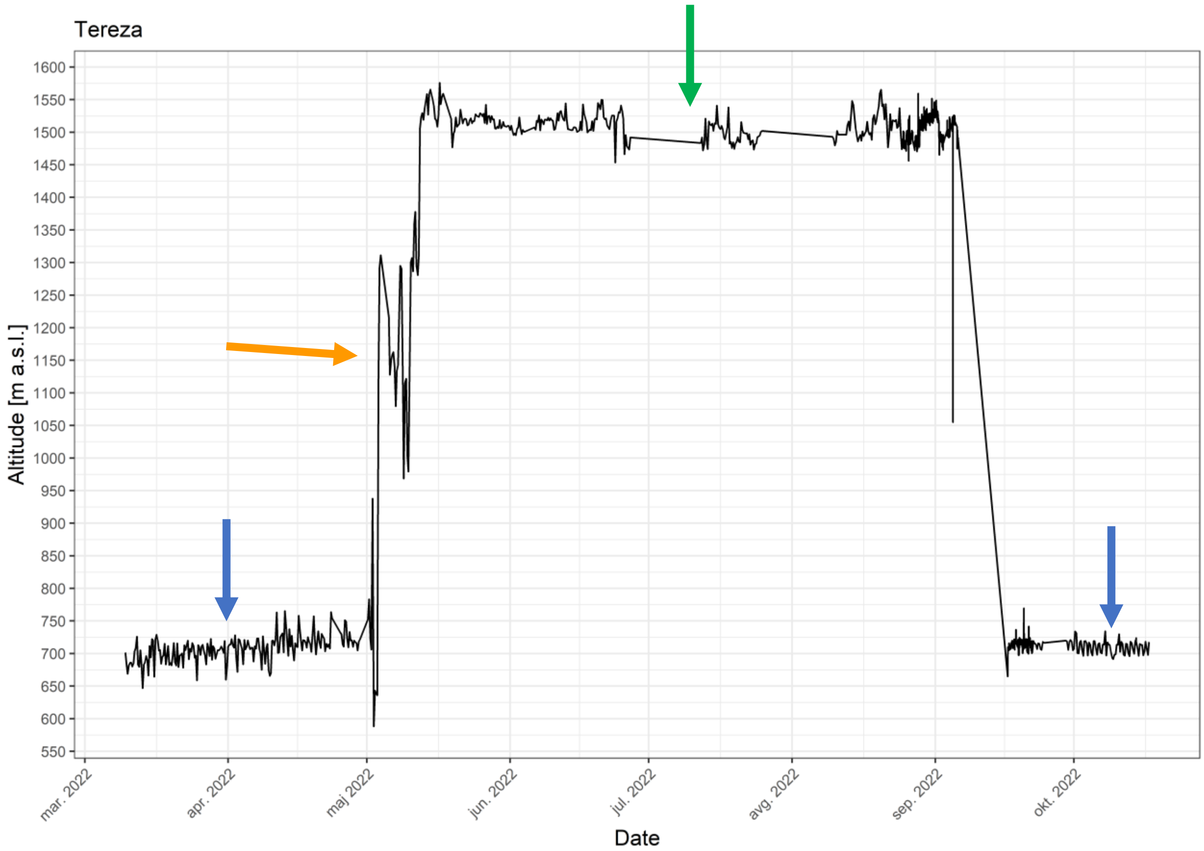


Figure 45: Altitudinal movement trajectory of a migratory female "Tereza". The colours of the arrows are retained the same as on Fig. 44: blue for winter home ranges, orange for the transient summer home range and green for the summer home range.

5. Live-captures and collaring of wolves

Studying large carnivores is extremely challenging. These animals are mainly active at night, have the ability to move over large areas and cover long daily distances. In addition, most of them are adept at avoiding contact with humans. Several modern non-invasive methods provide insight into feeding characteristics, identification of individuals by genetic sampling, and identification and study of activity patterns by photo-trapping. These methods give a very good insight into certain parameters of the ecology of individual species, but are not sufficient to gain knowledge of specific parameters such as (1) movement characteristics, (2) home range size, (3) habitat use, (4) predation rates, (5) reproduction and mortality rates, which are very important for understanding the causes of conflict and how to mitigate them. Without this knowledge, it is much more difficult to develop and implement a species conservation plan.

5.1. Radio- and GPS telemetry

In order to obtain such detailed data, it is often necessary to equip individuals with devices that allow scientists to monitor animals remotely in their natural habitat. Telemetry methods (VHF telemetry was used in the past, but nowadays GPS technology with the possibility of remote data transmission) have been used for 40-50 years to enable researchers to obtain data and to disseminate knowledge on the ecology of vast array of species. The intense changing of environment and the intensity of human activity make it necessary to continuously monitor and obtain new information on animal responses to environmental change. However, the study of large carnivores always raises more complex questions that can only be answered by monitoring tagged animals over longer periods of time. Therefore, LCIE believes that the need for targeted studies using telemetry will continue to exist in the future.

In September 2020 we started scanning the area of Jelovica in hope to find signs of wolf presence. At the beginning of October, we've been able to determine the core area of the Jelovica wolf pack based on the distribution of signs of wolf presence (scats, footprints, camera-trap footage). Based on the recordings, we estimated that there were 8 individuals in the Jelovica 2020 pack.

We have set the live-traps in the beginning of October 2020 and left them to lose our scent. After one week we activated them and started the capturing season in the Alps. There were 4 traps set in the core area of Jelovica wolf pack.

We used soft-catch leg holds, made in USA. The trap is buried on the side of the road with a lure (wolf scat) placed next to the trap. It needs to be set very carefully, without any human scent left around and no components sticking out of the soil. The trigger is pre-set to the appropriate weight to reduce the chances of catching smaller animals (foxes, badgers, …).

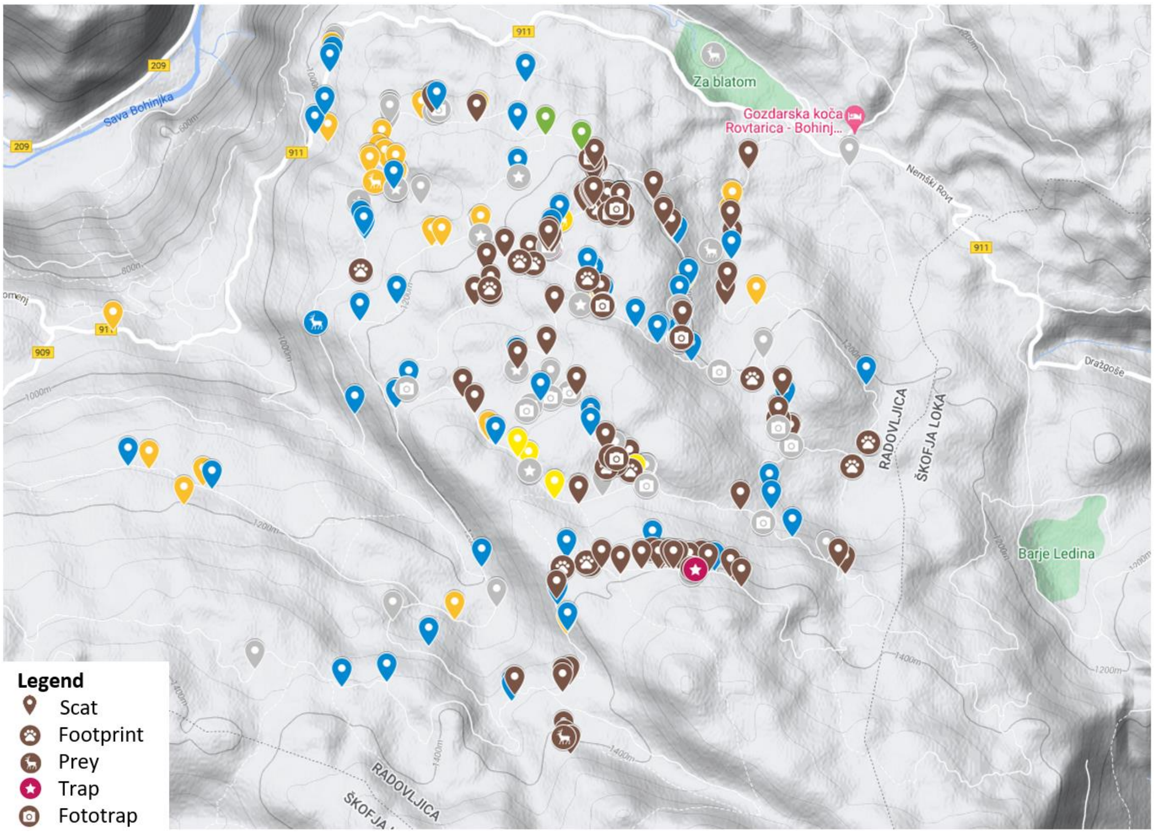


Figure 46: Signs of wolf presence in Jelovica plateau 2020/21.


Figure 47: Capture site with a wolf trap buried on the side of the road. In the left figure: inactive wolf trap (covered with a rock); in the right figure: active trap. In both figures animal overmarked the trap (left: overmarked by a wolf, right: overmarked by a marten).

The capturing season usually starts in the spring, when the snow melts and the temperatures don't drop below 0°C to reduce the chances of hypothermia and self-inflicted injuries on captured animals. We paused the capturing season in the period when the pups become mobile, but are not yet big enough to be captured (August, September and October).

5.2. GPS-telemetry of collared wolves

Wolf Jelko, November 2020

We captured the first wolf in the Jelovica area in November 2020. He was a 5-month-old male, weighing 29 kg. He stayed in the area of the natal pack until the end of March 2021, when he slowly started to move away from his pack. At first, he was still present on the Jelovica plateau occasionally, but mostly roaming on the western edge of the territory, probably being less and less in contact with the natal pack. In the beginning of April, he moved approximately 75 km west to Italian Resia plateau. Interestingly, five days after Jelko crossed Soča river, another wolf was photographed crossing the road and river Soča in almost the same spot as wolf Jelko. We assume that it could be his sibling, who was also encouraged to leave the natal territory. Wolf Jelko then tried to cross the SS13 traffic route and the Tilment river a few times, but it seemed this was too big of an obstacle for him. We informed Italian colleagues from University of Udine, who work in that area, and they already made a few field inspections and found two of his kills (roe deer) in a very rough terrain in the hills upon the Resia plateau.

During the period of the so-called transition home range, he made several attempts to leave the area, as indicated by individual unsuccessful excursions to the south, and especially to the west, where the area is crossed by the huge 100 m long Tagliamento River gravel system, along which there are major thoroughfares (expressways, fenced motorways) and a densely populated valley extending from the Po plain (Gemona) towards Tolmezzo.

The beginning of February is the period when the wolves start to mate, which may be the reason why the wolf has once again tried to leave the area in search of a sexual partner. Unfortunately, he was unsuccessful in doing so in a fragmented and anthropogenic landscape. Wolf mortality is relatively high in the early post-nesting period and then during the pup-rearing period, as most wolves never manage to establish their own territory and rear their own offspring. Unfortunately, Jelko confirmed this fact.

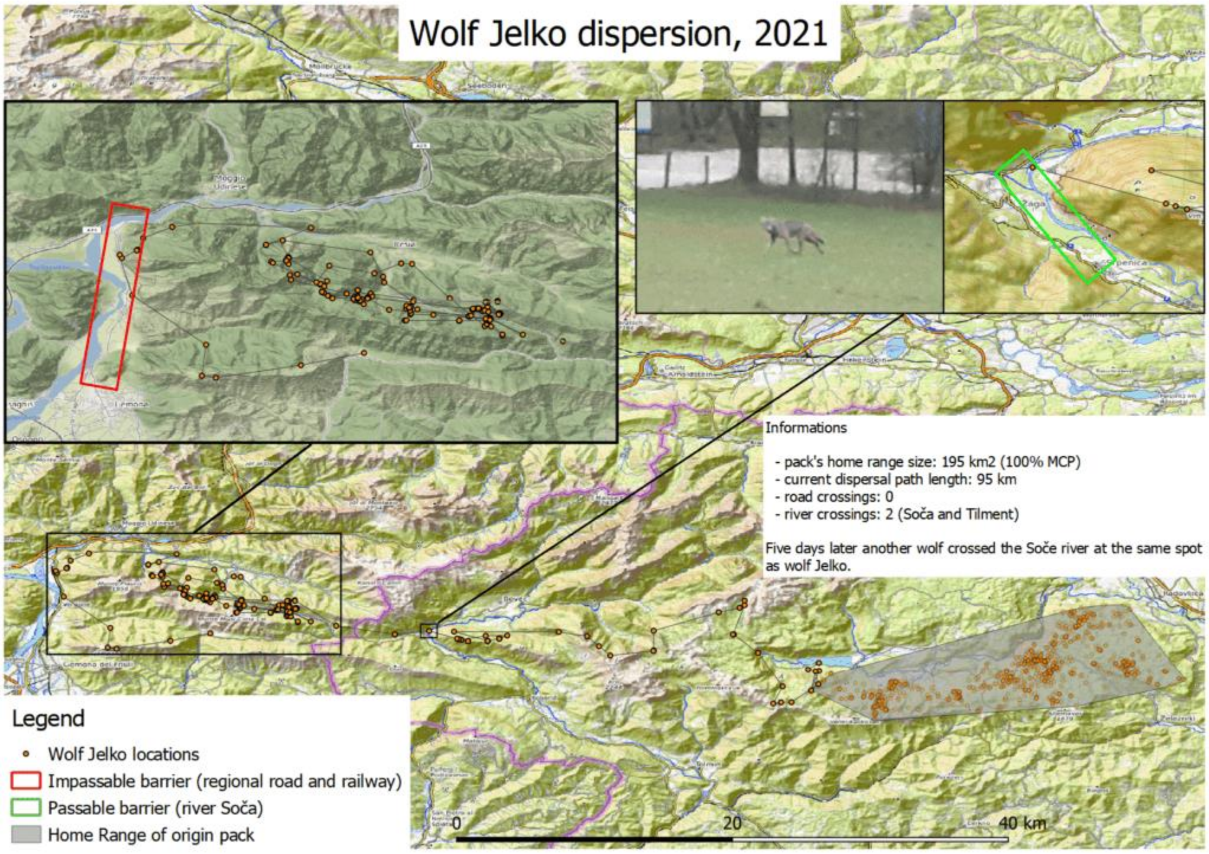


Figure 48: Male wolf Jelko dispersal in 2021.

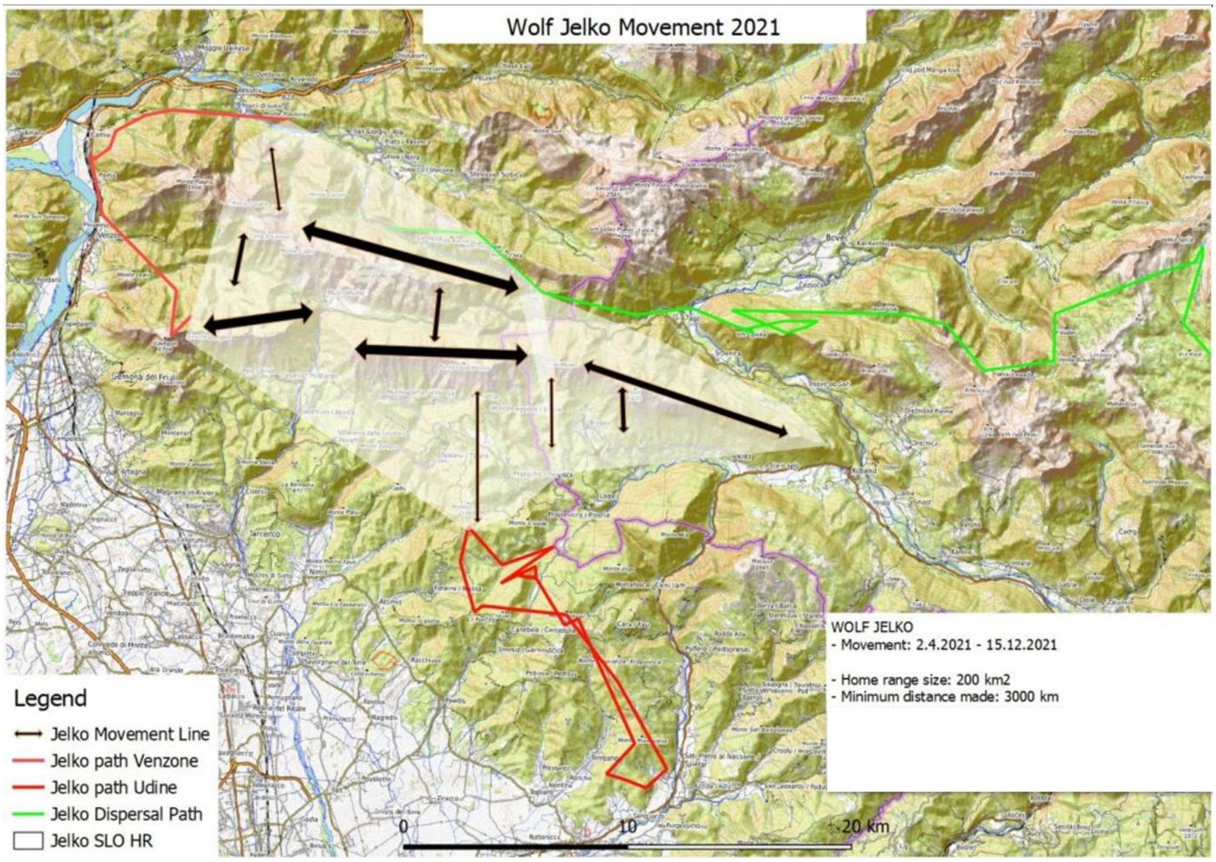
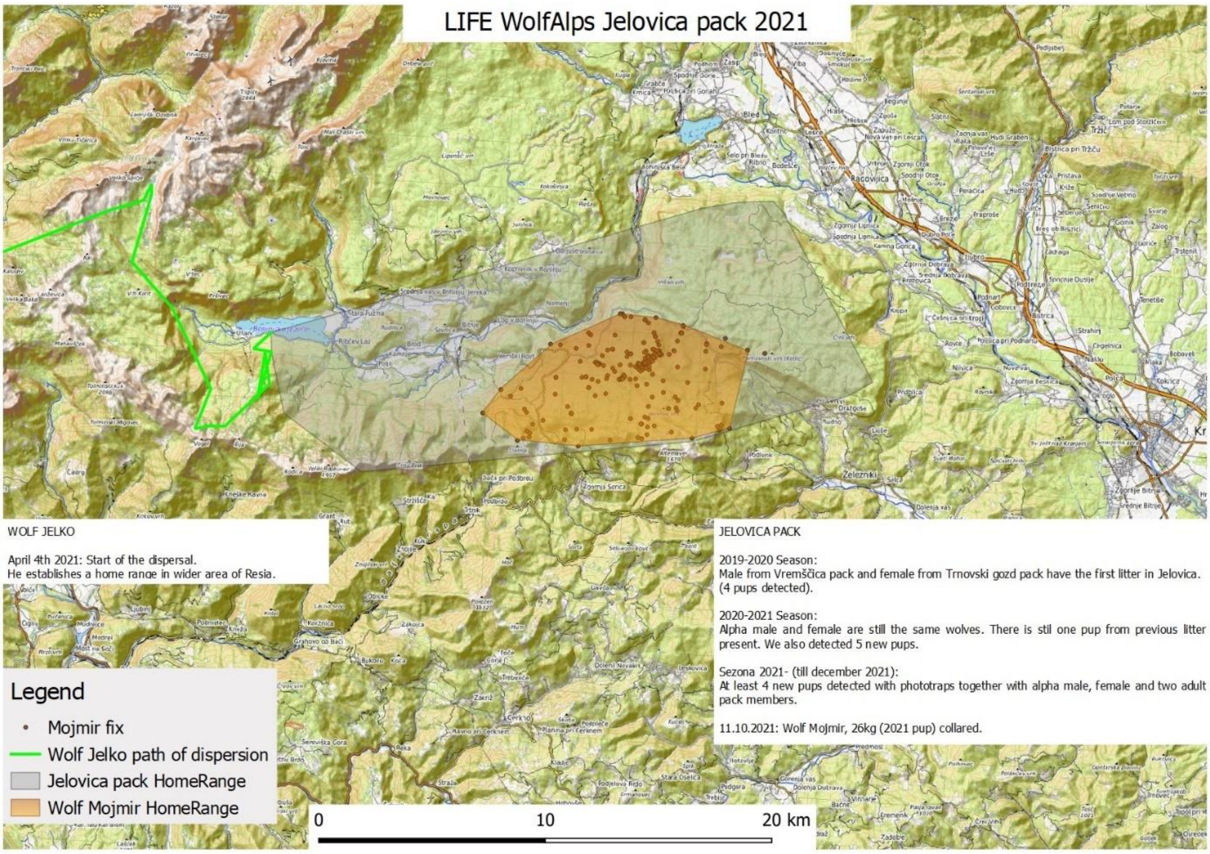


Figure 49: Wolf Jelko home range and movement in 2021.

Wolf Mojmir, 2021



In October 2021, the pups were big enough for capture, so we activated our traps again and on October 13, 2021, we captured and fitted with a GPS-collar a 26-kg male, a pup from the 2021 litter. We named him Mojmir, after his surprisingly calm response during the capture. Until November, the pups stayed near the so-called "rendezvous" area, with food brought to them by older members of the pack. To better assess the status of the pack, such as the number of pups and adults, we set up some additional cameras in this area. In November, the subadults became more and more active and started to follow the older members of the pack.

Figure 51: Pups from Jelovica pack in 2021.

By November 30, 2021, their home range was about one third of the home range of the pack. Unfortunately, after that, we no longer found a signal from Mojmir's collar. It could be due to the collar malfunction, poaching or the wolf managed to take the collar off in a place where there was no GSM coverage.

Wolf Neža, 2022

We captured and fitted with a GPS collar the female wolf Neža on 17.10.2022 on Jelovica plateau. We estimated her to be half a year old at the time. In the second half of December, the pack had an interesting excursion outside of the home range, when it moved through Vogel to the Voja valley, all the way to Pokljuka, and then returned to its home range. Until the second half of February 2023, Neža continued to move with the pack, but then she started to show the first signs of dispersal (moving away from her natal pack in search of her own territory). She first tried to move towards the Škofja Loka Hills, but soon returned, and a few days later tried with dispersal again, this time towards Cerkno. She returned the second time after three days and tried to go to Pokljuka, but she returned even the third time to the natal home area.

In March 2023, she went towards the Škofja Loka Hills again, crossed the Polhov Gradec Dolomites and went towards Razdrto, where she failed to cross the Ljubljana – Koper highway. She then turned back and returned to the Polhov Gradec Dolomites area, where she is still staying. We have not confirmed whether she has found a partner there.

After one year of monitoring, she has travelled a minimum of 5350 km, if we only consider the linear distances between the GPS points obtained from the collar. This distance is most probably at least 50% higher (approx. 7500 km) as the animal does not move as linearly between the GPS locations as shown on the map. In December 2023 she unfortunately managed to rip the cotton break-away belt and her collar dropped off.

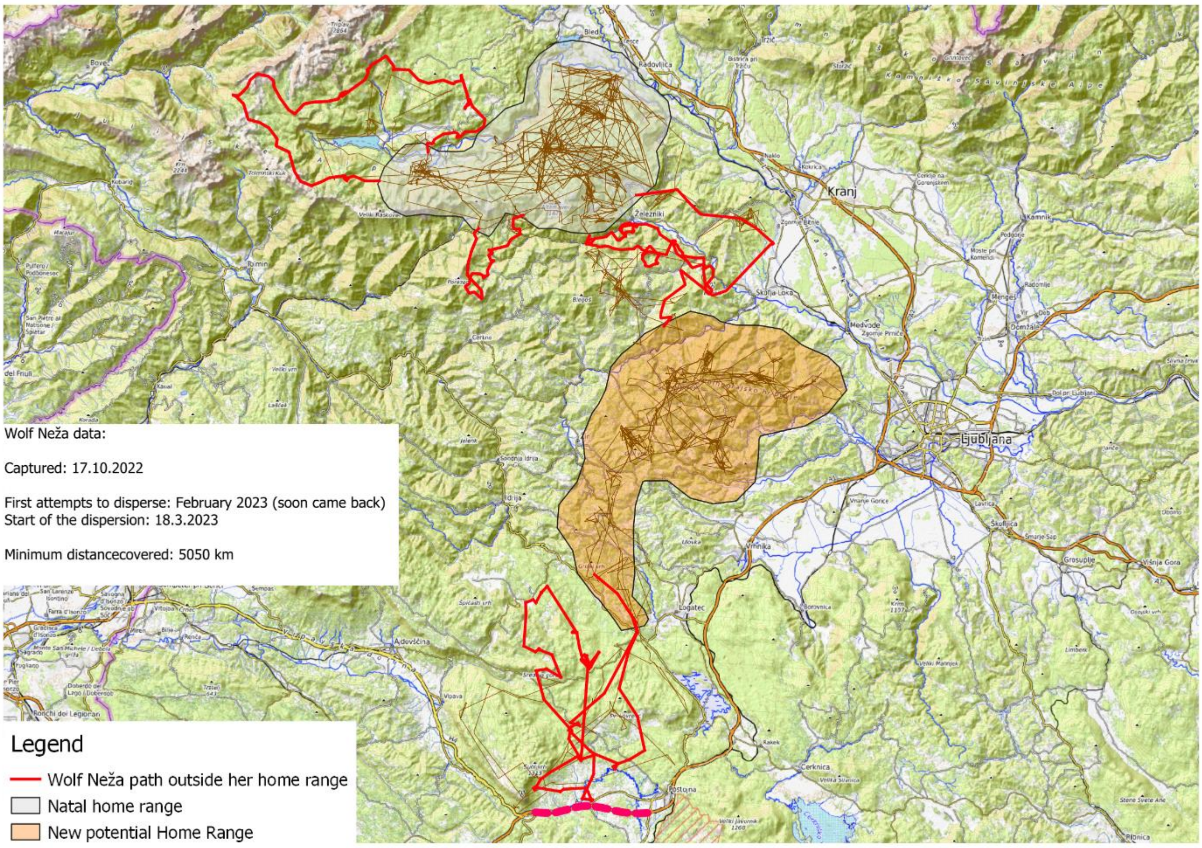


Figure 52: Female wolf Neža movement 2022/23.

When exploring the movement of GPS-tracked wolf Neža and 14 roe deer simultaneously, we wanted to find out how many times the wolf actually came into the proximity of GPS-collared roe deer.

During the monitoring period, the wolf came within 500 m of the GPS-tracked roe deer 438 times and 943 times within 500 - 1000 m of distance. There were 13 occasions, when the wolf came within 50 m of the roe deer and no predation occurred. These data illustrated the fact that only a minor share of wolf encounters with roe deer result in actual predation.

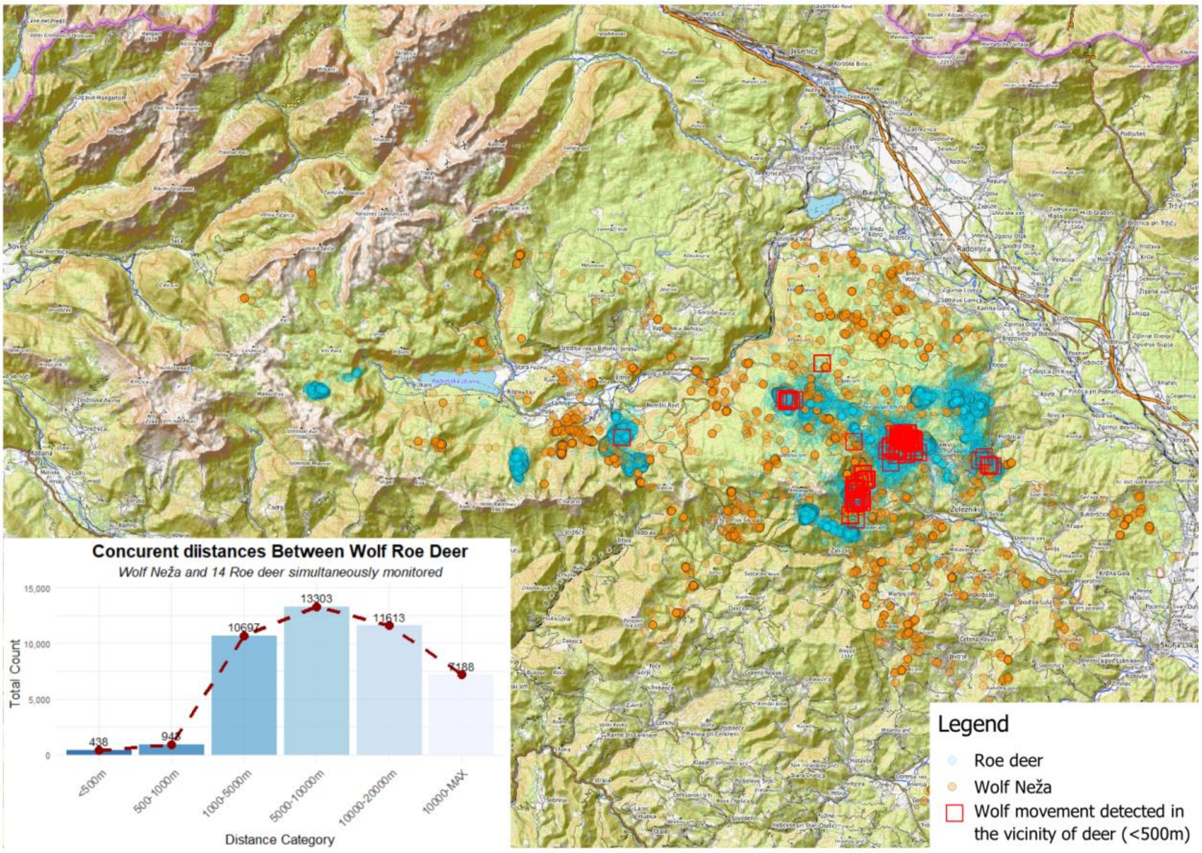


Figure 53: GPS locations of collared wolf Neža from the “Jelovica” pack (orange points) and of 14 collared roe deer (blue points), with marked those locations (red squares), when the wolf was less than 500 m distant from a roe deer.

6. Wolf scats and ungulate carcasses

Since the start of the project, we have been collecting wolf genetic data (scats, urine, saliva, blood…). Besides the genetic data, we have been closely monitoring the movement of the collared animals in order to collect as much information on animal ecology and movement characteristics as we could. We've been mainly collecting data from two areas: Pokljuka and Jelovica. Of course, we also monitored the movements of dispersing individuals.

We collected most of the scats when driving along the forest roads and also when tracking the wolves with the help of GPS locations and VHF signal. Altogether, we collected 291 scats and urine samples, and 215 video or photo media files with wolves on it.

Table 3: Scats collected during LIFE WolfAlps EU project (2019 – 2024).

Area	**N**
Jelovica (29.9.2020 - 25.3.2024)	**248**
Pokljuka (23.3.2021 - 25.3.2024)	**43**

Table 4: Media files collected (photos or videos) during LIFE WolfAlps EU project (2019 – 2024).

Area	**N**
Jelovica (25.3.2022 – 25.3.2024)	**126**
Pokljuka (25.3.2022 – 25.3.2024)	**89**

We set traps on 39 different locations in the area of the two packs. We were more successful with capturing wolves from Jelovica pack, because they had more stable movement patterns than Pokljuka pack. And also, there were more wolves in the Jelovica pack each year.

Table 5: Traps set during LIFE WolfAlps EU project (2019 - 2024).

Area	**N**
Jelovica (25.3.2022 – 25.3.2023)	**24**
Pokljuka (25.3.2022 – 25.11.2023)	**15**

We also collected data on wolf prey characteristics. On Jelovica plateau, we mainly acquired data with the help of GPS monitoring. We had been checking the potential kill sites and found altogether 45 kill sites. In Pokljuka, we didn't get a chance to capture a wolf, but we received a lot of help from Triglav National Park rangers who gave us the information about opportunistically-found wolf kill sites. We also carried out a couple of snow tracking sessions (randomly, not permanent transects) and found three kill sites in Pokljuka. Altogether, we thus detected 27 kill sites in Pokljuka.

Table 6: Wolf prey found during the LIFE WolfAlps EU project (2019 - 2024).

Area	**Red deer**	**Roe deer**	**Chamois**	**Mouflon**	**Eu. Hare**	**ALL**
Jelovica pack (25.3.2022 – 25.3.2024)	27	13	2	1	2	45
Pokljuka pack (25.3.2022 – 25.3.2024)	15	8	3	1	0	27

6.1. Physical fitness of wolf prey

The physical fitness is usually corelated with energy reserves in the body of wild animals. The biggest part of energy reserves in the body is stored as fat (Hickman in sod., 1997; Parker in sod., 2009). Physical fitness is influenced by several factors that can affect survival and reproduction (Cook et al., 2004; Parker et al., 2009). In areas with high seasonal variation, the availability and quality of food resources vary throughout the year, leading to differences in food intake at different times of the year and resulting in nutritional constraints (Illius, 2006). Physical fitness is usually also corelated with age and sex of the animal. Parasitism also has a significant negative impact on the physical fitness of animals (Irvine et al., 2006).

One of the most widely used methods for determining physical fitness is “Body fitness index” based on fat content in long bone marrow (Cheatum, 1949 and Ballard, 1995). The general perception of the scientific community is that animals with higher body fitness index will have lower chances to be predated than the ones with lower body fitness index. But this doesn’t mean that the animals with lower body fitness index are less healthy. It could be that they are just weakened because of different factors (mating season, lack of food, …).

To determine body condition, we used the method of determining the fat content of the bone marrow of long bones, which is commonly used to determine body fitness in ruminants (Neiland, 1970; Ratcliffe, 1980; Okarma 1984; Husseman et al., 2003). For the analysis, we preferentially used the femurs, from which fat reserves start to be drawn first (Okarma, 1984; Ratcliffe, 1970), but also the tibiae and the adductor femora, in cases where the first was not possible.

We analyzed only 13 wolf prey carcasses from the Alpine area because a killed carcass needs to be freshly found and its bones not yet damaged or exposed, in order to collect valid bone marrow samples. From the prepared samples from collected femur bones, we evaporated the fluids, subtracted the mineral part of the bone marrow and calculated proportion of the fat inside bone marrow (see Vovk, 2024).

Physical fitness of wolf prey: roe deer

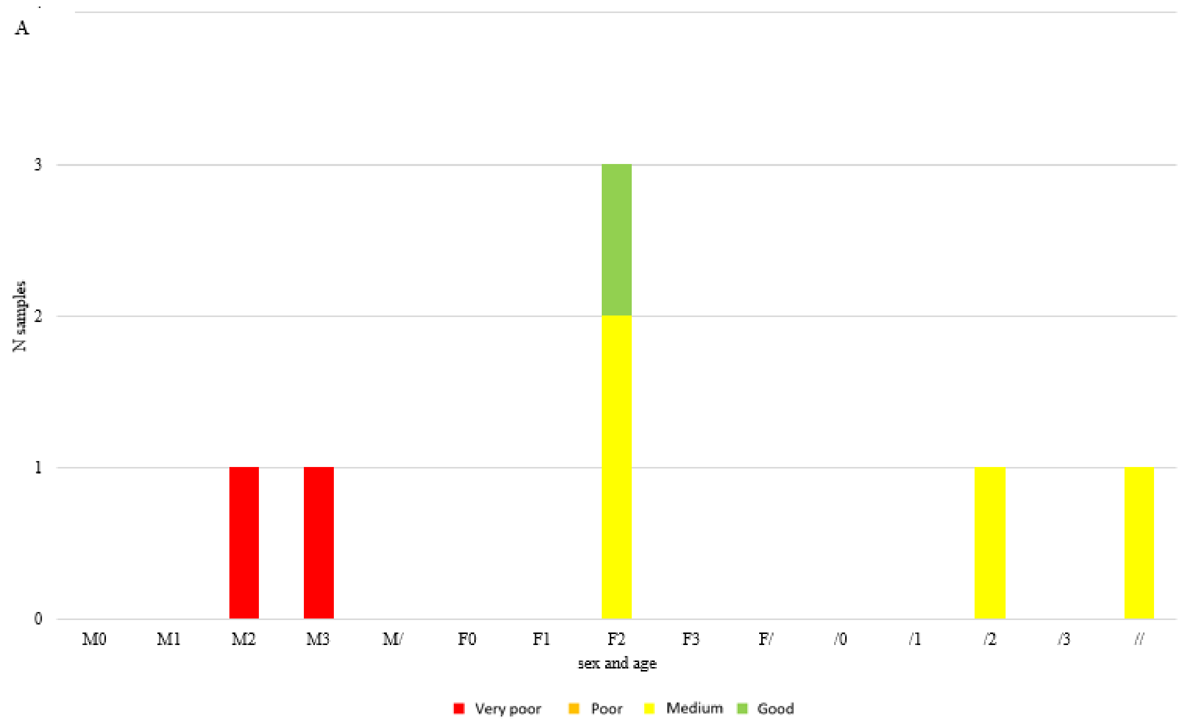


Figure 54: Distribution of collected samples of roe deer killed by wolves (n=7) according to sex and age of the killed animal (M0 - male fawns, M1 - yearling males, M2 - adult males (2-6 years), M3 - older males (7 years and older), M/ - males of unknown age, F0 – female fawns, F1 - yearling females, F2 - adult females (2-6 years), F3 - older females (7 years and older), F/ - females of unknown age, /0 - juveniles of unknown sex, /1 - yearlings of unknown sex, /2 - adults of unknown sex (2-6 years), older individuals of unknown sex (7 years and older), // - individuals of unknown sex and age) (Vovk, 2024).

The male roe deer killed by wolf were in very poor body condition according to Peterson's classification (one adult and one older male), while the females (all adults) were in medium (n=2) and good (n=1) body condition. The wolf also predated on two medium-condition roe deer, for which we could not determine the sex. One of them was an older individual, and we could not determine the age of the other.

Physical fitness of wolf prey: red deer

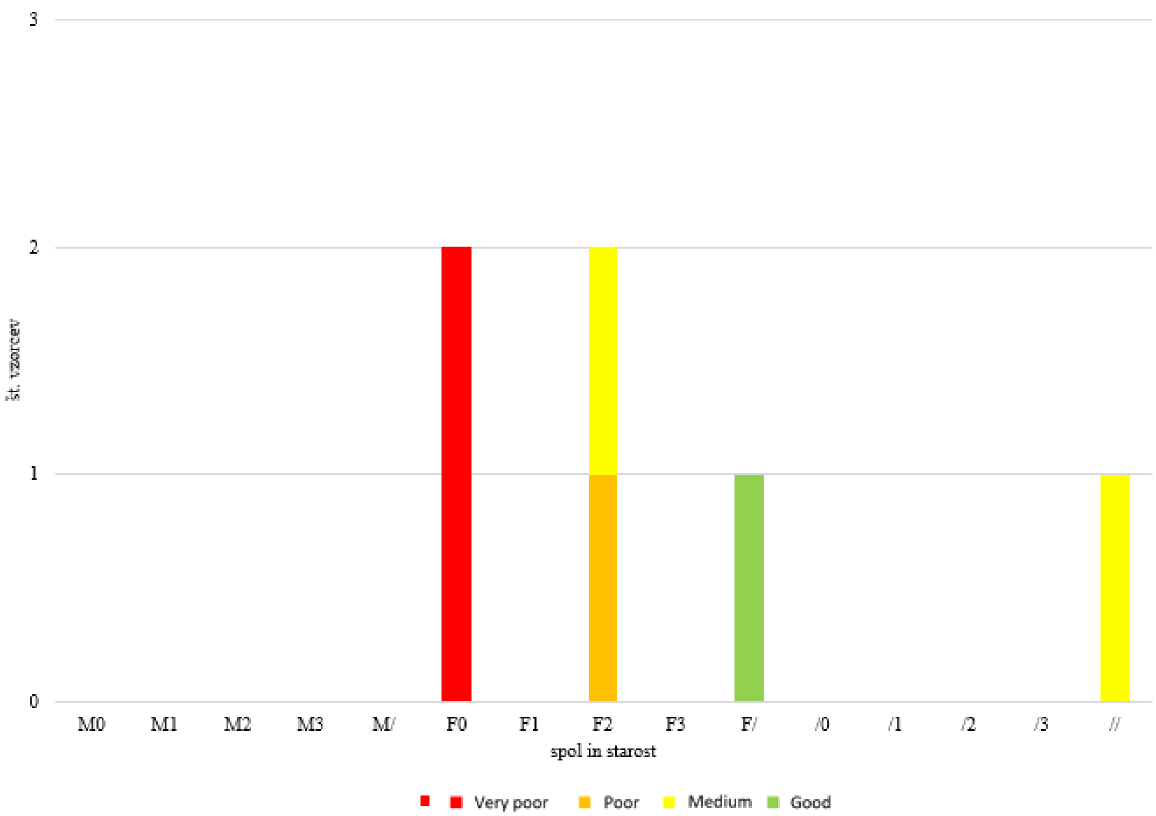


Figure 55: Distribution of collected samples of red deer killed by wolves (n=6) according to sex and age of the killed animal (M0 - male fawns, M1 - yearling males, M2 - adult males (2-6 years), M3 - older males (7 years and older), M/ - males of unknown age, F0 - female fawns, F1 - yearling females, F2 adult females (2-6 years), F3 - older females (7 years and older), F/ females of unknown age, /0 - juveniles of unknown sex, /1 - yearlings of unknown sex, /2 adults of unknown sex (2-6 years), older individuals of unknown sex (7 years and older), // - individuals of unknown sex and age) (Vovk, 2024).

The structure of red deer predated by wolves is one individual of unknown sex and age in medium body condition according to Peterson's classification, the rest were females: 2 calves in very poor body condition, one adult in poor body condition, one in medium body condition and one individual, whose age could not be determined, in good body condition.

The results show 29% of the roe deer predated by wolves were in poor body condition (n=2/7), which is only slightly higher than the percentage of roe deer in poor body condition found in the lynx prey (26%). On the other hand, 50% of the red deer predated by wolves were in poor body condition. Only females and one individual of unknown sex were predated.

Physical fitness of road killed roe deer

We also took the samples (N = 17) of roe deer collected from the road kills in the study area to compare it with samples from predation.

Roe deer

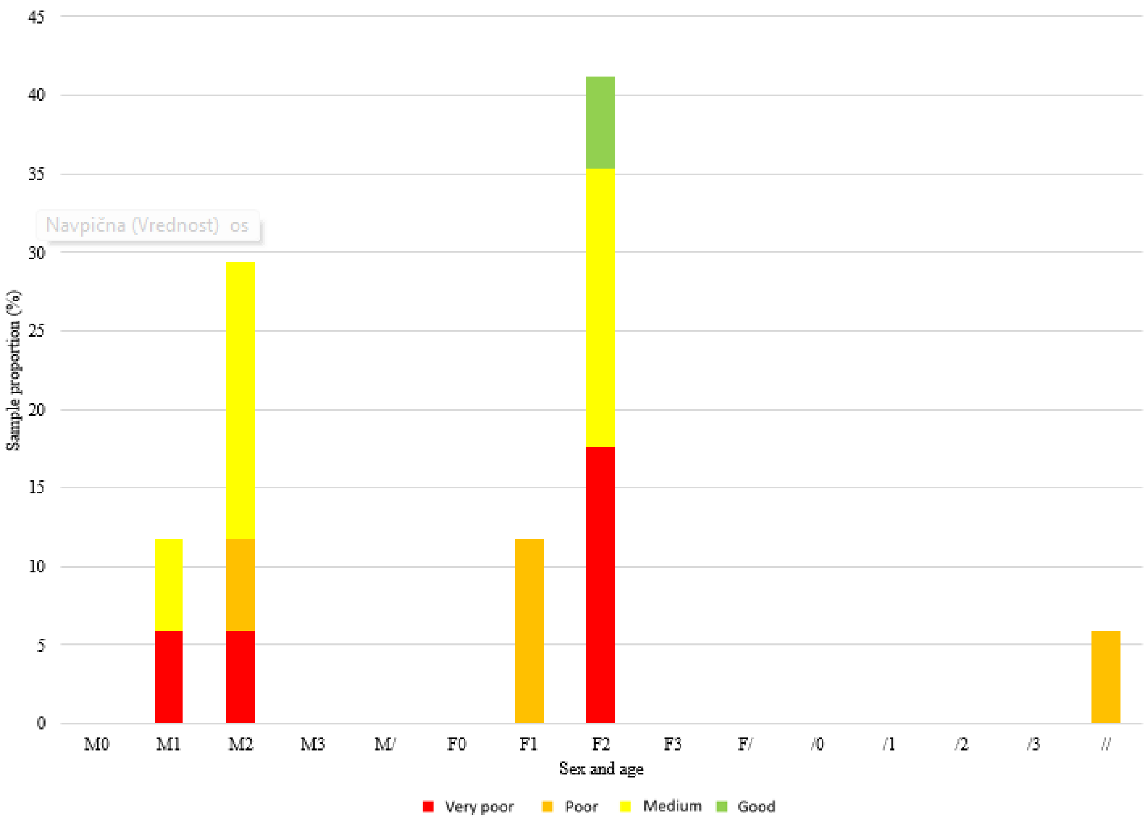


Figure 56: Distribution of the collected samples of roe deer (n=17) according to sex and age of the road-killed animals (M0 - male fawns, M1 - yearling males, M2 - adult males (2-6 years), M3 - older males (7 years and older), M/ - males of unknown age, F0 - female fawns, F1 - yearling females, F2 - adult females (2-6 years), F3 - older females (7 years and older), F/ females of unknown age, /0 – fawns of unknown sex, /1 - yearlings of unknown sex, /2 adults of unknown sex (2-6 years), older individuals of unknown sex (7 years and older), // - individuals of unknown sex and age) A according to Peterson's body condition classification (Vovk, 2024).

Among road killed roe deer there was one yearling male in very poor and one in medium body condition according to the Petersonos classification, one adult male in very poor, one in poor and three in medium body condition. Also taken were 2 yearling females in poor condition, 3 adult females in very poor condition, 3 in intermediate condition and one in good condition. We were unable to determine the sex and age of one roe deer in poor body condition.

Physical fitness of roe deer, culled by hunters

There were 78 culled roe deer carcasses analyzed that were provided by hunters from the study area to compare it with samples from predation.

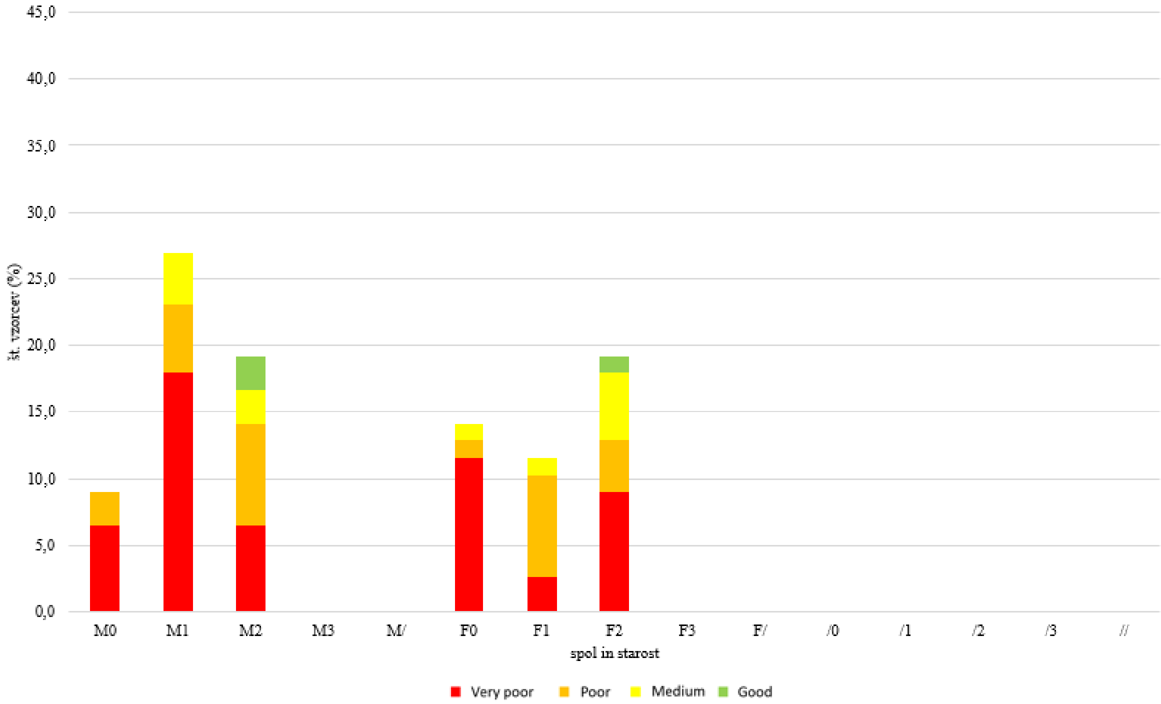


Figure 57: Distribution of the collected roe deer samples (n=78) according to sex and age of the culled animal (M0 - male fawns, M1 - yearling males, M2 - adult males (2-6 years), M3 - older males (7 years and older), M/ - males of unknown age, F0 - female fawns, F1 - yearling females, F2 - adult females (2-6 years), F3 - older females (7 years and older), F/ - females of unknown age, /0 - juveniles of unknown sex, /1 - yearlings of unknown sex, /2 - adults of unknown sex (2-6 years), older individuals of unknown sex (7 years and older), // - individuals of unknown sex and age) (Vovk, 2024).

When analyzing culled animals' condition by Peterson's classification, roe deer in poorer body condition dominated in all sex and age categories. Among the males, 5 fawns in very poor condition and 2 in poor condition were culled. Among yearling males, those in very poor body condition predominated (n=14), 4 were in poor body condition and 3 in medium body condition. 5 adult males were in very poor body condition, 6 in poor body condition, 2 in medium body condition and 2 in good body condition. There was also less animals culled with lower body condition in the female specimens. Among the female fawns culled, the predominant number of fawns were in very poor body condition (n=9), but there were also two fawns in poor and medium body condition (n=1 and n=1, respectively). 2 female yearlings culled were in very poor body condition, 6 were in poor body condition and 1 was in medium body condition (n=1, n=1). Most of the adult females were in very poor body condition (n=7), 3 adults were in poor body condition, 4 in medium body condition and 1 in good body condition.

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