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THE VALUE OF PROTECTED AREAS RANGER SERVICE PERSONNEL FOR BIODIVERSITY MONITORING: CASE STUDY IN PAKLENICA NATIONAL PARK (CROATIA)

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Abstract

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To preserve the long-term survival of habitats and wildlife, it is necessary to monitor their status. In protected areas, that is, biodiversity centres, rangers have excellent knowledge of specific locations and they spend a large amount of time in the field. But since rangers are not required to have a university degree, the question is whether they can be an added value in baseline survey monitoring. To investigate this issue, a case study was conducted in the Paklenica National Park (Paklenica NP), Croatia, using camera trapping survey between 2011 and 2016 at 22 camera sites. The aims of this survey were (1) to collect baseline data of mammalian diversity, (2) to analyse the regulatory effect of top predators on the trophic pyramid through top–down effects and (3) to estimate the data gathered by ranger service from the Paklenica NP. Data gathered through this study represents the first peer-reviewed list of medium- to large-sized mammals for Paklenica NP, as up till now, there is no peer-reviewed published paper of Paklenica NP mammalian diversity. Results showed that the recorded top predator–mesopredator–prey ratios were concordant with the trophic pyramid hypothesis. Also, as it was expected according to the literature, species richness indices were higher when top predators were present. On analysing the costs for conducting camera trapping survey by external and internal services, a significant difference was observed. Internal rangers' cost was nine times lower than the external service cost. Future research run by rangers needs to be conducted in way to capture all mammalian biodiversity. Therefore, we propose camera trapping methodology for rangers in the protected areas since this may be an invaluable tool for biodiversity monitoring.

Key words: rangers, camera trapping, trophic pyramid interactions, mammals.

Introduction

Nature provides many ecosystem services that enable human life and economic development, but nature is under constant anthropogenic negative impact (Diaz et al., 2019). In order to ensure the long-term survival of wild species and preserve habitats in a favourable condition, it is necessary to conduct systematic research that includes revision of the species richness lists, especially in protected areas. Efficient and reliable methods for rapid assessment of species richness and abundance are crucial to determine conservation priorities. Tracking animals by following footprints in dust, mud, sand or snow is probably the oldest known method of identifying mammal's presence in a certain area (Bider, 1968). In the past decades, non-invasive surveying technique using remote triggered photographic camera units have become common. The use of automatic cameras with infrared sensor triggered by 'warm objects that are moving' – animals is now a relevant technique to record species presence/richness, especially for medium- to large-sized mammals and terrestrial birds (Eymann et al., 2010; Norouzzadeh et al., 2018; Schneider et al., 2018). According to Burton et al. (2015), studies with camera traps are mostly focused on ecological objectives like relative abundance and presence–absence. They concluded that most camera trap studies focused on mammalian species, and mammalian carnivores were the most frequently targeted group (particularly large felids), followed by ungulates, small mammals (e.g. lagomorphs, rodents) and primates. Furthermore, camera trap surveys can generate standardised data on many species within mammal communities in protected areas across varied ecosystems (Chen et al., 2022). As the monitoring of mammalian species via camera traps is not so dependent on the environment to be sampled, constant assistance or even experienced field staff (Silveira et al., 2003), the question is whether protected areas' ranger service personnel can be an added value of the usual nature protection tool through baseline survey monitoring. Even with high initial costs of camera trapping, this method, compared to the line transects and track censuses, can be conducted more easily and with relatively low costs in a long term (Silveira et al., 2003). Camera trapping can be easily incorporated with regular ranger area control duties, therefore making data collection easy.

To date, there has been very little research on the role and skills of protected area ranger service personnel. But according to Chen et al. (2022), camera trap surveys conducted in protected areas can generate standardised data on many species within mammal communities across varied ecosystems; so, these surveys are very important for wildlife conservation. Rangers are usually mid-level employees who are primarily responsible for implementation of the plans and policies developed by the main office managers. According to Howard (2014), particularly important roles of a ranger are ability to make correct decisions about resource allocations, acting as a mediator to manage community expectations and flexibility in policy implementation. Surprisingly, most identified skills were not the technical skills (i.e. managing plants or animals), but skills such as setting priorities, multitasking and communication. The role of rangers in protected areas mostly refers to two group activities, education/interpretation and law enforcement/conservation, but roles vary from one national park to another. Rangers in Croatia are mainly involved in park protection, performing emergency duties to protect people and the park itself, participating in search and rescue operations and conducting investigations into accidents, complaints and illegal activities. Park ranger job qualifications vary depending on the country and the capacity in which rangers are hired. In Paklenica National Park (Paklenica NP), there are two levels of park rangers: ranger service officer and ranger service chief supervisor (Official Gazette, 2018). The required qualification for ranger service officer is completion of secondary education, while the qualification for ranger service chief supervisor is a bachelor's degree of biotechnical, natural, biomedical, technical or social orientation. Knowledge of work in the Geographic Information System (GIS) software is obligatory for both positions. In USA, minimal requirement is to possess some form of post-secondary education (Environmental Science, 2022). USA National Park Service requires a bachelor's degree related to the profession. The same requirements are in Australia (Parks Victoria, 2022) and South Africa (Shamwari, 2022). Further on, in Canada, while some positions require only a secondary school diploma, most ranger positions require a bachelor's degree or technical diploma in a field like conservation enforcement, natural resource management, outdoor education or forestry (Salazar, 2021). In Brazil, the requirements are slightly similar to those of Croatia; university degree is not obligatory, but it is recommended to study courses in the field of ecology, forestry and management during secondary education or coursework (Arnoni, 2018). In other European countries, the requirements are similar to those in Croatia. In Austria, university education is not compulsory, but it is necessary to complete two levels of training conducted by national parks (National Parks Austria, 2022). Most of the rangers in Germany are certified nature and landscape conservationists, whose requirement is to have a background of a so-called 'green' profession like forestry expert or agriculturist (Bundesverband Naturwacht, 2022). Also, in Germany, they have specialised bachelor's degree course 'Landscape Management and Nature Conservation', where students may choose the specialisation, protected area management. In addition to education, rangers have a very profound knowledge of the specific area (where animals are gathered, secret hideouts, waterholes, etc.) and/or have a long work experience within the protected area. During their regular field visits, they can collect large amounts of ecological data. In combination with the time spent working in the field (during regular visits), this can make them an invaluable 'tool' for biodiversity monitoring. Additionally, this may also be more cost effective for the management authority than hiring external professionals. Furthermore, protected areas often have an employed coordinator who has an ecological degree and can set up monitoring; so, rangers can do data collection. In this paper, we present one such mammalian survey conducted in total by rangers of the Paklenica NP using camera traps. Rangers in the Paklenica NP, beside their usual roles, have also focused on collecting data from biomonitoring (flora and fauna), which they regularly report to the conservation manager. Over the past period, rangers in the Paklenica NP have demonstrated excellent field survey skills and knowledge of different species like butterflies, birds and especially mammals, and they regularly wrote annual reports. They initiated the purchase of camera traps and with their installation on well-set positions on trails and roads, numerous valuable data were recorded. Data collected from the camera traps belongs to the survey in which the aim was to gather baseline data on mammalian species richness of the NP Paklenica, as well as to record other ecological information about the medium- to large-sized mammals, which might be useful for developing a comprehensive conservation management and monitoring plan.

First systematic research using camera traps in Croatia was conducted in 2002 as a pilot study for regular monitoring of large carnivores in Croatia (Gužvica et al., 2006). As this study represents the first peer-reviewed list of mammalian species for the Paklenica NP, time required to record all species present in the study area was calculated and the relationships between trophic levels were studied. Hypotheses were that the prey species will be much more often recorded than the predator species, and that the species richness index (SRI) value will descend from the top to the bottom of the trophic pyramid. Firstly, predator–prey ratio was analysed not only from the number of events with predator/prey, but also from the recorded abundance. Secondly, to analyse the Paklenica NP ecosystem food web in even more detail, three additional analyses were done: (1) comparison of the SRI in relation to presence of top predators, mesopredators and prey species; (2) comparison of recorded species distribution during 4-h intervals for three different situations: (a) when a top predator was recorded (with/without a mesopredator and/or prey), (b) when a mesopredator with prey was recorded and (c) when only prey was recorded and (3) principal component analysis (PCA) regarding the interaction of top predators, mesopredators and

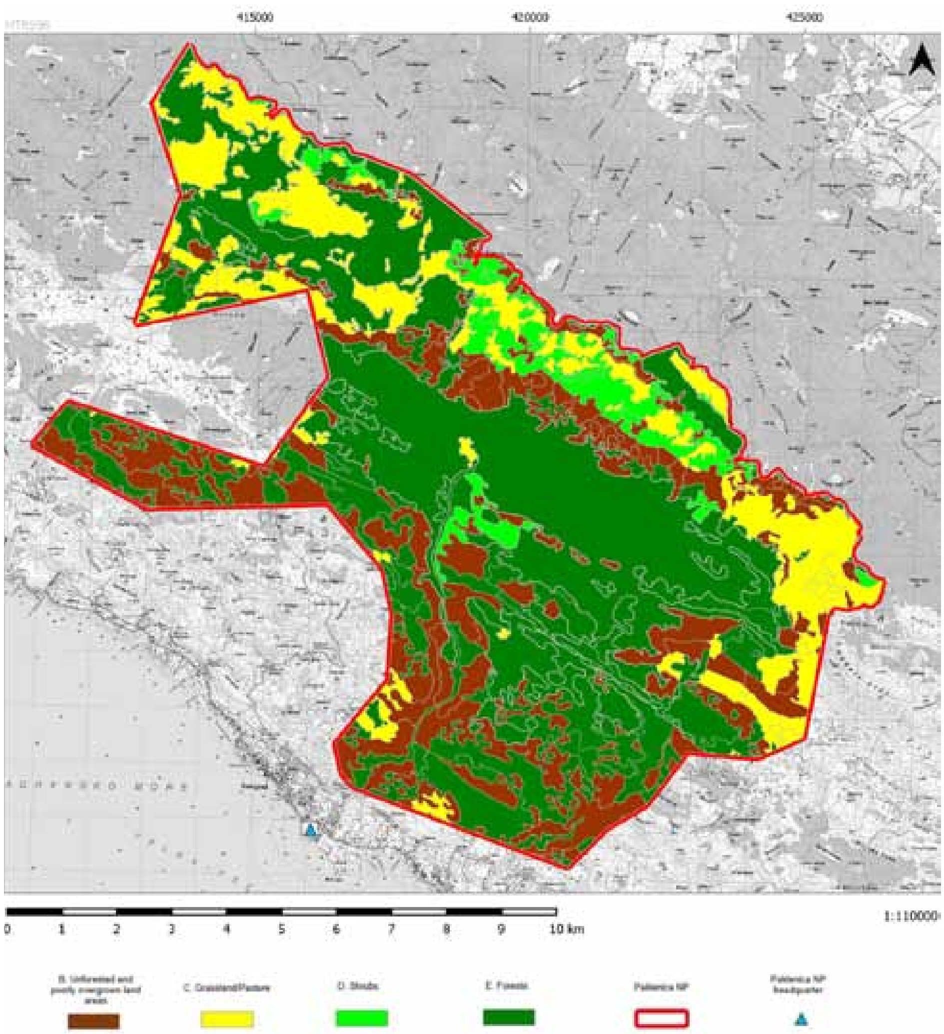


Fig. 1. The habitat map of the Paklenica National Park where camera trapping survey was conducted between 2011 and 2016.

prey for each survey location not only in dependence of camera trapping survey effort, but also in dependence of survey locations with different habitats and substrate types. And finally, the role of rangers in protected areas as an added value for biodiversity monitoring is analysed.

Material and methods

Study area

Paklenica NP is part of the Velebit Mountain and one of the eight national parks of Croatia. The area consisting of Velika and Mala Paklenica was proclaimed a national park in 1949 due to its unique geomorphological structures and natural best-preserved forest complex in the territory of Dalmatia (Fig. 1). The Paklenica NP extends on 95 km^2 and it includes the highest peaks of the Velebit Mountain, Vaganski vrh (1752 m a.s.l.) and Sveto brdo (1753 m a.s.l.). The relatively small area has an abundance of karstic geomorphological phenomena and forms (canyons), diverse flora and fauna, attractive landscapes and intact nature. Floristic features of the Paklenica NP are black pine forests and several types of beech forests. The area is characterised by four different habitat types: unforested and poorly overgrown areas, thermophilic oak, beech and fir forests, grassland/pastures and juniper shrubs (Fig. 1). The various habitats in the Paklenica NP and its complex orography support a very diverse fauna. Birds are the most numerous groups of vertebrates, with 260 species recorded to date; also, 31 amphibian and reptile species have been recorded, of which 11 are snake species. Mammals are represented by 59 species in five different taxonomic orders (unpublished; available in 'Paklenica National Park' Public Institution; Table 1). The most numerous mammalian order is Chiroptera with 24 species, followed by Rodentia (14 species), Carnivora (10 species), Eulipotyphla (six species) and Artiodactyla (five species). Out of 59 mammalian species recorded in the Paklenica NP, 42 species are protected under different categories. Twenty-one mammalian species are categorised by the Interna-

Table 1. List of mammals in the Paklenica NP with information regarding species recorded during camera trapping survey 2011–2016.

Order	**Species**	**Conservation status**					**Ct 2011–2016**
		CRD	**HD**	**BERN**	**CITES**	**SPS**	
Artiodactyla	*Capreolus capreolus*			III			+
	Cervus elaphus			III			+
	Ovis musimon			III			
	Rupicapra rupicapra	RE	II, IV, V*	III		+	+
	Sus scrofa						+
Carnivora	*Canis aureus*		V				+
	Canis lupus	NT	II, IV, V	II	A	+	+
	Felis sylvestris		IV	II	II, A	+	+
	Lynx lynx	RE	II, IV	III	II, A	+	+
	Martes foina			III			+
	Martes martes		V	III			+
	Meles meles			III			+
	Mustela nivalis			III			
	Ursus arctos	NT	II, IV	II	II, A	+	+
	Vulpes vulpes						+
Chiroptera	*Barbastella barbastellus*	DD	II, IV	II		+	
	Eptesicus serotinus		IV	II		+	
	Hypsugo savii		IV	II		+	
	Miniopterus schreibersii	EN	II, IV	II		+	
	Myotis alcathoe					+	
	Myotis aurascens					+	
	Myotis bechsteinii	VU	II, IV	II		+	
	Myotis emarginatus	NT	II, IV	II		+	
	Myotis myotis	NT	II, IV	II		+	
	Myotis mystacinus		IV	II		+	
	Myotis nattereri		IV	II		+	
	Nyctalus leisleri	NT	IV	II		+	
	Nyctalus noctule		IV	II		+	
	Pipistrellus kuhlii		IV	II		+	
	Pipistrellus nathusii		IV	II		+	
	Pipistrellus pipistrellus		IV	II		+	
	Pipistrellus pygmaeus					+	
	Plecotus auritus		IV	II		+	
	Plecotus kolombatovici	DD				+	
	Rhinolophus euryale	VU	II, IV	II		+	
	Rhinolophus ferrumequinum	NT	II, IV	II		+	
	Rhinolophus hipposideros	NT	II, IV	II		+	
	Tadarida teniotis		IV	II		+	
	Vespertilio murinus		IV	II		+	
Eulipotyphla	*Crocidura suaveolens*			III			
	Erinaceus concolor						
	Sorex alpinus			III			
	Sorex araneus			III			
	Suncus etruscus			III			
	Talpa europea						
Rodentia	*Apodemus epimelas*						
	Apodemus flavicollis						
	Apodemus sylvaticus						
	Chionomys nivalis	NT		III			
	Clethrionomys glareolus						
	Dinaromys bogdanovi	DD				+	
	Dryomys nitedula	NT	IV	III		+	
	Eliomys quercinus	NT		III			
	Lepus europaeus	NT		III			+
	Microtus multiplex liechtenstein						
	Mus domesticus						
	Glis glis	LC		III			
	Rattus rattus						
	Sciurus vulgaris	NT		III			+

Notes: *Only *R. rupicapra balcanica*
Conservation status: CRD = Croatian Red Book (IUCN category: EX – extinct, EW – extinct in the wild, CR – critically endangered, EN – endangered, VU – vulnerable, NT – near threatened, LC – least concern, DD – data deficient, NE – not evaluated, NR – not recognised); HD = the Annexes of the EU Directive of the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive); Bern = the Convention on the Conservation of Natural Habitats and of Wild Fauna and Wild Flora; CITES = the Convention on International Trade in Endangered Species of Wild Fauna and Flora; SPS = Croatian Ordinance on strictly protected species (OG, 144/13, 73/16)
CT 2011–2016 = camera trapping survey during 2011–2016 (+ = species recorded during survey)

tional Union for Conservation of Nature global conservation categories for Croatia, 28 are in the Annex II and Annex IV of the Habitats Directive, 42 are in the Annex I and Annex II of the Bern Convention and four are under CITES Convention. Furthermore, 31 mammalian species are categorised as strictly protected species under Croatian legislation. Also, the Paklenica NP is part of Natura 2000 (network of nature protection areas in the territory of the European Union) as site HR2000871 Nacionalni Park Paklenica. Large carnivores (i.e. top predators) inhabiting the Paklenica NP are brown bear (*Ursus arctos* L., 1758), grey wolf (*Canis lupus* L., 1758) and lynx (*Lynx lynx* Linnaeus, 1758). Mesopredators are golden jackal (*Canis aureus* L., 1758), red fox (*Vulpes vulpes* L., 1758), *Martes* sp., wild cat (*Felis silvestris* Schreber, 1777), European badger (*Meles meles* L., 1758) and least weasel (*Mustela nivalis* L., 1766). Medium- to large-sized mammalian prey species are roe deer (*Capreolus capreolus* L., 1758), red deer (*Cervus elaphus* L., 1758), mouflon (*Ovis aries musimon* P., 1811), chamois (*Rupicapra rupicapra* L., 1758) and wild boar (*Sus scrofa* L., 1758).

Camera trapping

Camera surveys were performed between 2011 and 2016 at 22 camera sites (Table 2), with one camera on each site. Sites were chosen opportunistically, that is, on trails that are often used by park rangers, so that the care of the cameras could be incorporated into the usual work tasks of the rangers. Positions of camera traps are shown in

Fig. 2. Passive infrared heat- and motion-sensing cameras were used. Camera models were Cuddeback and SpyPoint Cellular Cameras. The trigger varied between 5 s, 30 s and 1 min. The video/picture set-up was also set differently, but the set-up of the video was dominant. Cameras were placed at locations designed to maximise chances of encountering medium- to large-sized mammalian species. Each camera was fastened to a tree, 1 m above the ground, and focused to area without higher vegetation or onto an animal trail, to capture medium–large-sized mammalian species (Meek et al., 2014). Low-hanging branches and tall grass were trimmed at regular intervals to minimise camera

Fig. 2. Camera trapping sites at the Paklenica National Park during 5-yearlong camera trapping surveys (2011 and 2016).

Table 2. Camera trapping sites at the Paklenica NP during camera trapping survey with starting date, ending date and days in total for an interval.

YEAR / MONTH	ATTRACTANT	DAYS TOTAL
1. Anica luka	-	1
2. Brdo	-	130
3. Brezimenjaća	-	51
4. Buljma	-	2
5. Gornja draga	salt	479
6. Gornja Pila	ponds	3
7. Grabar	-	14
8. Katići	ponds	79
9. Katici sjever	-	10
10. Krivi Kuk	-	22
11. Mala Moćila	corn	242
12. Orlov kuk	salt	1298
13. Piskovita kosa	-	99
14. Podborovnik	-	63
15. Sipar Anica luka	-	1
16. Skiljici	salt	2
17. Solilo M.pec	salt	435
18. Suha draga	-	37
19. Velika moćila	-	157
20. Zapadak	pond	61
21. Zapadak Parića	ponds	9
22. Zapadak Šikića	salt, pond, corn	1279

Table 3. Data spreadsheet organisation.

Column name	Column meaning
Folder no.	Name of the folder (e.g. 1.Podborovnik-solilo M.pec 17.-19.11.2011)
ID no.	Name of the photo/video (e.g. PICT0001)
Photo/video	p = photo; m = video
Day	Day when the photo/video was taken
Month	Month when the photo/video was taken
Year	Year when the photo/video was taken
Time	Time when the photo/video was taken
Duration	Duration of the video (in seconds)
Temp	Temperature when the photo/video was taken (°C)
Night/day	n = night; d = day
Habitat	Habitat type where the camera was set (m = open meadow; k = semi-open karts habitat; v = low vegetation (bushes) up to 1.5 m; y = young forests; o = old forest [trunk thicker than approx. 30 cm])
Substrate	Substrate type where the camera was set (1 = stone; 2 = soil; 3 = sand; 4 = gravel; 5 = leaf litter)
Species	Latin name of the species – photocaptures of animals for which it was not possible to clearly determine the species (C category during assessment = safety assessment of species determination) were recorded as – ('dash')
Abundance	Abundance of the animals for each species on photo/video
Assessment	Safety assessment of species determination (A = 100% sure; B = maybe, but not sure; C = do not know species)
Species type	m = small prey (all Muridae); p = prey (larger than Muridae); v = small carnivore (everything smaller than large carnivores); c = large carnivore (bear, wolf, lynx, jackal); s = scavengers
Lure type	For example, salt, carcass (species), pond, etc.
Location	Location of the camera trap
Type of protection	Type of the area protection (n = non-protected area; if protected area, then write a name of the protected area [e.g. NP Paklenica])
County	Camera trap area county name
State	Camera trap area state name

misfires and provide an unobstructed view. Salt was used as an attractant in 20% of the survey locations, which can cause bias in the results. In 20% of the locations, camera traps were set next to small ponds. In 60% of the locations, cameras were not set near attractant or water source. If an attractant or water source was used, camera was directed to it. Cameras were triggered by movement and programmed to take pictures or videos in rapid succession (varying between 5 s, 30 s and 1 min). A semi-covert low-glow infrared flash was used to illuminate images at night. Cameras were checked once a month to change batteries and memory cards and to ensure proper functioning. All images were tagged with the time, date and temperature, while videos were only stamped with time and date.

Data collection and processing

Data from camera traps' memory cards was organised into folders, named by location and date, and stored on a central computer. Data spreadsheet was used for data entry, which was organised with 21 columns representing different data details (Table 3). As the capture delay period was uneven (varying between 5 s, 30 s and 1 min) due to constant improvements in research settings, independent events were defined as a picture/video with presence of an animal detected by a sensor and documented by a camera, that is event 5 min separated before previous event of the same species. Camera trapping survey effort (number of 24-h operational camera trap nights) at each location was calculated from the date the camera was set until the date it was retrieved or, if the cameras malfunctioned, until the date stamped on the last picture taken.

For all photocaptures, medium- to large-sized mammalian species determination was performed. The other groups of animals recorded on photos (Rodentia, Eulipotyphla, Chiroptera, *Martes* sp., Aves and Insecta) were not determined to the species level due to the camera traps setting methodology adapted to capture medium- to large-sized mammalian species. Mouse-like species (e.g. mice, rats, including all Eulipotyphla) were identified as 'small mammals' and all bats as Chiroptera. Furthermore, beech marten (*M. foina*) and pine marten (*M. martes*) were also not determined to species level because on most events, the species determination was not possible. So, ultimately, all these occurrences were classified as *Martes* sp. Also, species determination for insects and birds was not done, as they were identified in spreadsheet as Insecta and Aves. At last, there were also images of humans and domestic dogs, which were recorded as *Homo sapiens* and *Canis lupus familiaris*.

Data analysis

SRI was calculated only for medium- to large-sized mammalian species. SRI was calculated as the sum of all recorded different species for each survey location and for the entire research area. SRI was also calculated for different habitats, substrates, temperature groups, seasons, day/night periods and photo/movie records. In order to analyse the time required to record all species of animals present in the study area, correlation was used. Thus, correlation was calculated between recorded SRI and camera trapping survey effort for each survey location. Calculation was done by the software Past, version 4.05 (Hammer et al., 2001).

To analyse predator–prey ratio, the number of events when prey was recorded was compared to the number of events when predator was recorded for each site. Also, the sum of all prey individuals that were recorded was compared to the sum of all predator individuals. As this camera trapping survey methodology was not intended to calculate the abundance, correlation was calculated between the total number of events by each species and species abundance data. Calculation was also done by the software Past, version 4.05, and data sets were also normalised (log base 10) before calculating the correlation (Hammer et al., 2001). To analyse the Paklenica NP ecosystem food web in even more detail, three additional analyses were done. The food web was simplified on the trophic pyramid with three levels (top predator, mesopredator, prey). In the trophic pyramid of the Paklenica NP ecosystem, large carnivores were defined as top predators, small carnivores as mesopredators and non-carnivores as prey. Large carnivores were defined as species with average adult body masses ≥15 kg, while the remaining smaller carnivore species were defined as small carnivores, that is, mesopredators (Ripple et al., 2014). Therefore, first additional analysis was done comparing the SRI in relation to presence/absence of top predators, mesopredators and prey species. Additionally, SRI was compared regarding the presence of different top predators (wolf/bear/lynx). To analyse data sets in an even more detailed form regarding the interaction of top predators, mesopredators and prey in the Paklenica NP, second additional analysis was done. Distribution of recorded species during 4-h intervals was compared for three different situations: (1) when a top predator was recorded (with/without a mesopredator and/or prey), (2) when a mesopredator with prey was recorded and (3) when only prey was recorded. After all these, third additional analysis was done regarding the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) for each survey location not only in dependence of camera trapping survey effort, but also in dependence of survey locations with different habitats and substrate types. It was done by PCA to analyse the main groups of variables that are correlated. Analysis was done for four different data ranges: for all locations (20 in total), for locations (four) where cameras were set longer than a year, for locations (eight) where cameras were set longer than 3 months, and lastly, for locations (13) where cameras were set longer than 1 month. Furthermore, locations with top predator presence were analysed regarding locations without top predator presence. Also, the same PCA was done with data sets of total number of photos by each species on each habitat type and data sets of total number of photos by each species on each substrate type. Data sets of total number of photos by each species on each location were normalised (percentage), so that eigenvalues for variance could be calculated.

In order to quantify the financial aspect of the ranger service, a comparative analysis was done. The cost for conducting camera trapping surveys by external service was compared with the cost for conducting camera trapping surveys by nature park employees. Cost of a day of research conducted by external experts was collected from three biggest Croatian private companies that are conducting biological/ecological surveys. Cost per day of research conducted by the internal national park service was collected from the Paklenica NP. Their employees who can conduct camera trapping surveys are classified into four different categories: ranger service officer, ranger service chief supervisor, senior adviser and conservation manager. Further on, to calculate the number of days needed to conduct camera trapping survey from this case study in the Paklenica NP, camera trapping survey effort for each survey location was divided by 15, since it is common for camera trapping surveys to inspect each survey location every 15 days. Furthermore, the divided results (camera trapping survey effort for each survey location divided by 15) were increased by one additional day, which represents the first day of going to the survey location to set a camera trap. Lastly, the divided results increased by one additional day were summed up for all survey locations together to calculate the total number of days needed to conduct this camera trapping survey. The summed days were then multiplied by the cost of a day of each type of researcher and compared with each other. Since this case study was conducted jointly by ranger service officers and ranger service chief supervisor, their cost was calculated as the mean value.

Results

During these 5-yearlong camera trapping surveys, total survey efforts were 4474 camera days. Four locations had total survey efforts longer than 1 year and comprised 78% of the total survey effort, so the other 18 survey locations contained the remaining 22% of the total survey effort. Eleven locations had camera trapping survey efforts shorter than 2 months.

Fourteen mammalian species were recorded (Table 4) as follows: golden jackal (*Canis aureus*), grey wolf (*C. lupus*), European roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), wild cat (*Felix silvestris*), European hare (*Lepus europaeus*), Eurasian lynx (*Lynx lynx*), Eurasian badger (*Meles meles*), northern chamois (*Rupicapra rupicapra*), Eurasian red squirrel (*Sciurus vulgaris*), wild boar (*Sus scrofa*), brown bear (*Ursus arctos*), red fox (*Vulpes vulpes*), and marten (*Martes* sp.). Furthermore, other determined groups were Chiroptera, Insecta and Rodentia. Regarding NATURA 2000 site HR2000871 Nacionalni park Paklenica, all medium–large mammalian key species were recorded during this survey.

In total, 16,289 events (photos/movies with animals) were recorded with 16,132 events (99.04%), where it was possible to determine the species, whereas in 157 events (0.96%), it was not possible to determine the species. In these 16,132 events, there were, in total, 31,727 recorded individual animals (because in some photos, there were groups with up to 14 animals). Ungulates were the most frequently recorded: northern chamois (58.69% of all photos/movies), red deer (17.96%), wild boar (9.05%) and European roe deer (7.66%). On the other hand, the species with the lowest number of photos were predators: Eurasian lynx – 0.03%, grey wolf – 0.02% and golden jackal – 0.01%. Not including humans, the species that were recorded at most survey locations were wild boar, roe deer and northern chamois (64% of all camera trapping locations). Carnivores were recorded at less than 50% of all camera trapping locations as follows: red fox – 8 (3%), brown bear – 7 (32%), *Martes* sp. (beech and pine marten) – 7 (32%), wild cat – 5 (23%), grey wolf – 3 (14%), Eurasian lynx – 3 (14%) and golden jackal – 1 (5%).

Average number of recorded animals per event was 1.96 (standard error [SE] = 0.0109). Ungulates had higher average

Table 4. Species recorded during camera trapping survey for each camera trapping site at the Paklenica National Park.

Location		**1. Anica luka**	**2. Brdo**	**3. Brezimenjača**	**4. Buljma**	**5. Gornja draga**
From–to (intervals)		01.12.2011–01.12.2011	29.01.2013–11.05.2013; 25.10.2014–20.11.2014	27.06.2016–16.08.2016.	28.10.2014–29.10.2014.	18.01.2014–26.03.2015; 23.09.2015–07.11.2015
Total duration	Years					1
	Months		4	1		3
	Days	1	10	21	2	25
	Days sum	1	130	51	2	479
Species records	*Sus scrofa*			+		+
	Capreolus capreolus					+
	Rupicapra rupicapra	+	+			+
	Cervus elaphus					+
	Lepus europaeus		+			+
	Vulpes vulpes	+				+
	Ursus arctos		+			+
	Meles meles		+			+
	Martes sp.					+
	Felis silvestris					
	Canis lupus					
	Rodentia					
	Lynx lynx					+
	Canis aureus					
	Sciurus vulgaris					
	Homo sapiens		+		+	+
	Aves		+			+
	Canis lupus familiaris					
	Chiroptera					
	Insecta					

Table 4. Species recorded during camera trapping survey for each camera trapping site at the Paklenica National Park - continuation.

Location		**6. Gornja Pila**	**7. Grabar**	**8. Katići**	**9. Katici sjever**	**10. Krivi Kuk**
From–to (intervals)		17.03.2016–19.03.2016	12.10.2014–14.10.2014	01.01.2015–10.01.2015; 11.05.2015–17.05.2015; 17.04.2016–17.06.2016	05.12.2014–14.12.2014	09.11.2016–30.11.2016
Total duration	Years					
	Months			2		
	Days	3	14	18	10	22
	Days sum	3	14	79	10	22
Species records	*Sus scrofa*	+	+	+		
	Capreolus capreolus	+		+		
	Rupicapra rupicapra			+		+
	Cervus elaphus			+		
	Lepus europaeus					
	Vulpes vulpes					
	Ursus arctos					
	Meles meles					
	Martes sp.					
	Felis silvestris			+		
	Canis lupus					
	Rodentia					
	Lynx lynx					
	Canis aureus					
	Sciurus vulgaris					
	Homo sapiens		+	+	+	
	Aves					
	Canis lupus familiaris					
	Chiroptera					
	Insecta					

Table 4. Species recorded during camera trapping survey for each camera trapping site at the Paklenica National Park - continuation.

Location		**11. Mala Močila**	**12. Orlov kuk**	**13. Piskovita kosa**	**14. Podborovnik**	**15. Sipar Anica luka**
From–to (intervals)		08.07.2015–24.12.2015; 24.08.2016–03.11.2016.	18.01.2013–03.06.2013; 20.08.2013–17.02.2016; 06.04.2016–10.12.2016	08.12.2011–11.12.2011; 24.11.2015–23.12.2015; 24.08.2016–27.10.2016	18.10.2011–26.10.2011; 14.11.2014–06.01.2015	04.02.2013–04.02.2013
Total duration	Years		2			
	Months	7	18	3	3	
	Days	28	21	8	3	1
	Days sum	242	1298	99	63	1
Species records	*Sus scrofa*	+	+	+	+	
	Capreolus capreolus	+	+	+	+	
	Rupicapra rupicapra		+	+	+	+
	Cervus elaphus	+	+	+	+	
	Lepus europaeus	+	+	+	+	
	Vulpes vulpes	+	+	+	+	
	Ursus arctos	+	+			
	Meles meles	+	+	+		
	Martes sp.	+	+		+	
	Felis silvestris	+	+			
	Canis lupus		+		+	
	Rodentia		+			
	Lynx lynx		+			
	Canis aureus		+			
	Sciurus vulgaris					
	Homo sapiens	+	+	+	+	
	Aves		+			
	Canis lupus familiaris					
	Chiroptera					
	Insecta					

Table 4. Species recorded during camera trapping survey for each camera trapping site at the Paklenica National Park - continuation.

Location		**16. Skiljici**	**17. Solilo M.pec**	**18. Suha draga**	**19. Velika močila**	**20. Zapadak**
From–to (intervals)		30.12.2013–31.12.2013	22.10.2011–15.11.2011; 12.03.2013–23.03.2014; 04.06.2014–06.07.2014	30.05.2015–05.07.2015	01.08.2011–02.08.2011; 23.11.2011–27.11.2011; 23.04.2015–30.06.2015; 17.03.2016; 03.05.2016–21.07.2016	24.08.2011–08.09.2011; 09.11.2011–23.12.2011
Total duration	Years		1			
	Months		2	1	5	2
	Days	2	10	6	5	1
	Days sum	2	435	37	157	61
Species records	*Sus scrofa*		+		+	+
	Capreolus capreolus	+	+	+	+	+
	Rupicapra rupicapra	+	+	+	+	
	Cervus elaphus		+		+	+
	Lepus europaeus		+	+	+	
	Vulpes vulpes					+
	Ursus arctos		+		+	
	Meles meles		+			
	Martes sp.		+			+
	Felis silvestris		+			
	Canis lupus					
	Rodentia		+			
	Lynx lynx	+				
	Canis aureus					
	Sciurus vulgaris		+			
	Homo sapiens	+	+	+	+	+
	Aves					
	Canis lupus familiaris					
	Chiroptera					
	Insecta					

Table 4. Species recorded during camera trapping survey for each camera trapping site at the Paklenica National Park - continuation.

Location		21. Zapadak Parića	22. Zapadak Šikića	Total
From–to (intervals)		10.02.2016–19.02.2016	17.02.2013–25.06.2014; 17.08.2014–05.07.2016; 10.09.2016–20.09.2016; 07.10.2016–30.12.2016	
Total duration	Years		2	**6**
	Months		18	**69**
	Days	9	3	**233**
	Days sum	9	1279	**4474**
Species records	*Sus scrofa*	+	+	**14**
	Capreolus capreolus	+	+	**14**
	Rupicapra rupicapra		+	**14**
	Cervus elaphus		+	**10**
	Lepus europaeus		+	**10**
	Vulpes vulpes		+	**8**
	Ursus arctos		+	**7**
	Meles meles		+	**7**
	Martes sp.		+	**7**
	Felis silvestris		+	**5**
	Canis lupus		+	**3**
	Rodentia		+	**3**
	Lynx lynx			**3**
	Canis aureus			**1**
	Sciurus vulgaris			**1**
	Homo sapiens		+	**16**
	Aves		+	**4**
	Canis lupus familiaris		+	**1**
	Chiroptera		+	**1**
	Insecta		+	**1**

numbers of recorded animals per event as follows: northern chamois – 2.24 (SE = 0.014), wild boar – 2.19 (SE = 0.057), red deer – 1.58 (SE = 0.020), European roe deer – 1.37 (SE = 0.017). They also had higher maximal number of recorded animals per event (wild boar – 14, northern chamois – 11, red deer – 6, European roe deer – 5) as they are usually in groups/herds, while most carnivores were recorded only solitary (Eurasian lynx, grey wolf, golden jackal, *Martes* sp.).

Due to camera trapping locations (Fig. 3), three locations recorded the highest SRI with more than 10 different mammalian species, seven locations recorded between five and 10 different mammalian species, 10 locations recorded less than five different mammalian species and two locations did not recorded any wildlife species (humans were only recorded). Regarding the SRI for locations during day period compared to during night period, higher values were recorded during night than during day period.

Moreover, SRI was analysed with regard to different habitats, substrates, temperatures, seasons and day/night periods, and the highest SRI values were found for semi-open karst habitat, stone substrate, temperature group 0–9 °C, during autumn, during night and recorded on photo (Fig. 4).

To analyse the time required to record all species of animals present in the study area, species richness was compared with camera trapping survey effort for each survey location. The correlation coefficient between the log subject variables was 0.901 ($P < 0.05$), which confirms that the two data sets are positively correlated. In the first 200 days, eight of 14 species were recorded (almost 60%); with a further doubling of the effort, a maximum of one additional species was detected (Fig. 5). These additionally detected species were mostly elusive species that have been rarely recorded or large carnivore species that have low abundances as top predators. The same pattern can be seen analysing only top predator species records.

Regarding predator–prey rations, events were analysed when wildlife was recorded, and prey species were much more often recorded than predator species (15,655 records; 98.35% of all records were ungulates, i.e. prey species). Of the 263 recorded photos of predators in this camera trapping survey, 54% were top predators and 46% were mesopredators. The same pattern was seen on analysing data regarding the number of recorded animals, that is, abundance. Namely, 31,144 recorded animals (99.07%) were prey species and only 293 animals (0.93%) were predator species. Although this camera trapping survey methodology was not intended to calculate abundance, on comparing data of the total number of photos by each species and species abundance data, a positive correlation was found with a correlation value of 0.997 ($P < 0.05$).

To analyse the Paklenica NP ecosystem food web in even more detail, three additional analyses were done. The first additional analysis was done comparing the SRI in relation to presence of top predators, mesopredators and prey species. Average SRI in the presence of top predators was 8.56, which is higher than the average SRI in the presence of mesopredators (7.91) or prey species (5.35). Average SRI within all locations was 4.86. Regarding large carnivores, the highest average SRI was recorded in the presence of grey wolf (11.33). To analyse data sets in an even more detailed form regarding the interaction of top preda-

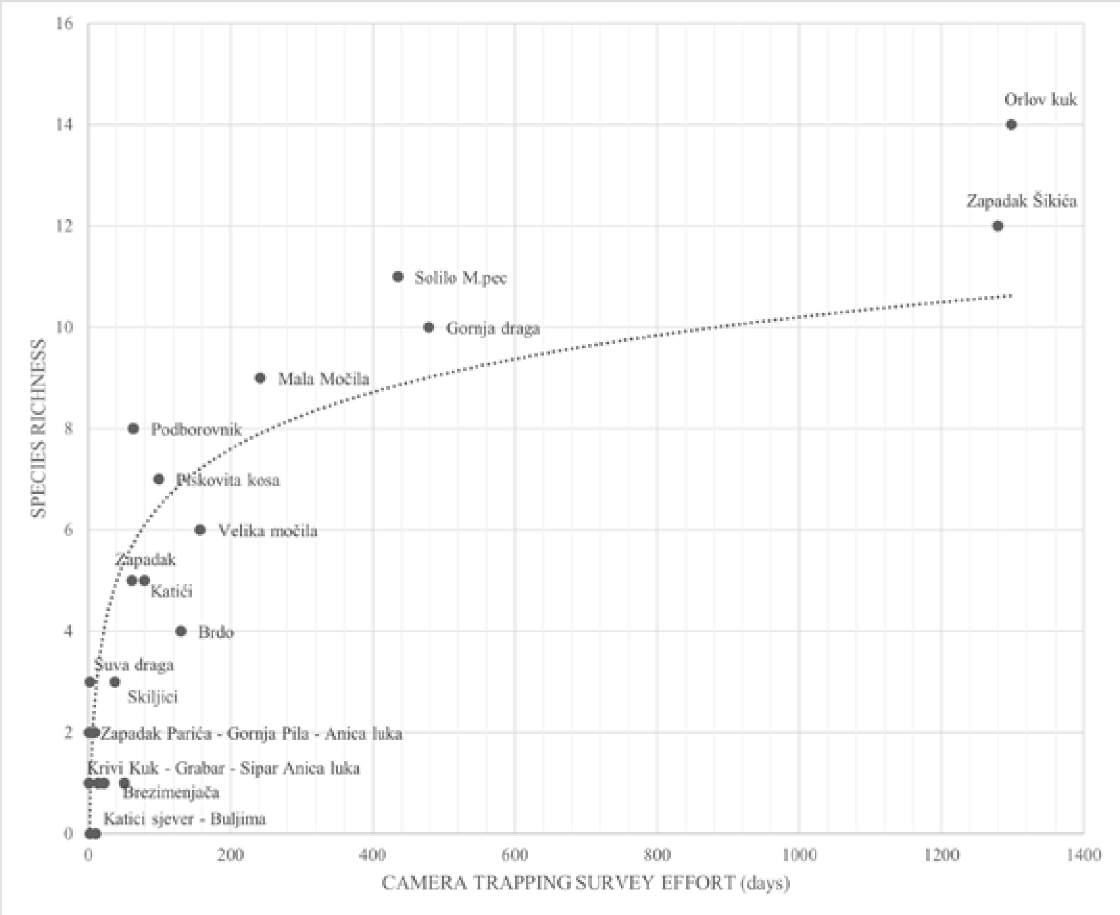


Fig. 3. Species richness of the survey locations.

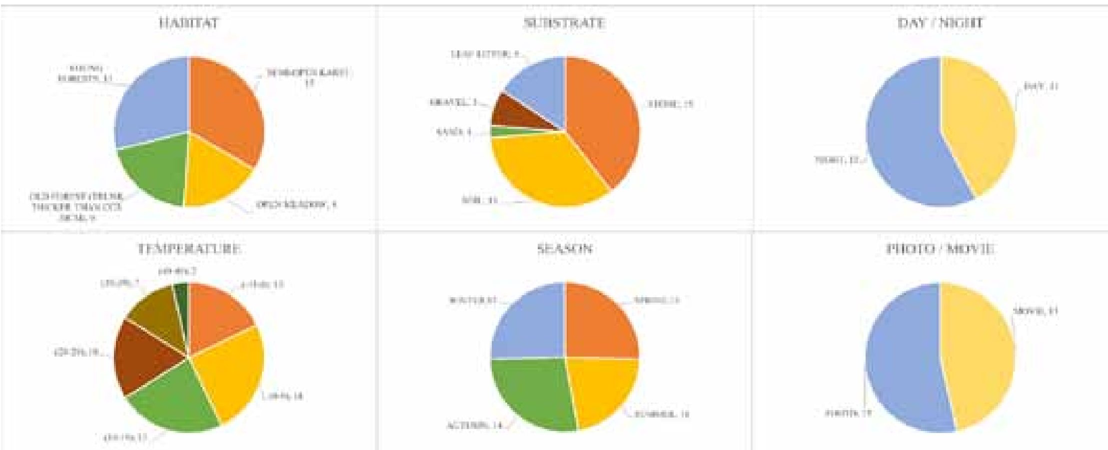


Fig. 4. SRI distribution based on six different characteristics of the camera trapping locations: habitat, substrate, temperature group, seasons, day/night period, photo/movie. (SRI: species richness index)

tors, mesopredators and prey in the Paklenica NP, second additional analysis was done. The distribution of recorded species at 4-h intervals was examined for three different situations: (1) when a top predator was recorded (with/without mesopredator and/or prey), (2) when only mesopredator was recorded with prey (without top predator) and (3) when only prey was recorded (without top predator or mesopredator). Of the total number of intervals in which a top predator was recorded (90 intervals), 80% fell on intervals where only a top predator was recorded, while in 20% of intervals, prey was recorded with a top predator. In intervals in which prey was recorded alongside a top predator, the highest percentage belonged to *Cervus elaphus* (38.46%)

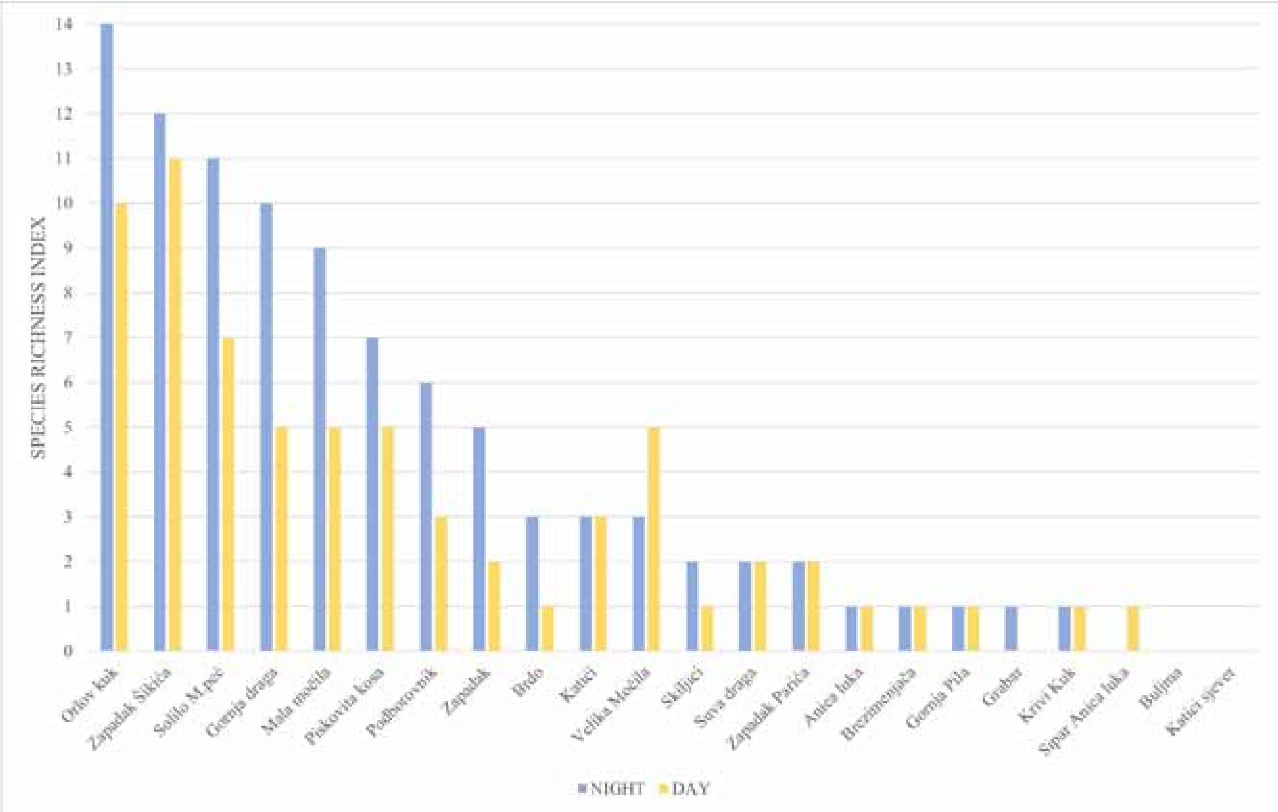


Fig. 5. Comparison of the recorded species richness and camera trapping survey effort for each survey location.

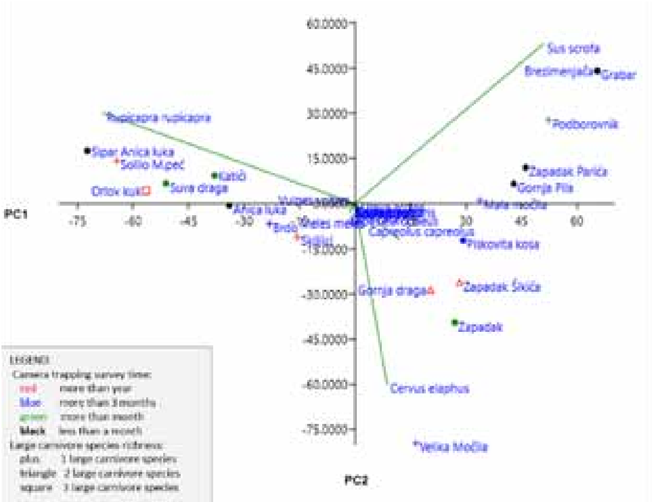
and *Rupicapra rupicapra* (38.46%), while the lowest percentage belonged to *Sus scrofa* (2.56%). There was no interval where a mesopredator was recorded with the top predator. Of the total number of intervals in which a top predator was not recorded (3146 intervals), 96.95% fell on intervals where only a prey was recorded, 1.81% on intervals where only mesopredator was recorded and 1.24% on intervals where mesopredator was recorded with prey.

After these, a third additional analysis (PCA) was done regarding the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of (1) camera trapping survey effort and number of different top predator species present and (2) survey locations with different habitats and substrate types.

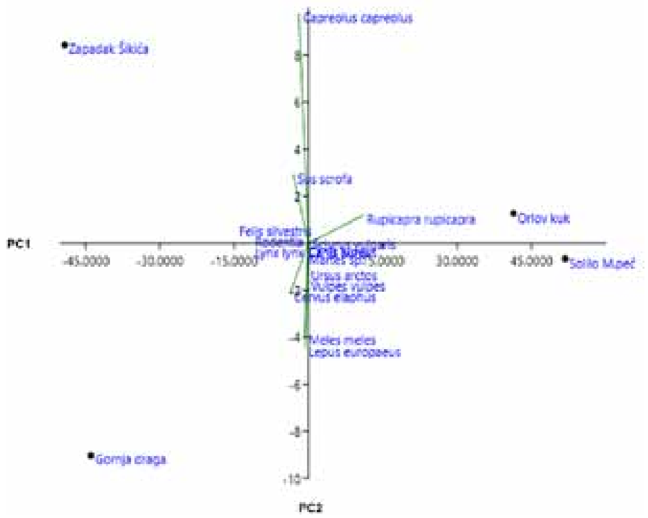
On analysing all camera trapping locations together (regardless of the different camera trapping survey efforts – PCA1; Fig. 6), noticeable grouping of survey locations or species was not observed. On analysing PCA1 graph, *S. scrofa* was the species which was the most dominant in the location Brezimenjača, Grabar and Podbornik (young forest habitat with soil substrate), *Cervus elaphus* was dominant in Velika Močila and Zapadak (young forest habitat with soil/leaf litter substrate) and *Rupicapra rupicapra* was dominant in Sipar Anica luka and Solio M.peć (karst habitat with stone substrate). Also, there was no grouping of survey locations according to the duration of the cameras or the presence of large carnivores. On analysing the locations where the cameras were set longer than a year (PCA2; Fig. 6), longer than 3 months (PCA3; Fig. 6) or longer than a month (PCA4; Fig. 6), noticeable grouping of survey locations or species was not observed. All four PCAs regarding different camera trapping survey efforts showed Ungulates (prey) as a dominant species. The analysis showed a certain grouping of localities in the direction of wild boar, chamois and deer. It is not exclusive, but may indicate that certain habitat types are dominated by certain dominant large prey, as they are the first ones who exploit the habitat (herbivores are related to available plants), followed by predators (lynx to chamois, wolf to wild boar and deer). Bear is present everywhere since it combines different habitats and prey types, and it is not an exclusive carnivore.

Regarding the PCA of the interaction of recorded species in dependence of survey locations within different habitats (PCA5; Fig. 6) and substrate types (PCA6; Fig. 6), noticeable grouping was not observed in this also.

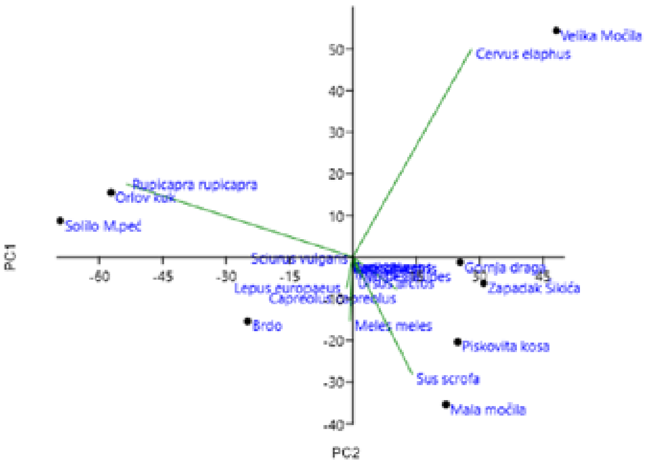
Regarding the comparison of costs for conducting camera trapping survey by external service and internal national park service, the findings were as follows. External service costs varied from 266 € per day to 400 € per day; so for further calculations, we used the mean value (332 € per day). Internal Paklenica NP service costs varied significantly depending on the employment rank. The cost of the ranger service officer's working day was 33 € per day, ranger service chief supervisor's cost was 44 € per day, senior adviser's cost was 55 € per day and conservation manager's cost was 62 € per day. The calculated total number of days needed to conduct this camera trapping survey case study was 333 days. Therefore, the total cost of this research could be as follows according to the type of employee who could conduct the survey: external service – 110,556 €, ranger service officer – 10,989 €, ranger service chief supervi-



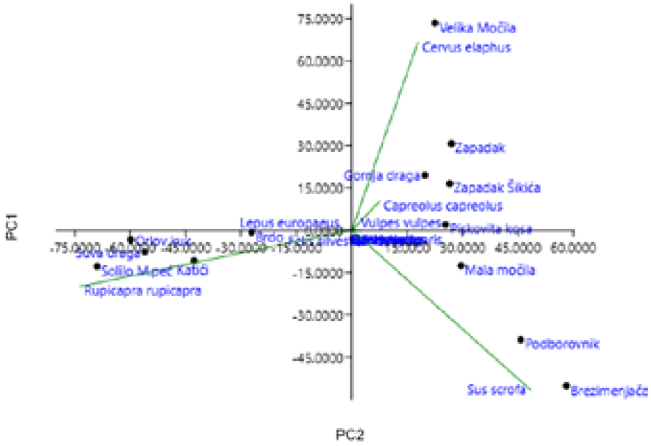
PCA1 – PCA graph representing the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of camera trapping survey effort and number of different top predator species present for all camera trapping locations together.



PCA2 – PCA graph representing the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of camera trapping survey locations where cameras were set for longer than a year.



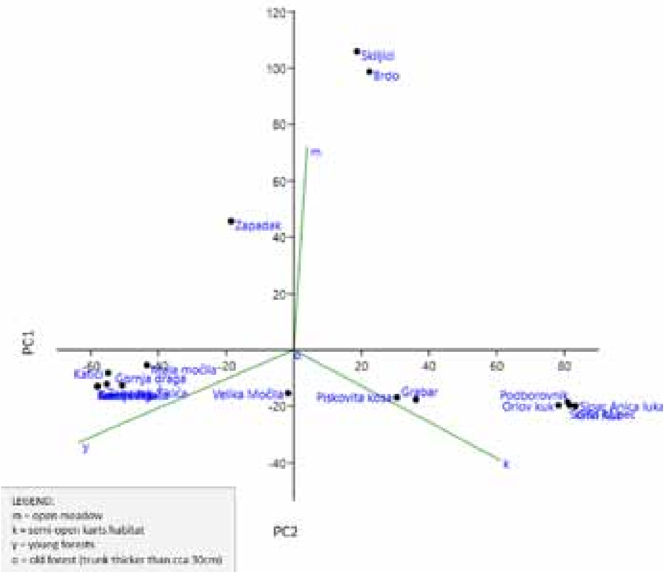
PCA3 – PCA graph representing the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of camera trapping survey locations where cameras were set for longer than 3 months.



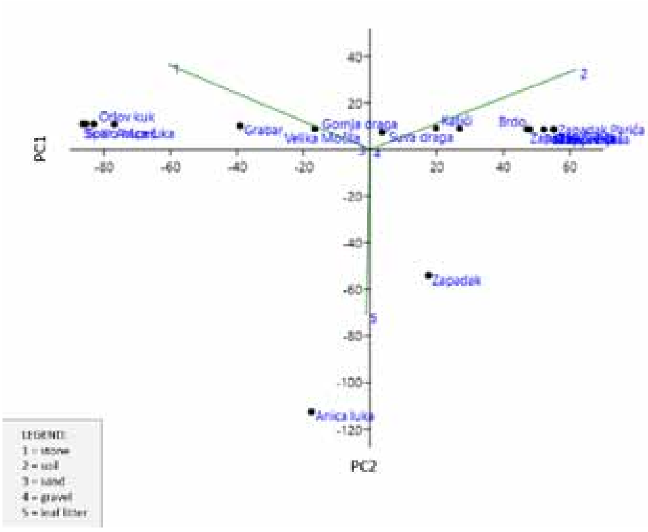
PCA4 – PCA graph representing the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of camera trapping survey locations where cameras were set for longer than a month.

Fig. 6. PCA (principal component analysis) graphs regarding the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of (1) camera trapping survey effort and number of different top predator species present and (2) survey locations with different habitats and substrate types.

sor – 14,652 €, senior adviser – 18,315 € and conservation manager – 20,646 €. The total cost of joint work by ranger service officers and ranger service chief supervisor was 97,736 €. External service had the highest cost price for conducting research, even five times higher than the cost of the Paklenica NP highest ranking employee, that is, conservation manager. Ranger service officer had the lowest cost for conducting research, nine times lower than the external service cost. Ranger service chief supervisor's cost was 33% higher than the ranger service officer's cost, senior adviser's cost was 67% higher and conservation manager's cost was 88% higher than the ranger service officer's cost. The total cost of joint work by ranger service officers and ranger service chief supervisor was seven times lower than the external service's cost.



PCA5 – PCA graph representing the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of survey locations within different habitats.



PCA6 – PCA graph representing the interaction within the levels of the trophic pyramid in dependence of survey locations within different substrate types.

Fig. 6. PCA (principal component analysis) graphs regarding the interaction of recorded species (i.e. top predators, mesopredators and prey as different levels of the trophic pyramid) in dependence of (1) camera trapping survey effort and number of different top predator species present and (2) survey locations with different habitats and substrate types.

Discussion

Data gathered through this study represents the first peer-reviewed list of medium- to large-sized mammalian species for the Paklenica NP, as up till now, no such publication exists on the Paklenica NP mammalian diversity. Considering unpublished data and grey literature available for the Paklenica NP, 15 medium–large-sized mammalian species (of 17 species previously recorded) have been recorded in this camera trapping survey, with no additional/new species. Out of 17 previously recorded species in the Paklenica NP, this survey did not record two mammalian species: mouflon (*Ovis musimon*) and weasel (*Mustela nivalis*) (unpublished; available in 'Paklenica National Park' Public Institution). Previous record of mouflon is probably the result of introduction by hunters; however, the reintroduced individuals did not create a stable population in the subject area and there was no subsequent reintroduction. On the other hand, weasel was probably not recorded during our survey because for small mustelids, camera trapping methodology needs adjustments; traps often fail to detect small and relatively fast-moving species due to the sensitivity of the passive infrared sensor (Mos, Hofmeester, 2020). Also, as Rodentia, Eulipotyphla, Chiroptera and *Martes* sp. were not determined to the species level, due to the camera setting methodology adapted to capture medium- to large-sized mammalian species, this survey did not record 12 previously noted species of Rodentia, two of Martes, six of Eulipotyphla and 24 of Chiroptera (unpublished; available in 'Paklenica National Park' Public Institution). Camera trapping can be also used for small mammals (Glen et al., 2013; De Bondi et al., 2010), but the set-up methodology is different than for medium/large mammals (Smith, Coulson, 2012). Of the medium-sized mammals from the order Rodentia, only *Lepus europaeus* and *Sciurus vulgaris* were determined to the species level. All three large carnivore key species of Natura 2000 site NP Paklenica (brown bear, grey wolf and Eurasian lynx) were recorded during this survey. This Natura 2000 site is part of a larger continuous area, that is, large carnivore habitat in the Dinaric region, which extends through Croatia, Slovenia and Italy and includes 10 sites. All 10 Natura 2000 sites are characterised by similar wildlife, especially as habitats for all three large carnivores that are present in nature parks across the Alpine/Dinaric region. Furthermore, two Alpine national parks (Dolomiti Bellunesi National Park, Italy and Triglav National Park, Slovenia) that are characterised by Alpine habitats and climate have similar mammalian diversity (unpublished: available for clarification in Dolomiti Bellunesi National Park, unpublished: available for clarification in Triglav National Park) as the Paklenica NP, which represents the Dinaric region, southern mountainous extension of the Alps.

Natural trophic pyramid relationships can be anticipated according to the total number of photos by each species, SRI, abundance and calculated 4-h intervals. Analysing these four numbers may be useful to study relationships in the trophic pyramid of the Paklenica NP ecosystem, especially top predator–mesopredator–prey relationship (Ritchie, Johnson, 2009).

It is not only expected in trophic pyramid that prey abundance is higher than the mesopredator abundance, but also that mesopredator abundance is higher than predator abundance (Dussault, 2020), but our results showed a different pattern primarily because regarding the target animals, the camera set-up of the ranger was not intended for smaller animals and the mesopredators of Paklenica NP are mostly smaller than the prey and secondarily, it is related to the uneven sampling and effort. In our study, more events were recorded with top predators than mesopredators. As top predators are above other smaller predators (mesopredators) in a trophic pyramid, it would be expected that top predator abundance is lower than mesopredator abundance (Trebilco et al., 2013). It is the same with food webs, where top predators are with smaller abundance than mesopredators and prey. This relation is common in nature; so, herbivores which are at the lower part of trophic pyramid are present in higher abundance and carnivores are at the top of the pyramid in lower abundance than their prey (ungulates). So, organisms that are higher in 'trophic pyramid of numbers' are less abundant than the ones lower down (Trebilco et al., 2013). This can be explained by the fact that the methodology of this camera trapping survey was adjusted to the recording of medium to large mammalian species, and therefore, the number of photos with smaller mammalian species, like smaller carnivores, was less than expected. Another possible explanation for the obtained result is that camera traps set for large species are usually set in semi-opened habitats for better overview (detection), which could be avoided by smaller species due to top predator presence. To verify if the obtained results could have been compensated by different camera trapping settings, it may be needed in future studies to set camera traps in different heights from the ground and use more heterogeneous habitats (Meek et al., 2014). Furthermore, Maffei, Noss (2008) recommend setting one camera at three to four home ranges in community where large carnivores are present, in order to avoid exaggerating the estimate. The camera should face a direction in relation to the expected animal travel and path of the sun. Also, it is needed to predict the vegetation growth because if we place the camera before the vegetation season and leave it there for a few months, the vegetation may grow so much that it will block camera traps and good results may not be obtained (Roveroa, 2013). Additionally, wind can move vegetation, which will trigger camera traps creating numerous blank photos. It is also important to use a very firm camera support because motion of the sensor may produce false triggers (Swann et al., 2004). Baits, including lures and attractants, are used widely in association with camera traps to increase the probability of detecting a target species or a suite of species (du Preez et al., 2014). Typical camera mode options include photos, video or both. Photos provide distinct points-in-time data that can be coded and analysed more easily than video, and also, still images can be extracted from video files. Video footage is commonly used in bird nest research and in studying animal behaviour (Kross, Nelson, 2011) and predation (Reif, Tornberg, 2006).

Furthermore, it is expected that the diversity of species grows as we ascend the trophic pyramid levels (Trebilco et al., 2013). We also confirm this in our survey; the highest SRI index was recorded when top predators were present, lower SRI was recorded when mesopredators were present, and the lowest SRI was recorded when only prey was present. As this study represents the first peer-reviewed list of mammalian species for the Paklenica NP, maximal species richness was calculated with the presence of top predators. Now it will be possible in further research to compare and analyse maximal species richness to identify changes in the ecosystem. Top predators have strong effects on the trophic dynamics and diversity of the systems in which they occur (Ritchie, Johnson, 2009), and also, diversity of higher trophic level organisms may serve as a key predictor of multifunctionality and, therefore, a good management target for a protected area like NP Paklenica (Schuldt et al., 2018).

On the other hand, on analysing the trophic relationships at 4-h intervals, the usual trophic pyramid relationships (Dussault, 2020) were recorded: most intervals were with only prey, there was no interval where a mesopredator was recorded with a top predator, while when a top predator was not recorded, most of the intervals were only with a prey and just a few of them were with only mesopredators or mesopredators with prey.

Also, it is interesting to note that northern chamois was the most photographed species (58.70% of all recorded photos) and the most abundant species (66.61% of all recorded animals). It was recorded predominantly at the survey locations Orlov kuk and Solilo M.peć, which are characterised by a semi-open karst habitat, natural habitat of the northern chamois that is more suitable than the woodland habitat (Fankhauser, Enggist, 2004). Although forest habitats may also be suitable for norther chamois, the species was less frequently recorded there because predators (brown bear and grey wolf) and a competitor (wild boar) have been recorded in the same area (Šprem et al., 2015). On the contrary, red deer and roe deer were mostly recorded in woodland habitats and less frequently in semi-open karst habitats, which corresponds to their ecology (Malnar et al., 2015; Hewison et al., 1998; Morellet et al., 2010). Furthermore, grey wolf, brown bear and wild boar were mostly recorded in the forest habitats, which is in accordance with previous studies (Skorup, 2005; Thurfjell et al., 2009). All the above can also be perceived on the PCA graphs. For example, wild boar was the most dominant for the location Brezimenjača, Grabar and Podbornik (young forest habitat with soil substrate), red deer for Velika Močila and Zapadak (young forest habitat with soil/leaf litter substrate) and northern chamois for Sipar Anica luka and Solio M.peć (karst habitat with stone substrate).

Correlation between recorded species richness and camera trapping effort recorded in this study confirms the hypothesis that increasing the camera trapping survey effort increases the recorded species richness. However, the maximum of the recorded species richness still differs depending on which species is monitored, how large the habitat is and what is the number of cameras (Si et al., 2014). Also, this survey confirms that the recorded SRI may be different among different habitats, substrates, or temperature. In our survey, higher SRI values were recorded in the central part of the Paklenica NP, even though this could be a consequence of the number of cameras set in the central area versus peripheral parts of the NP. Keeping in mind what has been previously said, we cannot unequivocally conclude that a certain research area is richer in species diversity than another since the camera trapping survey efforts were not uniform.

Since rangers have excellent knowledge of specific locations in protected areas and spend a large amount of time in the field, the question is whether they can be a valuable tool for monitoring the status of the wildlife species and habitats. Data collected through this camera trapping survey of mammals in the Paklenica NP, which was gathered by rangers, show similar biodiversity values as previous surveys conducted in the same area by ecologists (87.5% similarity). The reason for this is that rangers have a very profound knowledge of the specific area (where animals gather, their secret hideouts, waterholes, etc.) and/or have a long work experience within the protected area. Further, on analysing the costs for conducting camera trapping survey by external service and internal service, a significant difference was noted. From the cost analyses, the savings in financial resources are clearly visible if the research is conducted by internal ranger service. Therefore, the possibility that camera trap installation activities and further checks (battery change, data transfer) can be performed by internal ranger service rather than external service contributes to the added value of ranger service. Namely, this actually creates the possibility of conducting additional research in other areas of the ecology of protected areas, as less funding needs to be set aside for camera trapping surveys. However, it should be emphasised that this case study refers to the cost ratios among the employment ranks in Croatia, where university degree is not a compulsory qualification for the ranger service officer position. Despite the different aforementioned qualifications required for the position of ranger in other countries (USA, Canada, Australia, South Africa, Brazil, Germany, Austria), the difference between the costs of external service and internal ranger service is certainly lower. So, it is to be assumed that needs for financial resources allocation will be smaller for the internal ranger service than for the external service.

Certainly, it is necessary to continue research on the subject topic, that is, the value of rangers in biodiversity monitoring, especially in relation to the accuracy and precision of data collected by internal and external services. As stated earlier, during this camera trapping survey, 88% of previously recorded species were recorded, that is, two species were not recorded. However, since we did not have control group of researchers, we could not assess the accuracy of this data collected by Paklenica NP rangers. So, in future research, it would be important to include a control group of other employees or external experts for comparison with the internal rangers. Also, for the mentioned additional surveys, it is necessary to use the same methodology for camera trapping setting, that is, camera traps should be ideally set in line transects (or other uniform shape) with clearly defined distance within each other, so that all cameras are in all survey locations at the same period and attractants are the same. This may allow additional comparison analysis mentioned above and provide more relevant, that is, methodologically correct results.

Conclusion

This study represents first-peer reviewed list of mammalian species for the Paklenica NP. During this camera trapping survey, 15 mammalian species were recorded. As rangers and camera trapping may be an invaluable tool for biodiversity monitoring, it is necessary to propose camera trapping methodology that can be used by rangers in the NP. It is necessary to define a priori the target community, so that the right camera trap model (study design) can be used. Camera traps must be positioned in such a way that the resulting spatial coverage is representative of the landscape or target community for which the researcher wants to make inferences. The number of camera sites must be determined by the required accuracy and precision levels. Following these suggestions during future camera trapping surveys, rangers as well as external professionals may be able to perform all working tasks. Taking the example of Croatia, using rangers in camera trapping surveys is also cost efficient, and the money used for external experts can be allocated for other activities.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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