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Status and distribution of Eurasian lynx (*Lynx lynx*) in Slovenia from 2005 to 2009

Stanje in razširjenost evrazijskega risa (*Lynx lynx*) v Sloveniji v obdobju 2005–2009

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Abstract: In Slovenia, the status of the re-introduced Eurasian lynx population is monitored using the SCALP (Status and Conservation of Alpine Lynx Populations) methodology. Monitoring is organized by the Slovenia Forest Service in cooperation with other institutions and individuals. We analysed the data for the 2005–2009 monitoring period and compared it with the previous periods to explore population status and trends for the northern part of the Dinaric population. During this last pentad we recorded six C1 category data points, 832 data points of category C2, and 96 points of category C3. These numbers are comparable to the previously reported period of 2000–2004. The spatial distribution of signs of lynx presence remained similar compared to the previous period. Presence and status of the lynx are easier to interpret because of additional telemetry data and a habitat suitability that has been produced since the last report. We assume that this lynx population is critically endangered, because of demographic as well as genetic reasons. To prevent local extinction, an active approach is needed for revitalization of the population which would address demographic factors as well as improve the depleted gene pool.

Keywords: Eurasian lynx, *Lynx lynx*, Dinaric population, monitoring, distribution, Slovenia.

Izvleček: V Sloveniji poteka monitoring prisotnosti introducirane populacije evrazijskega risa na osnovi SCALP metodologije v organizaciji Zavoda za Gozdove Slovenije ob sodelovanju drugih inštitucij in posameznikov. Z analizo podatkov in primerjavo s preteklimi obdobji podajamo stanje in trend severnega dela dinarske populacije. V petletnem obdobju 2005–2009 je bilo zabeleženih 6 podatkov C1; 832 C2 in 96 C3 kategorije, kar je podobno kot v preteklem obdobju 2000–2004. Tudi prostorsko so podatki podobno razporejeni po Sloveniji. Predstava o prisotnosti in statusu risa se dopolnjuje s podatki radiotelemetričnega spremljanja in modelom primernega prostora, ki je bil izdelan v zadnjem petletnem obdobju. Predvidevamo, da je populacija kritično ogrožena tako zaradi demografskih kakor tudi genetskih razlogov. Za uspešno varstvo bo treba aktivno pristopiti k revitalizaciji populacije tako s popolnjevanjem in varovanjem demografske in spolne strukture kakor tudi reševanjem osiromašenega genskega sklada.

Ključne besede: Evrazijski ris, *Lynx lynx*, dinarska populacija, monitoring, razširjenost, Slovenija.

Introduction

Eurasian lynx (*Lynx lynx*) was exterminated in Slovenia in the early 20th century. The current population originates from a 1973 reintroduction, when three pairs of animals have been released from quarantine enclosures. These animals were captured for reintroduction in Rudogorje (Slovakia). The newly established population showed incredible dynamics of population growth and spatial expansion (Čop 1994). Relatively intensive hunting was introduced already in 1978 as a part of the population management. Lynx hunting reached its peak in 1990 when 13 animals were legally shot in Slovenia (Kos et al. 2004, Potočnik et al. 2009). The lynx now present in Slovenia belong to the north-western part of the Dinaric population, which is sometimes considered to be divided into Dinaric and Alpine subpopulations (Koren et al. 2006). It is a part of the population that extends to the south-eastern Alps and presents an important source for potential recolonization of the Alps from East. It is therefore crucial for establishment of the potential future pan-Alpine metapopulation. The southern (Dinaric) and northern (Alpine) subpopulations are separated by Ljubljana–Koper highway and additionally by areas of unsuitable habitat (Skrbinšek 2004). Therefore it is important to maintain the connectivity between the subpopulations and adapt conservation efforts accordingly.

Since the reintroduction, there was a considerable effort applied in intensive monitoring of signs of presence and registration of all detected lynx mortalities (Čop 1994, Čop and Frković 1998, Staniša et al. 2001, Koren et al. 2006). However, the estimations of population size that followed were based on misunderstood, often anecdotal data, lack of knowledge and individual (often erroneous) opinions of individual managers, which caused considerable overestimations of the population size with estimates of up to 200 animals (data Slovenian Hunting Association, State`s Hunting Grounds, unpublished). These estimates were the basis for approval of high hunting quotas, and possibly also a promoter of illegal killings, especially after the protection of lynx in 1993 when only exceptional harvest was allowed based on the decision of the competent minister. Systematic, science-based, fine-scale monitoring is a prerequisite for successful conservation, especially if it includes management actions such as hunting, as well as for establishing positive attitudes of different interest groups (Treves 2009, Treves and Naughton – Treves 1999). Uncertainty in population size estimates can cause extinctions in exploited lynx populations (Saether et al. 2010). Lynx monitoring frequently includes high proportion of uncertain data that can give biased results on distribution and abundances (Molinari-Jobin et al. 2012a).

Lynx habitat in Slovenia is fragmented into several habitat patches (Skrbinšek 2004). With exception of Snežnik–Javorniki and Kočevje forest habitat patches, other areas are fragmented by linear barriers or agricultural/urban landscape, with fragments that are frequently the size of only a single average lynx territory, or even smaller. Dispersal and distribution of lynx in such fragmented landscape is very unpredictable. Habitat fragmentation can have considerable effect on occupancy of the patches as well as on adequate sex structure within the patches (Niedzialkowska et al. 2006, Molinari-Jobin et al. 2010, Samelius et al. 2011). Only through systematic and intensive recording of signs of lynx presence categorized according to reliability we can track dynamics and spatial pattern of lynx distribution (Molinari-Jobin et al. 2012a,b). In this paper we present the results of the monitoring of signs of lynx presence and determination of Dinaric lynx population status in Slovenia between 2005 and 2009.

Methods

Data collection

Data on signs of lynx presence have been collected following methodology described by Koren et al. (2006). Data on signs of lynx presence, dead lynx and attacks on domestic animals have been continuously recorded since the population was established population in 1973 (Čop 1994). Since 1994 lynx monitoring has been coordinated by Slovenia Forest Service (SFS) (Staniša 2001, Jonozovič 2004, Koren et al. 2006,). The data are classified into three reliability levels in accordance with the SCALP guidelines (Molinari-Jobin et al. 2012a) and the possibility to verify the collected data: C1: Confirmed "hard facts", verified and undisputable records of lynx presence such as (1) dead lynx, (2) live captured lynx, (3) good-quality and geo-referenced lynx photos (e.g., from camera traps), and (4) samples (e.g. excrements, hair) attributed to lynx by means of scientifically reliable analyses, such as genetic analysis. C2: Records confirmed by a lynx expert (e.g. trained member of the SFS or Slovenian Hunting Society) such as (1) killed livestock or (2) wild prey, and (3) lynx tracks or other assessable signs of lynx presence. C3: Unconfirmed category: observations (kills, tracks, other signs of lynx presence too old or not thoroughly documented, but with description indicating lynx presence) and all unverified observations such as sightings and vocalizations.

Research activities were intensified during the 2005–2009 period with live capturing of lynx, GPS telemetry, monitoring of lynx using hair-traps and photo-traps, prey analysis and habitat and population modelling (Potočnik 2004, Skrbinšek 2004, Krofel 2006, Krofel et al. 2006, Krofel 2008, Skrbinšek and Krofel 2008, Potočnik et al. 2009, Kos et al. 2011, Krofel et al. 2012). Some of these data, particularly from Snežnik–Javorniki area are also included in the report. All reported damages on domestic animals have been inspected by authorized SFS personnel.

Data analysis

All recorded data of lynx signs of presence were entered into the monitoring databases, kept and analysed at the regional unit of SFS in Tolmin. The number of lynx presence data according to their category, including mortality data and damages attributed to lynx, were graphically presented and compared to previous pentads. Lynx population ranges for particular pentads were calculated using geo-referenced lynx presence data of all three categories and fixed kernels, using least square cross-validation (LSCV) approach at 50, 75 and 90% probability area, were prepared (ESRI, ArcGIS 10.0).

Results

Monitoring of lynx distribution

During the 15-year period of collecting and recording signs of lynx presence, coordinated by SFS, 2357 records have been collected according to the SCALP methodology. The number of recorded data have been increasing over the pentads (1995–99: 505; 2000–04: 908; 2005–09: 944). The increase is mainly due to an increasing proportion of C2 data (Tab.1). Majority of the data (71%) were collected in the southern (Dinaric) subpopulation, others in northern (Alpine) subpopulation.

During the last pentad (2005–09) the number of signs of lynx presence has been constantly decreasing from 249 in 2005 to 158 in 2009 (Fig. 1). The decline is most pronounced for C2 data (Fig. 2). In the last pentad there were seven C1 data from photographed or collared lynx and nine data from non-invasive genetic samples (scats, urine, hair), collected during that period. The majority of C1 data from the previous periods referred to killed (shot) lynx. On the other hand, during our study period no dead lynx were reliably recorded (Fig. 3).

In State`s Hunting Reserves (LPNs) that are managed by SFS, daily monitoring of large carnivores has been implemented since 1991. Among them, the highest number of signs of lynx presence during the last pentad was recorded in LPN Jelen (278 km^2), however there has been substantial decline in the last three years (Fig. 4). Similarly, in LPN Medved (379 km^2) the number of records was low compared to the previous periods (Fig. 4). In other LPNs such intensive monitoring was started in 2008.

Distribution of lynx presence

In Slovenia, lynx are present in two areas: (1) Alpine area and (2) Dinaric area. – Sporadic and mostly unconfirmed (C3) data have been reported also from Kamnik–Savinja Alps in the north of Slovenia.

In the last three pentads we did not observe any major change in the range where signs of lynx presence have been recorded. Lynx population ranges (95% fixed kernel) over pentads were 5820, 6270 and 5530 km^2 (Figs. 5–7). The concentrations of the signs remained more or less constant

Data category	Southern subpopulation			Northern subpopulation			Total/country		
	1995 - 1999	2000 - 2004	2005 - 2009	1995 - 1999	2000 - 2004	2005 - 2009	1995 - 1999	2000 - 2004	2005 - 2009
C1	12	7	6	1	0		13	7	16
C2	230	674	770	77	93	62	307	767	832
C3	61	48	7	124	86	89	185	134	96
Total/period	303	729	783	202	179	151	505	908	944

Table 1: Number of data of lynx presence by different SCALP categories.
Tabela 1: Število znakov prisotnosti risa po različnih SCALP kategorijah.

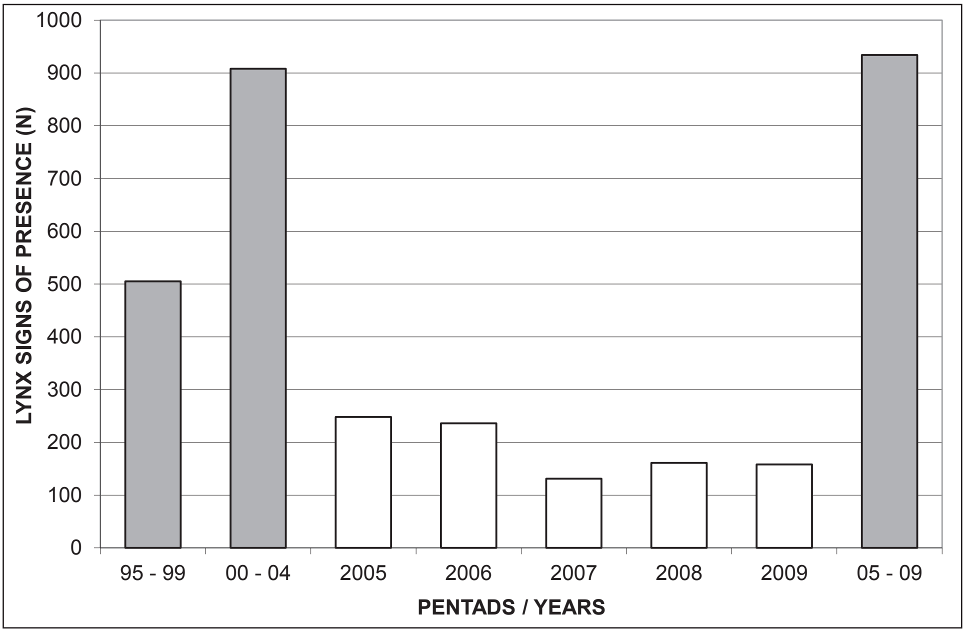

Figure 1: Dynamics of recorded lynx presence data over the pentads between 1995–2009. Lynx presence data in the last pentad – white bars.
Slika 1: Dinamika vseh podatkov monitoringa med petletnimi obdobji v letih 1995–2009. Podatki monitoringa v zadnjem petletnem obdobju – beli stolpci.

only in the area of the Snežnik plateau, whereas in the other areas signs have declined. In the last pentad, compared to the previous monitoring periods, substantial decline of the presence data was detected in south-eastern Slovenia (Kočevsko region) and in the Alps (Figs. 5–7).

Damages attributed to lynx

Inspected livestock damages attributed to lynx during the entire 15 year monitoring ranged between 2 (1996) and 34 (2001) cases and estimated annual value of damages ranged between 400 € and 35,800 € (Tab. 2). Number of reported cases of damages attributed to lynx in last pentad was smaller than in previous pentads and number of killed animals declined for more than 80% compared to the previous period (Tab. 2, Fig. 3).

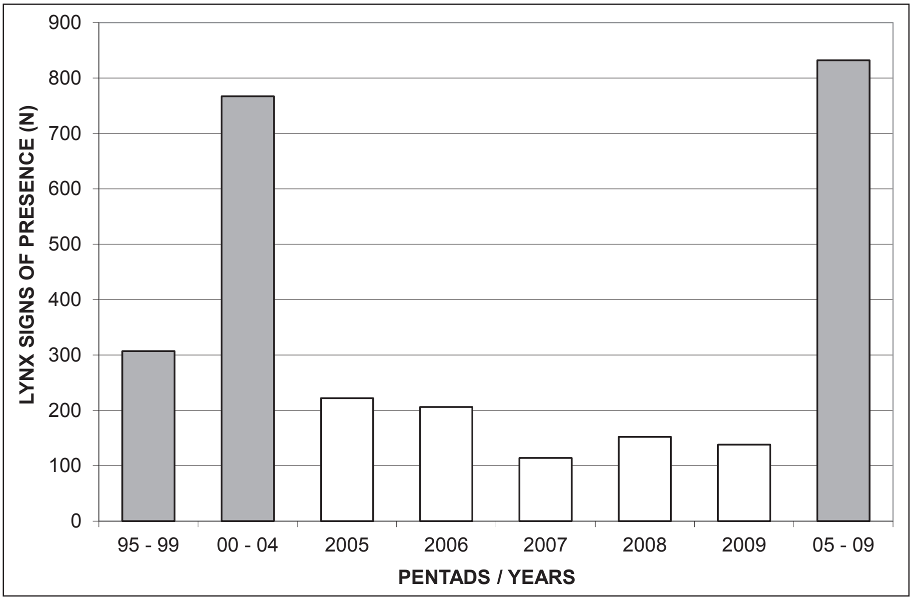

Figure 2: Dynamics of C2-category data collected over the pentads between 1995–2009. Lynx presence data for the last pentad – white bars.

Slika 2: Dinamika zbiranja C2 podatkov med petletnimi obdobji v letih 1995–2009. Podatki monitoringa v zadnjem petletnem obdobju – beli stolpci.

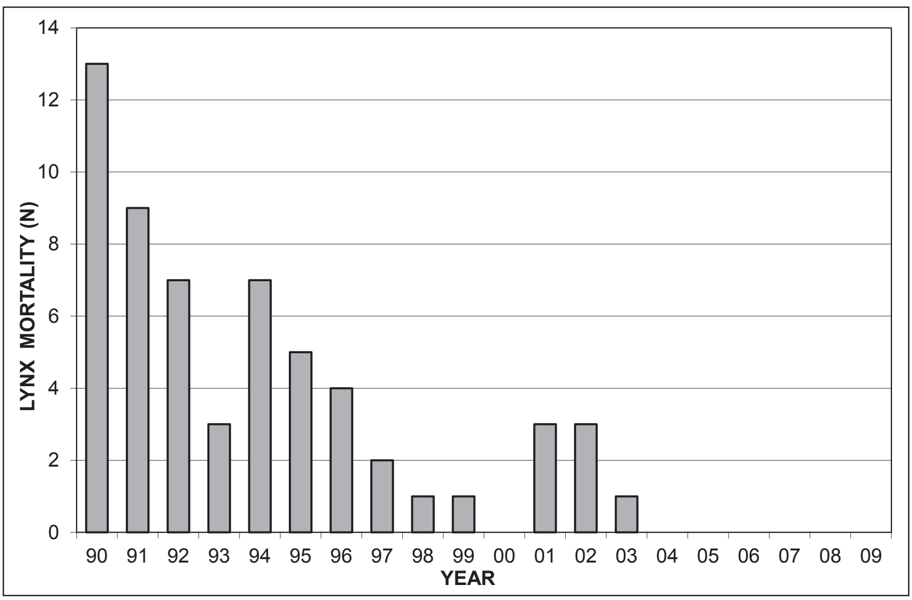

Figure 3: Number of recorded lynx mortality (killed or found dead) in Slovenia from 1990 to 2009.

Slika 3: Število zabeleženih mrtvih (odstreljenih ali drugače poginulih) risov v Sloveniji od 1990 do 2009.

Discussion

Continuous monitoring according to the SCALP methodology (Molinari-Jobin et al. 2012a) provides a basic insight into the lynx population in Slovenia. In the period 2005–2009 the distribution of signs of lynx presence indicates a similar distribution range as in the previous periods. However, the results also indicate that the population size is declining.

It is shown that during the 15 years of monitoring the number and proportion of C2 category data was constantly increasing, while the number of C3 category data declined. Increasing number of experts from SFS and other institutions were getting involved in the lynx monitoring during this period. Also research projects on lynx with intensive field work in the last pentad additionally increased the monitoring effort. Thus the number of the monitoring data over the entire period is not reflecting the lynx population density; however the relative spatial distribution of the data is still a good indicator of the population's spatial distribution. During the last pentad there was only one unverified case of lynx mortality on the Ljubljana–Zagreb highway in 2008 (Poličnik et al. 2010). It was registered in reports of the Slovenian motorway company DARS, but this data is not reliable since the carcass was not preserved, checked or photographed, and it was determined to be a lynx only by an unidentified DARS employee (B. Pokorny, personal communication). During the last pentad the competent Ministry issued no hunting quota. As the lynx population size was estimated to be substantially declining, the decision of the Ministry was that hunting to regulate the population and to maintain higher tolerance for lynx is not eligible anymore (Marn 2008). In the period between 1978 and 1993 lynx were hunted, similarly to Norway for recreational hunting and for other reasons (Herfindal et al. 2005).

Only C3 category data are available in the area of Trnovski gozd in the south-west and Kamnik–Savinja Alps in the north. Although lynx presence in this region currently cannot be confirmed, C3 category data can be useful to indicate potential

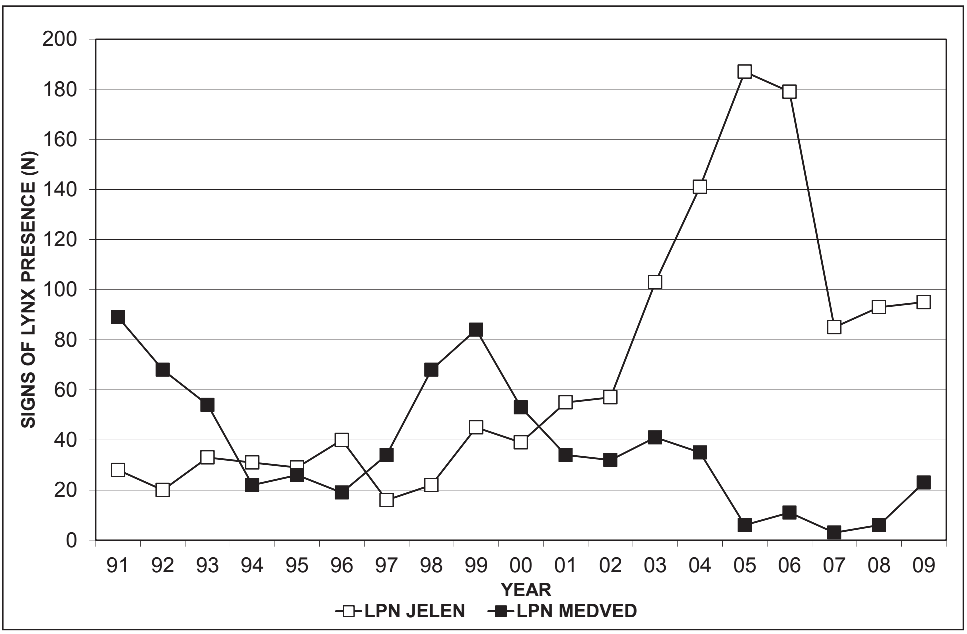

Figure 4: Dynamics of recorded lynx presence data within the monitoring programme in state hunting reserves LPN Jelen and LPN Medved.

Slika 4: Dinamika zbranih podatkov znakov prisotnosti v okviru monitoringa v LPN Jelen in LPN Medved.

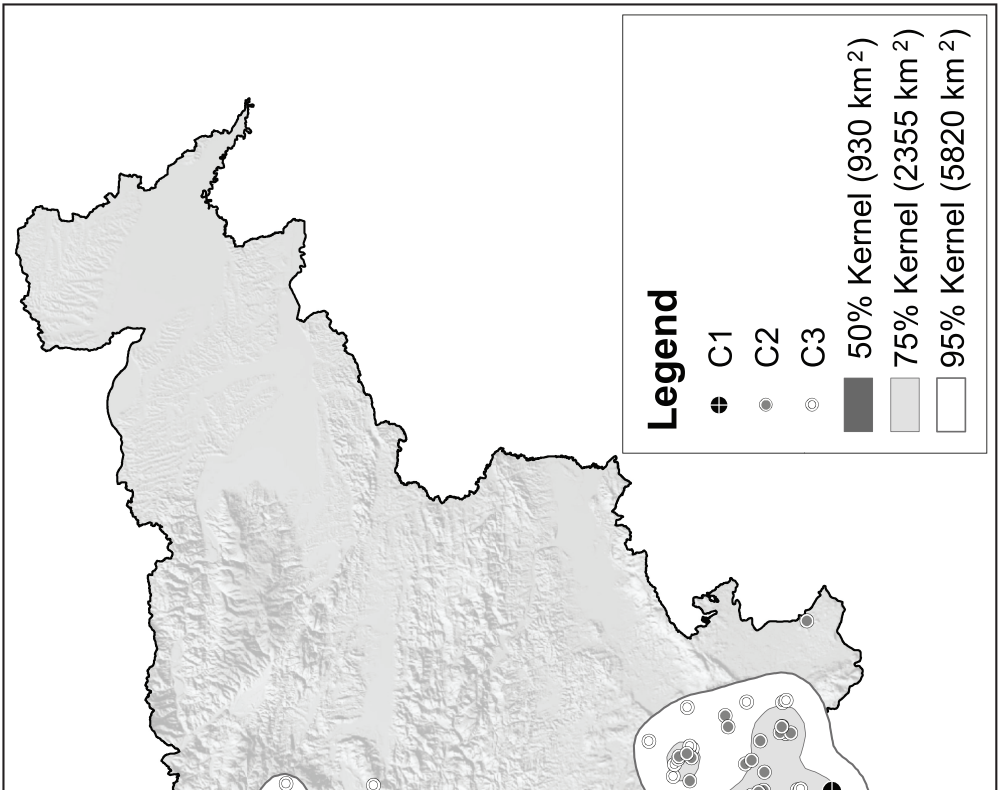

Figure 5: Lynx population range in Slovenia 1995–1999.
Slika 5: Populacijsko območje risa v Sloveniji 1995–1999.

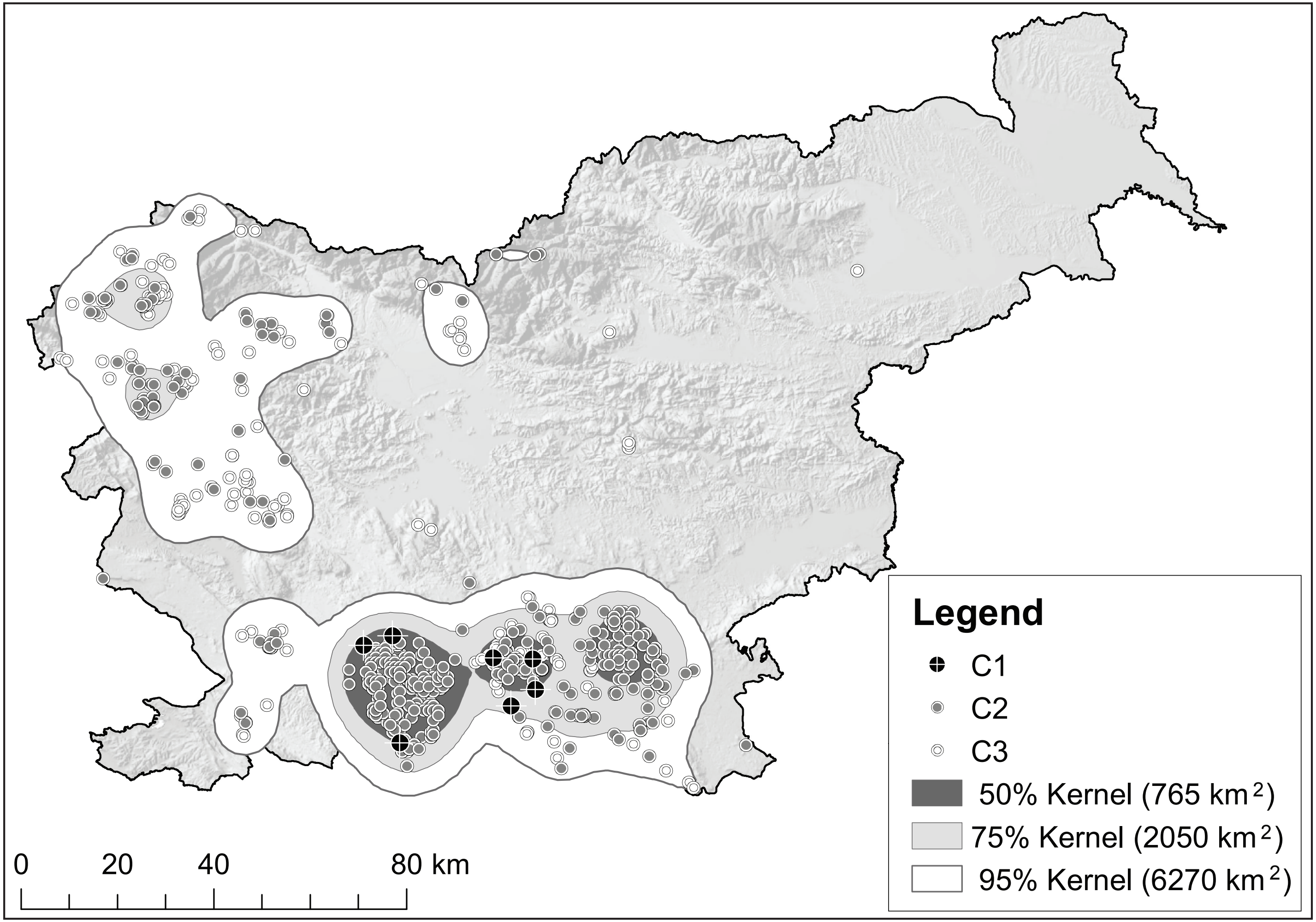

Figure 6: Lynx population range in Slovenia 2000–2004.
Slika 6: Populacijsko območje risa v Sloveniji 2000–2004.

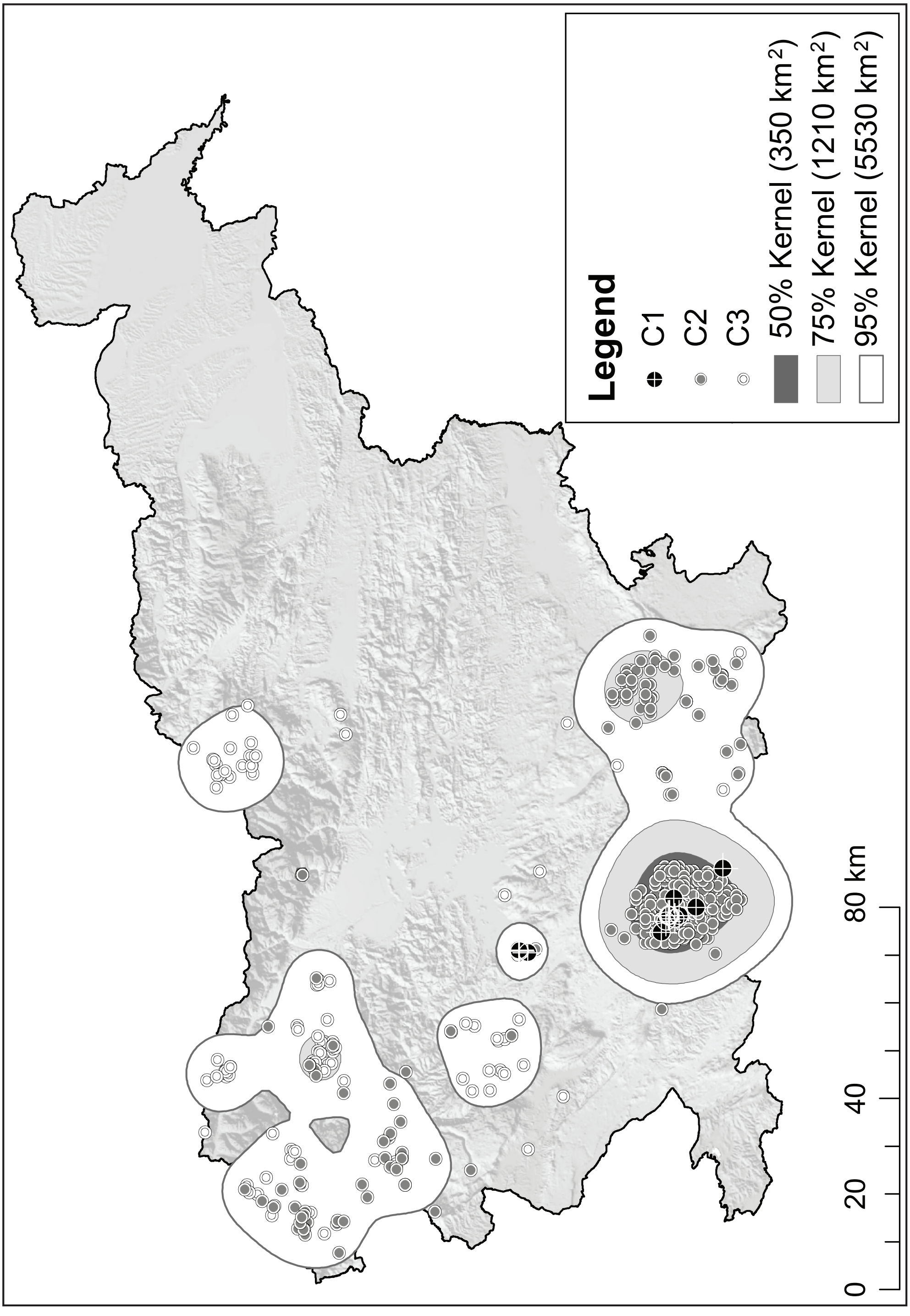

Figure 7: Lynx population range in Slovenia 2005–2009.
Slika 7: Populacijsko območje risa v Sloveniji 2005–2009.

lynx presence (Molinari-Jobin et al. 2012a) and identify the areas where the monitoring effort should be intensified.

In the period 2005–2009 we observed the strongest decrease in the number of lynx records in Kočevsko region. Since the re-introduction there were regularly two reproductive pairs present in forest plateaus Velika gora and Goteniška gora with more or less constant reproduction until 2003 (Huber et al. 1995, I. Kos et al. unpublished data), but only sporadic single animals have been detected in the last pentad. In 2012 one unsuccessful attempt of reproduction which ended with the death of the young GPS-collared female and her three kittens was observed (unpublished data). High numbers of C2 category data as well as C1 data in Snežnik region coincide with telemetry study of two females with kittens and two males (Krofel et al. 2012). Their neighbouring territories extended partially over the border to Croatia. According to reports on lynx sightings in Snežnik–Javorniki region there was probably another reproductive pair in Javorniki area. Snow-tracking, telemetry data (Krofel et al. 2006; Krofel et al. 2012), genetic monitoring (Polanc 2012), hair-trapping (Krofel 2008), photo- and video-trapping (unpublished data), and sightings of lynx in Slovenia indicate regular reproduction only in the Snežnik–Javorniki forest complex that is probably the last permanent reproductive stronghold in Slovenia, and probably inhabited by three reproductive pairs. This region represents also the largest habitat patch suitable for the lynx in Slovenia (Skrbinšek 2004) and continues across border to Croatia. In other regions, especially in the eastern and northern Slovenia, the suitable habitat is more fragmented due to human settlements and agriculture or due to linear barriers like rivers, highways and other infrastructure. In Europe lynx occurrence was predominantly in regions (grid size 50x50 km) with forest cover over 50% (Mikusinski and Angelstam 2004). Lynx was negatively associated to human settlements and transportation infrastructure (Niedzilkowska et al. 2006). Prey and direct human disturbance probably play an important role as well.

There is a potential threat of further lynx habitat fragmentation in Slovenia associated with development of transportation infrastructure (e.g. highway Ljubljana – Zagreb) or with establishing new industrial zones (e.g. Podskrajnik – Rakek) at corridors between forest patches. According to the lynx habitat model in Slovenia (Skrbinšek 2004) there are currently only two large suitable habitat patches (Pohorje and Zasavje) with no signs of lynx presence.

We can expect the data that are collected within a particular habitat patch to frequently refer to only one or very few animals, predominantly males. Among 65 genotyped non-invasive samples (scats, urine), males in the analysed sample represented more than 78% (Polanc, 2012). Males disperse more frequently and over larger distances (Molinari-Jobin et al. 2010a; Samelius et al. 2011). This partially explains sexually biased population structure obtained from the genetic analyses on the population edges and slower colonization rate of lynx toward the south-eastern Alps. Low reproduction due to absence of potential mates associated with fragmentation and possible decreased survival due to human activities is besides unfavourable genetic burden another possible reason for empty habitat patches or patches occupied by only a single lynx.

This re-introduced, bottlenecked population (only three pairs with some already related animals; mother – son (Štrumbelj 1996)) is evidently experiencing a decline, has a very low effective population size and carries a weak genetic legacy. Genetic analyses of Dinaric population showed the lowest genetic diversity of all studied European populations (He = 0.482 and on average 3.11 alleles per locus) (Sindičić et al. submitted). Genetic diversity is dissolving through genetic drift, and is lower for samples collected after the year 2000 (He = 0.42 and average allelic diversity = 2.5). Effective inbreeding in comparison with the source population is 0.22, but raises up to 0.30 in the 2000–2010 period (Polanc 2012, Sindičić et al. submitted). Since lynx appear in low densities, are rarely found dead or handled by researchers, and the amount of research done on the Dinaric population is limited, no signs of inbreeding depression were yet detected. However, inbreeding depression has been proven in captive bred lynx and in some wild lynx in Switzerland (Ryser-Degiorgis 2001, Ryser-Degiorgis et al. 2004), and can be reasonably expected in the Dinaric lynx. Therefore we should assume that there is a need to augment the Dinaric population with animals from another population in the near future. When selecting the animals for

YEAR	Nr.of cases	Nr. animals killed	SIT	EUR
TOTAL 1995-1999	71	116*	11,154,000	25,805
1995	25	?	1,250,000	5,750
1996	2	3	93,000	400
1997	8	13	310,000	1,450
1998	21	66	7,770,000	10,205
1999	15	34	1,731,000	8,000
TOTAL 2000-2004	126	375	16,298,200	71,522
2000	14	49	2,159,000	9,600
2001	34	128	6,502,700	29,100
2002	19	47	2,975,000	13,400
2003	28	58	2,637,000	10,987
2004	31	93	2,024,500	8,435
TOTAL 2005-2009	86	169	5,598,175	23,325
2005	25	67	2,039,803	8,499
2006	15	29	780,132	3,250
2007	8	11	337,440	1,406
2008	18	29	1,021,200	4,255
2009	20	33	1,419,600	5,915

** without year 1995*

Table 2: Damages to livestock estimated to be caused by lynx.
Tabela 2: Ocenjene škode na domačih živalih, pripisane risu.

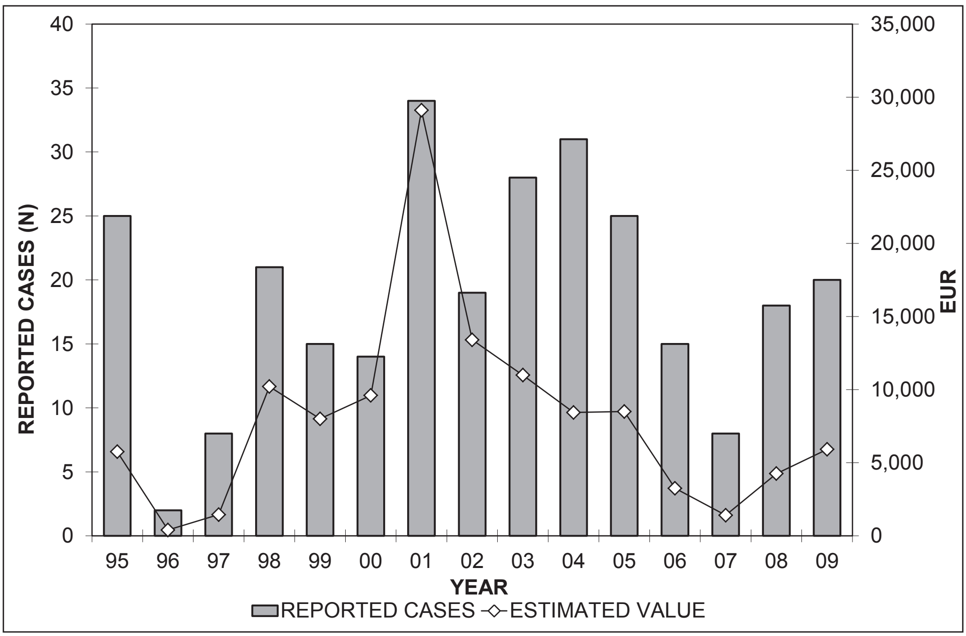

Figure 8: Number of reported cases and estimated value of damages attributed to lynx during the 1995–2009 period.
Slika 8: Število ocenjenih škodnih dogodkov in ocenjena nominalna vrednost škod pripisanih risu v obdobju 1995–2009.

population augmentation, genetic and ecological factors of potential donor populations should be considered (Schmidt et al. 2011, Skrbinšek et al. 2012). Successful conservation of lynx as well as other large carnivores depends mainly on the positive attitudes of the general public and specific interest groups (Røskaft et al. 2007). The only way to ensure survival of the lynx population in a human-dominated landscape is to ensure its coexistence with humans. According to research of public attitudes toward large carnivores, the general public as well as hunters strongly support the idea of augmenting the lynx population in Slovenia (Slana 2010).

Monitoring intensity varies between different regions of Slovenia. For example, the south-western part of the population range in Slovenia (Primorska region) rarely gets snow cover. We can expect a lower detection rate of lynx presence in this areas since a substantial part of the data in other regions comes from snow-tracking. Data from snow-tracking are especially important for detection of females with kittens (Linnel et al. 2007, Andren et al. 2012), thus other methods, like photo-trapping (Zimmermann et al. 2010) or intensive hair-trapping (Demšar 2005, Krofel 2008, Schmidt and Kowalcyk 2006) should be implemented for lynx monitoring in the regions without snow.

When we took into the account the monitoring data presented in this paper, the data on reproduction events (four to five per year), available lynx habitat (as predicted with the habitat model) in the areas where lynx presence was confirmed (manuscript in preparation, 4490 km^2 of suitable habitat in 10 habitat patches of sufficient size) and knowledge about spatial requirements of lynx (eg. Kos et al. 2004), we can conclude that the number of lynx in Slovenia during the 2005–2009 period has declined compared to the previous pentads. On basis of this analysis we can also estimate that 15 to 25 resident lynx may have been still remaining in the population during the reported period (manuscript in preparation). A decrease was detected in the Alpine subpopulation and in the south-eastern part of the Dinaric subpopulation.

Conclusions

(1) In the period 2005–2009 a larger proportion of lynx presence data were registered within the higher quality categories compared to the previous pentads.
(2) No verified lynx mortality has been recorded during the last pentad.
(3) The lynx habitat in Slovenia is characterized by four areas, of which two are areas of (1) southern (Dinaric) and (2) northern (Alpine) subpopulation, one area represents an isolated patch with occasional lynx presence (3) Kamnik–Savinja Alps), and (4) the area of suitable habitat without lynx presence.
(4) During this last 2005–2009 monitoring pentad the population range of the lynx remained approximately the same as in the previous five-year period; however a decrease in relative population density has been detected during the last years of this period.
(5) Compared to the previous five-year periods, there was a decrease in the number of registered attacks of lynx on small livestock.
(6) During the 2005–2009 period the number of lynx in Slovenia seems to have been decreasing. This decrease seems to be the strongest in south-eastern part of the lynx distribution.
(7) The survival of lynx population in Slovenia without an intensive and pro-active conservation program is uncertain.

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