Topographical and vegetational characteristics of lynx kill sites in Slovenian Dinaric Mountains

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Abstract. We report on topographical and vegetational characteristics of 13 sites where Eurasian lynx (*Lynx lynx*) killed its prey in the Dinaric mountain range in Slovenia. The results suggest that lynx does not necessarily need dense vegetation and rugged terrain to successfully hunt its prey, however, it may influence its hunting success. A large part of the successful hunts took place on steep slopes and rugged terrain. 39% of kill sites were located in dolines, implying the potential importance of these karst structures for the hunting of large carnivores on ungulates in karst areas such as Dinaric Mountains.

Keywords: Eurasian lynx, *Lynx lynx*, predation, kill sites, Dinaric Mts, Slovenia

Izvleček. TOPOGRAFSKE IN VEGETACIJSKE ZNAČILNOSTI MEST, KJER SO RISI UPLENILI SVOJ PLEN V DINARIDIH V SLOVENIJI - Preučili smo topografske in vegetacijske značilnosti na 13 lokalitetah, kjer so evrazijski risi (*Lynx lynx*) uplenili svoj plen na območju Dinaridov v Sloveniji. Rezultati so pokazali, da lahko risi uplenijo svoj plen tudi na mestih brez goste vegetacije in razgibanega terena, vendar pa večja možnost kritja verjetno lahko vpliva na njegov lovni uspeh. Velik del uspešnih poskusov lova je potekal na strmih pobočjih in na razgibanem terenu. 39 % mest uplenitev je bilo ugotovljenih v vrtačah, kar kaže na potencialni pomen le-teh pri lovu velikih zveri na parkljarje na kraških območjih, kot so Dinaridi.

Ključne besede: evrazijski ris, *Lynx lynx*, predacija, mesta uplenitev, Dinaridi, Slovenija

Introduction

There are many factors that have been reported to affect the hunting behaviour and hunting success in carnivores (Sunquist & Sunquist 1989, Funston et al. 2001, Sand et al. 2006). Among them are also features of the habitat, where the hunt is taking place. Husseman et al. (2003) noted that micro location characteristics are more important for the stalking predators, such as felids, than for coursing predators, such as canids, for which the hunt usually takes place on much larger scale and the kill site is less habitat-specific.

When approaching their prey before the attack, all felids rely extensively on physical features in the environment that provide them with cover (Sunquist & Sunquist 1989). Since the presence of stalking cover influences the distance traversed in the final charge, it may have important effect on the hunting success.

Eurasian lynx (*Lynx lynx*), along with grey wolf (*Canis lupus*), is the main predator of ungulates in the Dinaric Mountains in Slovenia. Lynx hunts alone and usually stalks its prey or attacks it from ambush; surprise is therefore an important factor for hunting success (Kos et al. 2005). To be successful, lynx must get within a few meters of prey animal and it rarely chases its prey more than 100 meters (Krofel 2006).

Within the ongoing study on lynx ecology in Slovenian Dinaric Mountains, we are also studying the characteristics of kill sites that might be important for the hunting success of the lynx. Here, some of the preliminary results of this study are presented.

Study area

The study was conducted in the north-western part of Dinaric mountain range. Dinaric mountains extend along the Adriatic coast from the Friuli plain in Italy in the north-west to the Albanian mountains in the south-east. Study area (46°10'-45°25'N and 13°33'-15°13'E) is located in the High Karst region of Slovenia, covering 3287 km^2 (Kladnik 1998). Altitude ranges from approximately 168 m to the peak of Mount Snežnik at 1796 m, with average of 762 m and average inclination of 11° (source: DMV 12,5; Geodetska uprava RS). Limestones and dolomites are prevalent in the area, and the relief shows typical karst phenomena, such

as dolines, collapse dolines, uvalas, horizontal caves, vertical shafts, steep canyons, poljes, etc. Surface water is rare as water runoff is largely underground. The climate is a mix of influences from the Alps, the Mediterranean sea and the Pannonian basin with annual temperature averaging 5-8 °C, ranging from average maximum of 32 °C to a minimum of -20 °C, and average annual precipitation of 1400-3500 mm. The forest coverage of the High Karts region is 79%. Most of the area is covered by fir-beech association (Abieti-Fagetum dinaricum), with four dominant tree species: common beech (*Fagus sylvatica*), silver fir (*Abies alba*), Norway spruce (*Picea abies*), and sycamore maple (*Acer pseudoplatanus*) (Kordiš 1993). Population density in the High Karst region averages 28 inhabitants / km^2 (Kladnik 1998).

In Dinaric forests of Slovenia, lynx hunts mainly roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), fat dormouse (*Glis glis*) and, to a lesser extent, other rodents, chamois (*Rupicapra rupicapra*), red fox (*Vulpes vulpes*), and birds (Krofel 2006). Two other species of large carnivores are also present in the area, i.e. brown bear (*Ursus arctos*) and grey wolf.

Methods

Lynx kill sites have been inspected between 2002 and 2006. We searched for lynx prey remains while snow tracking. In addition, we monitored the movement of one radio-marked female and searched for prey remains, if the lynx returned to the same location on consecutive days (Krofel et al. 2006). We also inspected dead animals found by chance during our field work and those found by local hunters and foresters.

We registered the vegetation and terrain characteristics in the radius of approximately 30 m around each kill site. We defined 4 categories for the tree density around the kill site: clearing (no trees or the average estimated distance between trees greater than 20 m), sparse (average estimated distance between trees 5 – 20 m), moderate (average estimated distance between trees 2 – 5 m), and dense tree density (average estimated distance between trees shorter than 2 m). Forest stands were categorized as deciduous, coniferous or mixed. We also noted the presence of deadwood on the ground and estimated the coverage of the understory higher than 30 cm, which we defined as: absent (no understory), sparse (less than 10% cover), moderate (10 – 50% cover), and abundant (more than 50% cover). We also subjectively estimated the ruggedness of the terrain: unrugged (relief more or less flat),

moderately rugged (some vertical rocky structures and minor undulation of the terrain, sometimes with few shallow dolines), and very rugged terrain (many vertical rocky structures and/or undulated terrain with many dolines and rocky cliffs). The inclination of the ground was pooled in three categories: less than 10 °, 10 ° - 45 °, and more than 45 °. In order to make results more comparable, all estimations were made by the same person (M.K.). Due to unsystematic manner of data collection before 2003, not all parameters were available for every site.

Results

In total, 13 lynx kill sites have been inspected (Tab. 1). At 11 sites, we found remains of a roe deer and at two a carcass of a red deer. Most of the inspected kill sites (54%) were located on the Menišija and Logatec plateau in the north-central part of the study area. Kill sites were found at the altitudes between 269 and 1060 m (mean 600 m). Locations of inspected kill sites are presented in Figure 1.

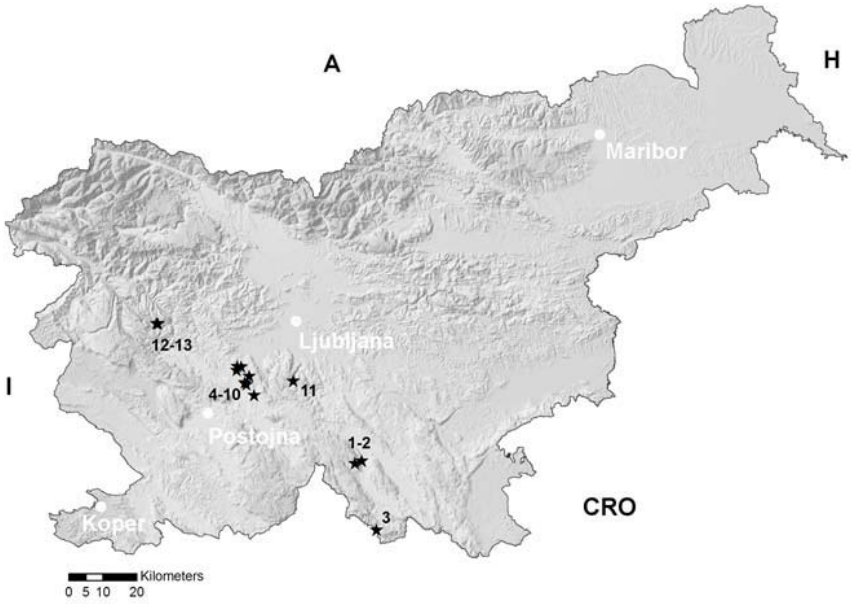

Figure 1: Locations of inspected lynx kill sites (n = 13). Numbers correspond to those in Tab. 1.
Slika 1: Lokacije najdenih ostankov risovega plena (n = 13). Številke lokacij ustrezajo tistim v tab. 1.

Table 1: List of inspected lynx kill sites and their characteristics.
Tabela 1: Seznam pregledanih mest, kjer so risi uplenili svoj plen, z njihovimi značilnostmi.

No./ Št.	Location/ Lokacija	Date/ Datum	Prey / Plen: Starost/ Age	Prey / Plen: Sex/ Spol	Prey / Plen: Species / Vrsta	Altitude/ Višina	Relief/ Relief	Inclination / Naklon	In a doline/V vrtači	Forest stand/ Gozdni sestoj	Tree density/ Gostota dreves	Understory/ Podrast	Deadwood/ Vejevje	Snow-cover/ Snežna odeja
1	Črni vrh, Velika gora	10.12. 2002	6 months/ 6 mesecev	F	*Cervus elaphus*	1060 m	very rugged/ zelo razgiban	-	no / ne	mixed/ mešani	moderate/ zmerna	-	-	present/ prisotna
2	Jelendol, Velika gora	27.3. 2003	3-4 years/ 3-4 leta	F	*Cervus elaphus*	650 m	unrugged/ nerazgiban	<10°	no / ne	mixed/ mešani	sparse/ redka	-	present/ prisotno	
3	Srebotnik, Kolpa	14.3. 2006	> 7 years/ > 7 let	F	*Capreolus capreolus*	269 m	moderately rugged / srednje razgiban	>45°	no / ne	deci-duous/ listnat	sparse/ redka	sparse/ redka	present/ prisotna	absent/ brez
4	Pranger, Logaška planota	1.3. 2003	adult/ odrasel	M	*Capreolus capreolus*	572 m	very rugged/ zelo razgiban	-	yes / da	mixed/ mešani	moderate/ zmerna	sparse/ redka	absent/ brez	present/ prisotna
5	Pranger, Logaška planota	21.3. 2004	2-3 years/ 2-3 leta	M	*Capreolus capreolus*	527 m	moderately rugged / srednje razgiban	10-45°	yes / da	mixed/ mešani	moderate/ zmerna	absent/ brez	present/ prisotna	present/ prisotna
6	Drnulca, Menišija	1.2. 2005	> 7 years/ > 7 let	M	*Capreolus capreolus*	519 m	unrugged/ nerazgiban	<10°	no / ne	mixed/ mešani	sparse/ redka	sparse/ redka	present/ prisotna	5 cm
7	Bukov vrh, Menišija	2.3. 2005	9 month/ 9 mesecev	F	*Capreolus capreolus*	627 m	moderately rugged / srednje razgiban	<10°	no / ne	coni-ferous/ iglast	moderate/ zmerna	moderate/ zmerna	present/ prisotna	present/ prisotna
8	Bodič, Menišija	5.3. 2005	2-3 years/ 2-3 leta	F	*Capreolus capreolus*	516 m	very rugged/ zelo razgiban	10-45°	yes / da	mixed/ mešani	moderate/ zmerna	moderate/ zmerna	absent/ brez	40 cm
9	Ržišče, Menišija	17.3. 2005	4-6 years/ 4-6 let	F	*Capreolus capreolus*	603 m	very rugged/ zelo razgiban	<10°	no / ne	mixed/ mešani	moderate/ zmerna	moderate/ zmerna	present/ prisotna	absent/ brez
10	Dolgi tali, Menišija	25.5. 2005	4-6 years/ 4-6 let	F	*Capreolus capreolus*	708 m	moderately rugged / srednje razgiban	-	yes / da	mixed/ mešani	sparse/ redka	moderate/ zmerna	absent/ brez	absent/ brez
11	Trenk, Krimsko hribovje	16.3. 2006	> 7 years/ > 7 let	M	*Capreolus capreolus*	686 m	moderately rugged / srednje razgiban	10-45°	yes / da	mixed/ mešani	sparse/ redka	moderate/ zmerna	absent/ brez	30 cm
12	Sr. Kanomlja, Idrijsko hribovje	20.1. 2006	adult/ odrasel	-	*Capreolus capreolus*	707 m	unrugged/ nerazgiban	>45°	no/ne	mixed/ mešani	sparse/ redka	absent/ brez	absent/ brez	present/ prisotna
13	Sr. Kanomlja, Idrijsko hribovje	23.1. 2006	1,5 years/ 1,5 leta	M	*Capreolus capreolus*	651 m	moderately rugged / srednje razgiban	>45°	no/ne	mixed/ mešani	dense/ gosta	moderate/ zmerna	absent/ brez	50 cm

We estimated the tree density and understory cover in 13 and 11 cases, respectively. Usually, the lynx killed its prey in the forest of sparse or moderate tree density (46% instances each). In only one case (8%) the kill took place in a dense forest and never on a clearing (Fig. 2). The majority (85%) of prey remains were found in mixed forest stands, one in deciduous and one in coniferous forest stand. 55% of kill sites had moderate understory cover, followed by sparse (27%) and absent (18%) understory cover (Fig. 3). No prey remains were found at places with abundant understory cover. Deadwood was present on the ground on 50% of the sites (n = 12).

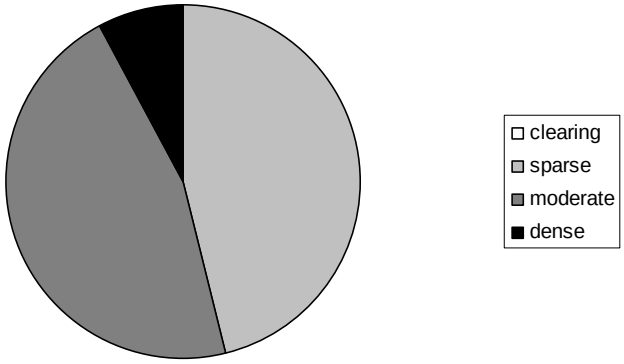

Figure 2: Density of trees at the lynx kill sites in Slovenian Dinaric Mts. (n = 13).
Slika 2: Gostota dreves na mestih, kjer so risi uplenili svoj plen, v Dinaridih v Sloveniji (n = 13).

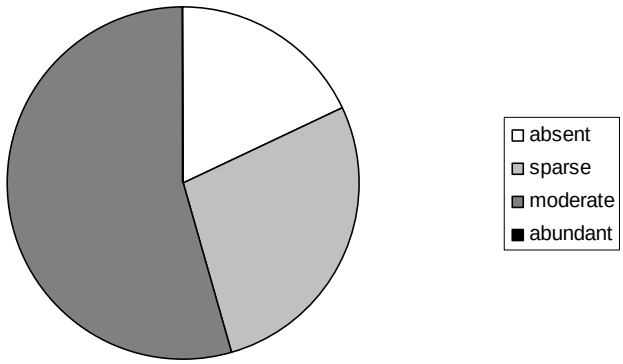

Figure 3: Understory cover at the lynx kill sites in Slovenian Dinaric Mts. (n = 11).
Slika 3: Pokrovnost podrasti na mestih, kjer so risi uplenili svoj plen, v Dinaridih v Sloveniji (n = 11).

Regarding the relief, most of the kills (46%, n = 13) took place in a moderately rugged terrain (Fig. 4). In four cases (31%), we found prey remains in a very rugged terrain, and in three cases (23 %) in unrugged terrain. In 5 out of 13 instances (39%), prey remains were found in dolines.

In cases when the course of the hunt could be determined in successful attacks of lynx on ungulates (n = 11), most of the chases (63%) took place on slopes with more than 10° inclination, 57% of these with the estimated inclination of more than 45° (Fig. 5).

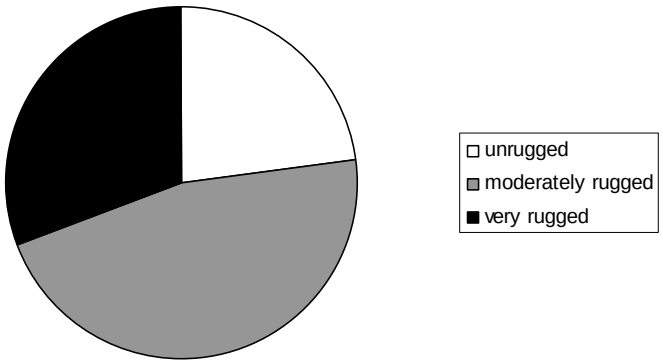

Figure 4: Relief characteristics of the lynx kill sites in Slovenian Dinaric Mts (n = 13).
Slika 4: Razgibanost terena na mestih, kjer so risi uplenili svoj plen, v Dinaridih v Sloveniji (n = 13).

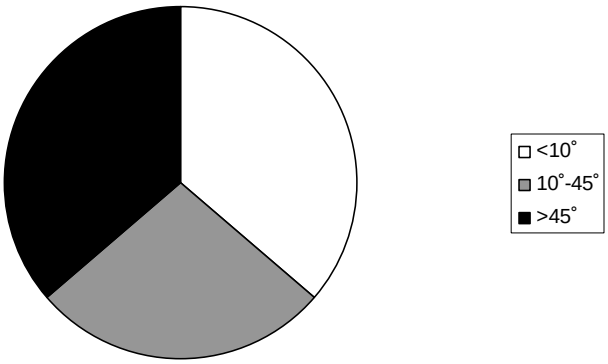

Figure 5: Estimated inclination of the slopes, where the hunt took place for successful lynx attacks in Slovenian Dinaric Mts (n = 11).
Slika 5: Ocenjen naklon pobočja na mestih, kjer so risi lovili svoj plen v Dinaridih v Sloveniji (n = 11).

Discussion

According to our results, Eurasian lynx do not necessarily need dense vegetation for hunting, as they have also successfully captured their prey in places without understory cover and in open forest. However, more data on the characteristics of sites, where the chases were unsuccessful, will have to be collected, to ascertain how vegetation cover affects lynx hunting success. Also the characteristics of kill sites will have to be compared with random sites within the lynx home range to ascertain the degree of selectivity. In addition, it would be interesting to study habitat use of prey animals in the same area, to determine the lynx role in selection of the sites where hunting takes place and how important in this respect is the prey preference for particular habitats. It should be kept in mind that results may be somewhat biased, as there is probably greater probability that prey remains are found at sites with less vegetation, if lynx tracks are unavailable.

Hunting behaviour of most felids usually involves stalking or ambushing their prey and therefore cover might have important role in hunting success, as argued by some authors (Sunquist & Sunquist 1989, Branch 1995; Funston et al. 2001). Contrary to this, Pedersen et al. (1999) noted that Eurasian lynx in Sweden never used dense cover when hunting reindeer (*Rangifer tarandus*). However, in that study lynx rarely stalked their prey and never attacked it from ambush. Also, it must be noted that reindeer lives in large herds and as Sunquist & Sunquist (1989) stated, cover is more important when hunting solitary animals.

Murray et al. (1995) reported that vegetative cover did not affect hunting success of Canadian lynx (*Lynx canadensis*) when hunting snowshoe hare (*Lepus americanus*) in Yukon and that lynx hunted most frequently in sparse forests. Similarly, in Białowieża in Poland Eurasian lynx killed its prey at sites with lower tree density than at random sites (Podgorski 2006). Also, no significant difference was noted there in the amount of understory, forest type or forest age, however, there were more structures advantageous to stalking prey (deadwood, bushes) and lower visibility at kill sites than at random sites. As reported for Kalahari leopards (*Panthera pardus*), which also usually approach their prey with stalking, the vegetative cover is not a limiting factor to hunting success even in arid habitats (Bothma et al. 1994).

In our study, lynx often caught its prey in rugged terrain and on steep slopes. Again, comparison with random sites will have to be made for better evaluation. It could be implied that rugged relief is beneficial to lynx due to their agility and because uneven surface hinder the prey from attaining the maximum speed, which is higher compared to that of lynx (Hucht-

Ciorga 1988). Exception in this regard may be the chamois, which is better adapted to living in rugged terrain and therefore less vulnerable to lynx predation in such areas (Jobin et al. 2000). Rocky ground, which is common in rugged karst landscape, can also enable lynx a more silent approach and vertical structures can provide additional cover when stalking. On the other hand, however, the precipitous craggy terrain can be dangerous for the predator during hunting, especially when hunting large prey (Ross et al. 1995, 1997).

Interesting to note is also the substantial proportion of kill sites in dolines (Fig. 6). One of the reasons for this may be in the tendency of deer to preferentially escape downwards, which was observed in 5 out of 6 cases, when lynx was hunting on an uneven terrain (Krofel 2006). If the hunt takes place in the vicinity of a doline and the prey animal tries to escape downwards, it eventually reaches the bottom. There it does not have any other option but to run upwards, which slows it down and enables the predator to close in for the kill. Besides, during the winter snow often accumulates at the bottom of dolines, and this can additionally slow down the fleeing animal.

Similarly, high frequency of kill sites found in dolines was also recorded for the wolves in the Dinaric Mts in Slovenia (Krofel et al., unpublished data). Because of the cooperative hunting, dolines might have even greater importance for the wolves than for solitary cats, as one pack member may chase prey into a doline, while others circle around and intercept it during the ascent on the other side.

Further research is needed to determine how important these karst structures are in the course of the hunts on ungulates, but it appears that this may be one of the peculiarities of hunting behaviour of large carnivores in the karst areas, such as the Dinaric mountain range.

Figure 6: The doline, where female lynx killed a roe deer (Logatec plateau, central Slovenia).
Slika 6: Vrtača, kjer je risinja uplenila srno (Logaška planota, osrednja Slovenija).

Povzetek

Evrazijski ris se, tako kot velike mačke, pri lovu pogosto približa plenu z zalazom ali pa nanj čaka v zasedi (Kos s sod. 2005). Pri tem je pomembno, da ima na voljo dovolj kritja (Sunquist & Sunquist 1989). V okviru raziskav ekologije evrazijskega risa v Sloveniji ugotavljamo tudi značilnosti mest, kjer so risi uplenili svoj plen. Predstavljamo rezultate preliminarne raziskave, v okviru katere smo ugotavljali reliefne in vegetacijske značilnosti na 13 mestih, kjer so risi uplenili cervide na območju Dinaridov v Sloveniji.

V večini primerov so risi uplenili svoj plen v redkem ali zmerno gostem gozdu (46 % v vsakem). V 55 % primerov so plen uplenili na mestih z zmerno gostoto podrasti, v 27 % v redki podrasti, v 18 % primerov pa podrasti ni bilo. To nakazuje, da ris za uspešen lov ne potrebuje gostega rastja, vendar pa za zdaj še ne moremo trditi, da gostota vegetacije vpliva na lovni uspeh.

46 % mest uplenitve je bilo na območju z zmerno razgibanim terenom, 31 % na predelih z zelo razgibanim terenom, v 23 % pa je bil teren okoli mesta uplenitve nerazgiban. Velik del uspešnih poskusov lova je potekal na strmih pobočjih, in sicer 63 % na pobočjih z ocenjenim naklonom več kot 10° in 36 % na pobočjih z ocenjenim naklonom več kot 45°. Sklepamo

lahko, da je bolj razgiban teren za risa ugoden, ker plen na takšnih predelih teže doseže svojo maksimalno hitrost, ki je večja od risove (Hucht-Ciorga, 1989), do večjega izraza pa pride tudi risova gibčnost. Poleg tega vertikalne skalne strukture dajejo risu možnost kritja, kar mu olajša zalezovanje oziroma čakanje v zasedi, skalnata podlaga pa omogoča tudi tišje gibanje. Vendar po drugi strani skalnat in prepaden teren za plenilca pomeni večjo možnost nesreče in poškodb pri lovu. Še posebej to velja za plenjenje večjega plena, s katerim se mora plenilec potem, ko ga ujame, še nekaj časa boriti, pri čemer se poveča nevarnost poškodb (Ross s sod. 1995, 1997).

Precejšen delež (39 %) mest uplenitev je bil zabeležen v vrtačah. Razlog za to bi lahko bil v tendenci plena, da pogosto beži navzdol, kot smo ugotovili na podlagi sledenja v snegu (Krofel 2006). Če lov poteka v bližini vrtače in lovljena žival zbeži po pobočju navzdol, se kmalu znajde na dnu vrtače, kjer nima druge izbire, kot da beži navzgor, to pa jo upočasni, kar olajša plenilcu, da jo ujame ali podre. Podobno kot pri risu smo ostanke plena večkrat našli v vrtačah tudi pri raziskavah plenjenja volkov na območju Dinaridov v Sloveniji (Krofel s sod., neobjavljeno). Precejšen delež plena, ki smo ga našli na dnu vrtač, kaže na potencialni pomen tega kraškega pojava pri lovu plenilcev na velike sesalce, kar je verjetno ena izmed posebnosti pri plenilskem vedenju zveri na kraških območjih, kot so Dinaridi.

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