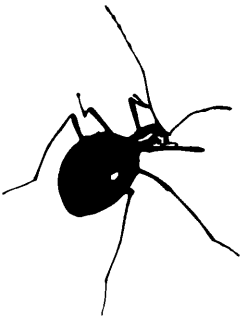

LJUBLJANA, JUNE 2004 Vol. 12, No. 1: 57–72

XVII. SIEEC, Radenci, 2001

CENOSES AND SPECIES PHENOLOGY OF CARABID BEETLES (COLEOPTERA: CARABIDAE) IN THREE STAGES OF VEGETATIONAL SUCCESSION IN UPPER PIVKA KARST (SW SLOVENIA)

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Abstract - The Carabid beetle cenoses in three stages of vegetational succession in selected karst area were studied. Year–round phenology of all species present is presented. Species richness of the habitats, total number of individuals trapped and the nature conservation aspects of the vegetational succession of the karst grasslands are discussed.

KEY WORDS: Coleoptera, Carabidae, cenose, phenology, vegetational succession, karst

Izvleček CENOZE IN FENOLOGIJA VRST KREŠIČEV (COLEOPTERA: CARABIDAE) V TREH STADIJIH ZARAŠČANJA KRASA NA ZGORNJI PIVKI (JZ SLOVENIJA)

Raziskali smo cenoze hroščev krešičev v treh sukcesijskih stadijih zaraščanja izbranega kraškega območja. Za vsako od ugotovljenih vrst je podana njena celoletna fenologija. Obravnavani so pestrost vrst po habitatih, skupno število ujetih osebkov in naravovarstveni vidiki zaraščanja kraških travišč.

KLJUČNE BESEDE: Coleoptera, Carabidae, cenoze, fenologija, zaraščanje, kras

Introduction

Until the late 19th century the Slovene Littoral Karst (Kras) and, in part, the southern slopes of the higher karst plateaus in southern Slovenia, resembled rocky semi-desert, covered sparsely by grass and scrub. This condition was brought about

by intense agricultural use, overgrazing by sheep and goats, burning and logging since ancient times. There are only small remnants left of the original forests. In the early 19th century the Austrian government began a series of successful reafforestation campaigns. As a consequence of nearly two centuries of reafforestation efforts, the Littoral Karst is now predominantly (55 %) forested, mainly by Austrian pine (*Pinus nigra*) plantations and secondary forest. The Austrian pine woodlands are pioneers and when they reach maturity they naturally convert to the original broad-leaved forests as the pine dies out. At the same time the Austrian pine is now spreading over the abandoned calcareous grasslands and bare, stony ground that is now disappearing very rapidly. Flowery karst meadows are from nature conservation view highly valuable when assessed using different animal and plant groups such as birds (Trontelj 2000), butterflies (Habeler 1992, Čelik & Rebeušek 1996) and plants (Kaligarič 1997). Lack of human exploitation of very biodiverse karst grasslands and meadows is therefore bringing about the loss of this biodiversity. In recent years this has become one of important nature conservation issues in Slovenia.

Only a few and local Carabid beetle cenose and species phenology investigations have been made in Slovenia so far (Drovenik 1978, Slapnik 1988, Furlan 1988, Vrezec 2000) and knowledge is still fragmented. In the present study I have investigated the species' richness and species' phenology of the Carabid beetles in the different stages of vegetational succession and I especially tried to answer the question of how the Carabid beetle cenoses react to the high rate of afforestation in the Slovene karst.

Investigated Area and Methods

I investigated the Carabid beetle fauna in three vegetational succession stages in the Upper Pivka karst in south-west Slovenia. The Pivka karst is an extensive valley on the western slopes of the high karst Snečnik plateau. The Snežnik plateau, at above 1000 meters in altitude, is well forested mainly with broadleaf and mixed forests of beech *Fagus sylvatica* and *Abieti-Fagetum s.lato.* The investigated area at approximately 600 m above sea level was once totally deforested pastures and grasslands. There remained only small remnants of Oak woodlands spared for litter collection. I investigated Carabids in the three succession stages of vegetational succession. The first area where I collected the Carabid beetles is dry, calcareous karst grassland and meadows that include bare, stony ground which is being rapidly swamped by various kinds of scrubland and mainly young Austrian pine trees in different phases of succession. The second vegetational succession stage that I investigated the Carabid beetles was a plantation of mature Austrian pine woodland. The trees are dense and there are few other tree species, but in a last ten years many other broad-leaved species such as wild cherry *Prunus avium*, oak *Quercus sp.* and flowering ash *Fraxinus ornus* have started to grow.

I chose the mature oak forest as a final stage of the vegetational succession of the area. In the turkey oak woodland *Quercus cerris* and durmast oak *Quercus petrea*

predominate, but there are some other broadleaf tree species as well as some Austrian pine trees in the forest clearings.

In each investigated habitat, I put 10 simple pit-fall traps in line approximately 15 meters apart. The 1/4 litre plastic containers were filled with salt solution for preservation. I added to the solution some drops of detergent to avoid static and some millilitres of old vinegar that is known as a ground beetle attractant. The traps were covered by tree bark to avoid flooding in the case of rain.

I started with sampling in June 1995 and finished in June 1996. The traps were checked approximately every two weeks and in winter time every three weeks. The specimens that were counted, prepared and determined are preserved in the Collection of Notranjski muzej Postojna. The systematic is that followed by Drovenik & Peks (1999).

The year-round phenology histograms for the most common species (eudominant and dominant) are made on the basis of the data collected. To evaluate the Carabid beetle cenoses of the three studied vegetational succession stages in the investigated area we calculated active dominance (DA) for all three investigated habitats using the formula (Tarman 1992):

DA = No. individuals particular species x 100 / No. of all individuals of all the species

Eudominant species	> 10 %
Dominant species	5 to 10 %
Subdominant species	2 to 5 %
Recedent species	1 to 2 %
Subrecedent species	< 1 %

Results

During the trapping over the one year period 1043 individuals were collected of 28 species of Carabid beetle. The smallest number (171) of the individuals was trapped in the dry karst grassland in the first stages of vegetational succession. In the Austrian pine woodland the number of trapped individuals was the highest (573) and lower again (299) in the last habitat of oak woodland. Among 28 collected species 20 species were trapped in the karst grassland, 21 in the Austrian pine woodland and 17 species in the oak woodland.

The number of individuals of a particular ground beetle species and the percentages of species in each investigated habitat are shown in the Table 1.

Table 1: The number of individuals of a particular Carabid beetle species and the percentages of species in each investigated habitat in Upper Pivka karst (SW Slovenia).

	Karst grassland	%	Pinus nigra woodland	%	Quercus sp. woodland	%	Together
Carabus catenulatus	13	7,6	6	1	50	16,7	69
Carabus hortensis	0	0	19	3,3	79	26,4	98
Carabus convexus	0	0	2	0,3	17	5,7	19
Carabus violaceus	50	29,2	3	0,5	2	0,7	55
Carabus coriaceus	33	19,3	7	1,2	5	1,7	45
Leistus rufomarginatus	0	0	26	4,5	3	1	29
Notiophilus biguttatus	0	0	1	0,2	0	0	1
Notiophilus palustris	0	0	2	0,3	0	0	2
Notiophilus rufipes	3	1,8	4	0,7	1	0,3	8
Notiophilus substriatus	1	0,6	0	0	0	0	1
Panageus bipustulatus	1	0,6	0	0	0	0	1
Myas chalybaeus	1	0,6	20	3,5	2	0,7	23
Poecilus koyi	1	0,6	0	0	0	0	1
Pterostrichus melanarius	1	0,6	1	0,2	0	0	2
Abax carinatus	0	0	1	0,2	0	0	1
Abax ovalis	8	4,7	229	40	65	21,7	302
Abax parallelepipedus	7	4,1	100	17,5	54	18,1	161
Molops ovipennis	29	17	37	6,5	10	3,3	76
Calathus fuscipes	4	2,3	4	0,7	1	0,3	9
Calathus cf. glabricollis	3	1,8	1	0,2	1	0,3	5
Synuchus nivalis	2	1,2	0	0	0	0	2
Laemostenus cavicola	0	0	1	0,2	1	0,3	2
Harpalus marginellus	0	0	1	0,2	1	0,3	2
Lebia clorocephala	1	0,6	0	0	0	0	1
Dromius notatus	8	4,7	1	0,2	1	0,3	10
Microlestes sp.	2	1,2	0	0	0	0	2
Aptinus bombarda	2	1,2	107	18,7	6	2	115
Brachinus explodens	1	0,6	0	0	0	0	1
No. of individuals	171		573		299		1043
No. of species	20		21		17		28

1. Carabid beetle cenoses

Karst grassland Carabid beetle cenose

Among the 20 species that were found in the dry calcareous karst grassland of the investigated area 3 species are eudominant (Fig.1). The most common is *Carabus*

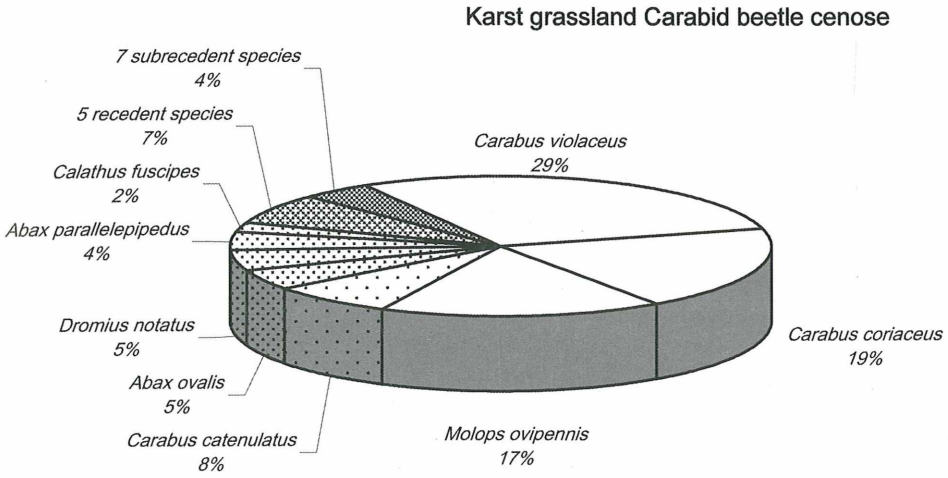

Fig. 1: Karst grassland Carabid beetle cenose in Upper Pivka karst (SW Slovenia).

violaceus (29 %), followed by *Carabus coriaceus* (19 %) and *Molops ovipennis* (17 %). *Carabus catenulatus* (8 %) is recognised as a dominant species. There are 4 subdominant species: *Abax ovalis*, *Dromius notatus*, *Abax parallelepipedus* and *Calathus fuscipes*. Among 5 recedent species there are *Notiophilus rufipes*, *Calathus cf. glabricollis*, *Synuchus nivalis*, *Microlestes sp.* and *Aptinus bombarda*. There were 7 subrecedent species represented only by one specimen as *Notiophilus substriatus*, *Panageus bipustulatus*, *Myas chalybaeus*, *Poecilus koyi*, *Pterostrichus melanarius*, *Lebia clorocephala* and *Brachinus explodens*.

Austrian pine (*Pinus nigra*) woodland Carabid beetle cenose

In the Austrian pine dense and mature woodland the Carabid beetle cenose is significantly different (Fig. 2). The subdominant species are *Abax ovalis* (41 %),

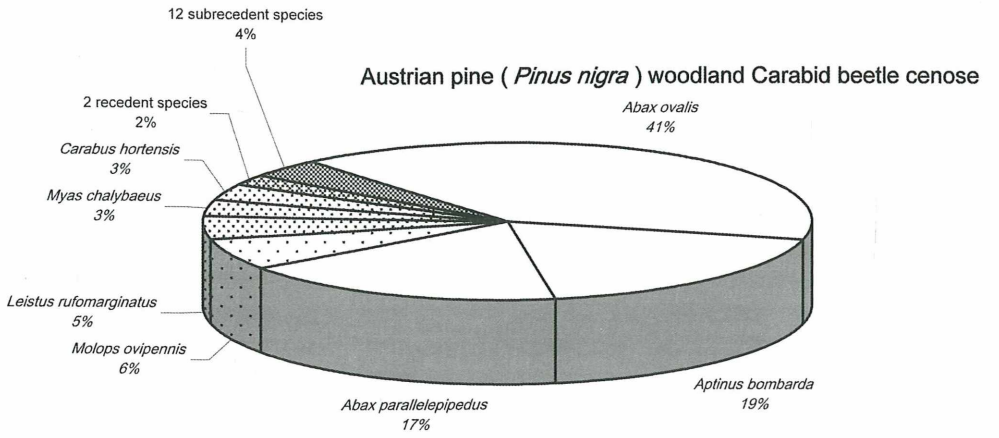

Fig. 2: Austrian pine (*Pinus nigra*) woodland Carabid beetle cenose in Upper Pivka karst (SW Slovenia).

Aptinus bombarda (19 %) and *Abax parallelepipedus* (17 %). *Molops ovipennis* here is classified as a dominant. The subdominants are *Leistus rufomarginatus* (5 %), followed by *Myas chalybaeus* (3 %) and *Carabus hortensis* (3 %). There are 2 recedent species; *Carabus coriaceus*, and *Carabus catenulatus*. Plenty of subrecedent species are represented by 1-4 trapped individuals: *Carabus convexus*, *Carabus violaceus*, *Notiophilus biguttatus*, *Notiophilus palustris*, *Notiophilus rufipes*, *Pterosttrichus melanarius*, *Abax carinatus*, *Calathus fuscipes*, *Calathus cf. glabricollis*, *Laemostenus cavicolla*, *Harpalus marginellus* and *Dromius notatus*.

Oak (*Quercus* sp.) woodland Carabid beetle cenose

The number of species present in the oak woodland is lowest. Among the 17 species found *Carabus hortensis* (26 %), *Abax ovalis* (22 %), *Abax parallelepipedus* (18 %) and *Carabus catenulatus* (17 %) are eudominant (Fig. 3). The dominant found is *Carbus convexus* (6 %). The subdominant species are *Molops ovipennis* (3 %) and *Aptinus bombarda* (2 %). Two species, *Carbus coriaceus* (1.7 %) and *Leistus rufomarginatus* (1 %) are recedent. There are 8 subrecedent species presented in the traps only by 1 or 2 specimens. These are *Carabus violaceus*, *Notiophilus rufipes*, *Myas chalybaeus*, *Calathus fuscipes*, *Calatus cf. glabricollis*, *Leamostenus cavicola*, *Harpalus marginellus* and *Dromius notatus*.

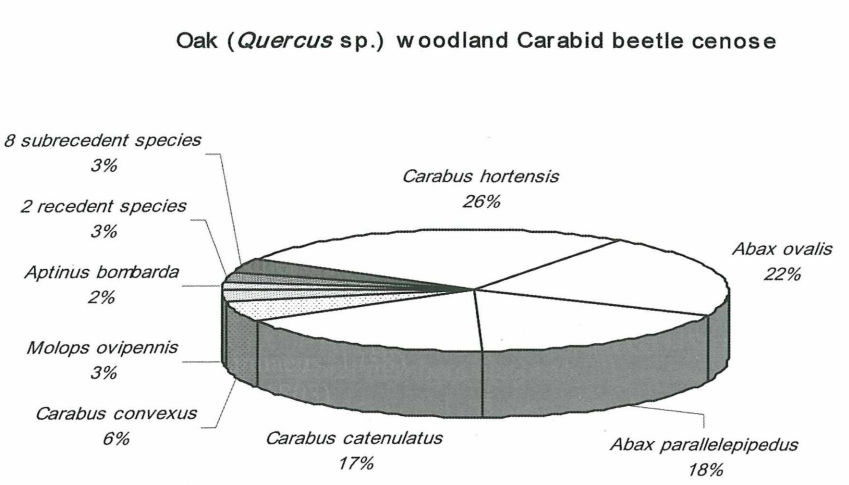

Fig. 3: Oak (*Quercus sp.*) woodland Carabid beetle cenose in Upper Pivka karst (SW Slovenia).

2. Carabid beetle species phenology and habitat preferences

Carabus catenulatus Scopoli, 1763

According to the Drovenik (1978) investigations the species is most common at the

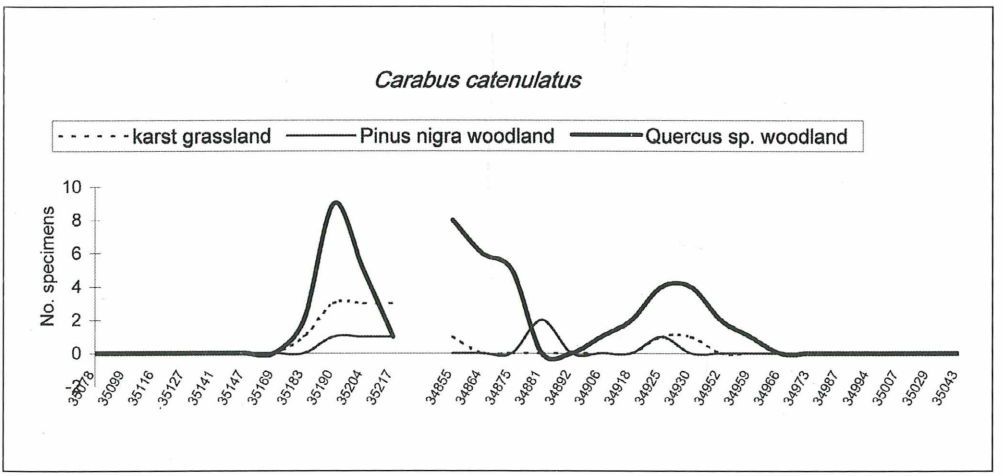

Fig. 4: *Carabus catenulatus* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

edges of meadows and woodlands, especially on the exposed sunny slopes. It was found in all three investigated habitats but thermophilic oak woodland seems to be most suitable for this species. There it is one of 4 eudominant species. The species starts to emerge at the end of April, reaches peak presence in May and shows an obvious decline at the end of June. The next generation starts at the end of July and finishes its appearance at the end of September. The specimens in other habitats show a similar phenology (Figure 4).

Carabus hortensis (Linnaeus 1758)
This strictly forest and thermophilic species is the most common Carabid beetle species in the oak woodland and subdominant in the Austrian pine forest. The phenogram (Fig. 5) shows three or even four peaks that could be influenced by weather conditions. The first specimens were trapped in the middle of May and the last at the start of November. At the end of August and end of September no specimens of this species were found in the traps.

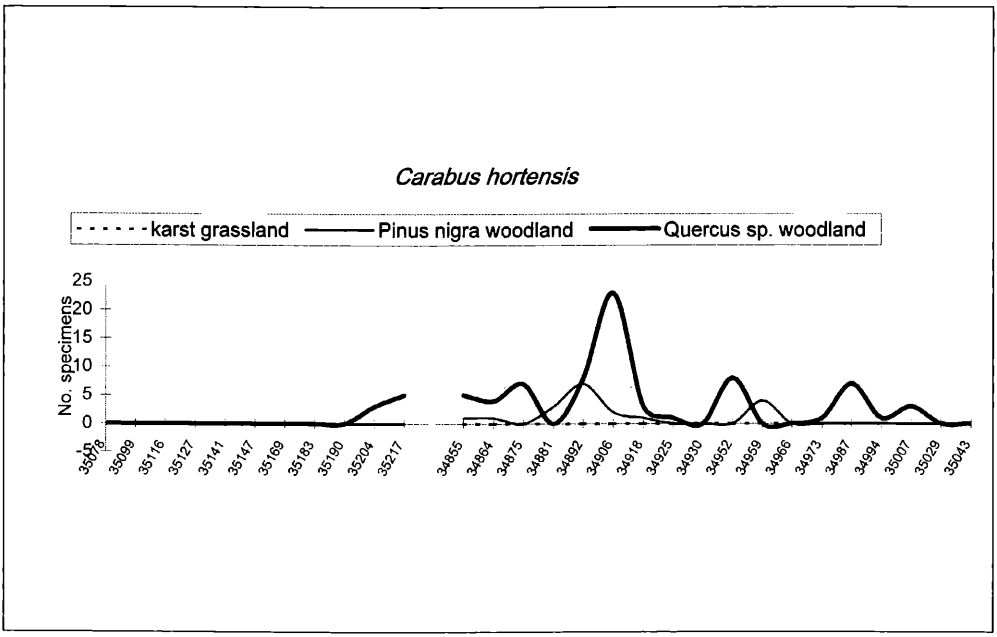

Fig. 5: *Carabus hortensis* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

Carabus convexus (Fabricius 1775)
Our data clearly show that this species prefers the thermophilic oak woodland. In the coldest Austrian pine forest we trapped only two specimens and none in the dry grassland. It seems that the species has three generations one in April and May, second in July and August and a third in October.

Carabus violaceus (Linnaeus 1758)
Contrary to *C. convexus* this species clearly shows a preference for grassland habitats. It was the most common (eudominant) species in the karst grassland under investigation. The specimens trapped in the other two habitats seem to coincide with breeding dispersal. Despite of the fact that the first specimens had already emerged in May the most obvious peak (probably a second generation) starts at the end of July and finishes in the middle of September (Figure 6).

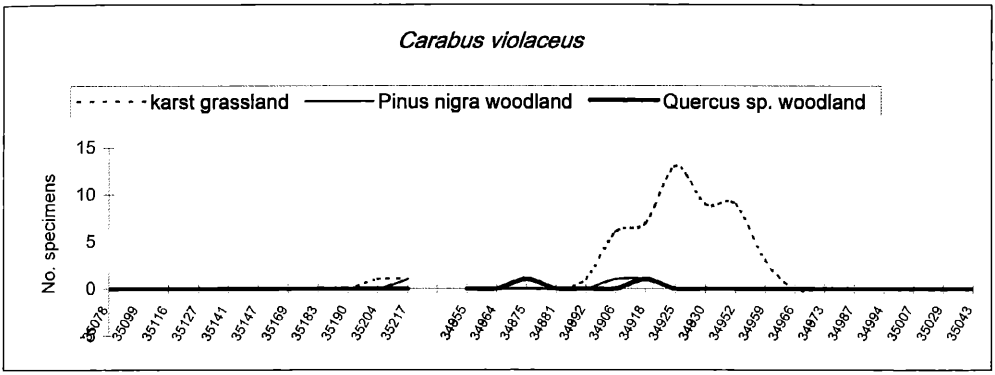

Fig. 6: *Carabus violaceus* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

Carabus coriaceus (Linnaeus 1758)
Similar to the *C. violaceus* in preferring non-wooded habitats too, but we occasionally found some specimens in both the two woodland types also. The species has two or three generations. The first specimens were trapped at the end of April and the last at the start of November. The species becomes abundant at the end of May, in the middle of July and especially between the end of August and end of October (Figure 7).

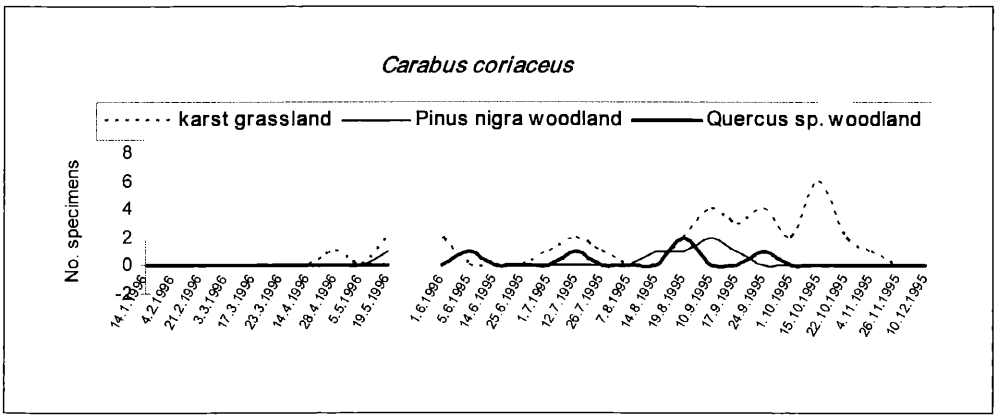

Fig. 7: *Carabus coriaceus* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

Leistus rufomarginatus (Duftschmidt 1812)
In the investigated area the pine woodland seems to be the most suitable habitat. Only three specimens were trapped in the oak woodland. The species is present in the cold part of the year from the October to January with an obvious peak in mid-November. The second less obvious generation emerges in May.

Notiophilus biguttatus (Fabricius 1779)
Only one specimen of this species was trapped in Austrian pine forest on 19th May.

Notiophilus palustris (Duftschmidt 1812)
One specimen of this species was trapped on 19th May and another on 15th October, both in the Austrian pine forest.

Notiophilus rufipes (Curtis 1829)
Among the *Notiophilus* species this was the commonest one. 3 specimens were trapped in the karst grassland, 4 in the Austrian pine forest and 1 in the oak forest. It is present in April, July and in September.

Notiophilus substriatus (Waterhouse 1833)
Only 1 specimen was trapped (4. 11. 1995) in dry grassland which shows the heliophilic character of this species.

Panagaeus bipustulatus (Fabricius 1775)
This southern European species prefers dry habitats, proved by our finding of a specimen on 1st July in the dry grassland.

Myas chalybaeus (Palliardi 1825)
The distribution of this Balkan species also reaches southern Slovenia. Our data clearly show that it prefers Austrian pine woodland, where it is subdominant among the other species. It starts to emerge in June but becomes commonest in July and August. The latest specimen was trapped at the end of September.

Poecilus koyi (Germar 1824)
This species is also a south European representative. It prefers open areas. The only specimen trapped was in the karst grassland on the 14th August.

Pterostichus melanarius (Illiger 1798)
This species was found only twice. One specimen was on 26th July in Austrian pine forest and the second on 10th September in the grassland.

Abax carinatus (Duftschmidt 1812)
Contrary to the *Abax ovalis* this species is rare in the investigated area. The only specimen was found in the pine forest on 26th July.

Abax ovalis (Duftschmidt 1812)
This central and southern Europe species has a montane and subalpine character. It prefers wet forest habitats. Therefore it is not a coincidence that it was most common in the Austrian pine forest and a bit less common but still eudominant in the oak woodland. The species occurs only accidentally in the grassland habitat. This species starts to emerge in the middle of May, it reaches its first maximum in second half of May. The next distinctive appearance of the species is in July and beginning of August and the third one, quite obvious in mid-November. The last specimen was trapped on 26th November (Figure 8).

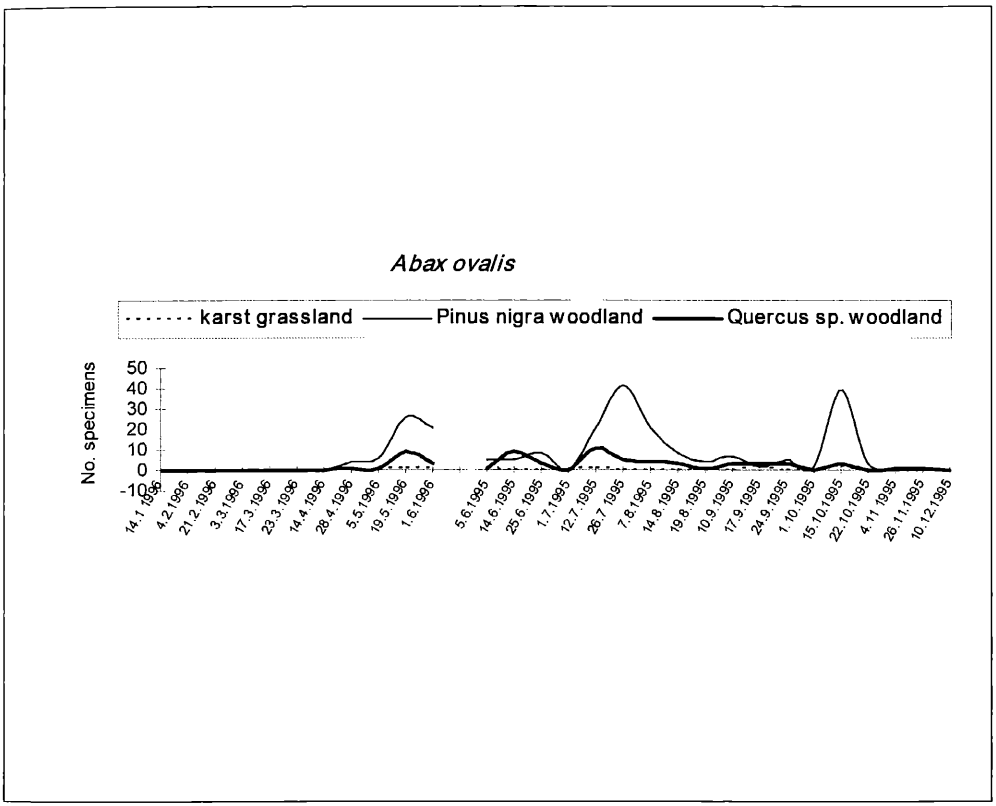

Fig. 8: *Abax ovalis* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

Abax parallelepipedus (Piller & Mitterpacher 1783)
In the investigated area this species shows similar figure to *Abax ovalis*. The species predominates in the Austrian pine forest, but is a bit less common in the oak woodland and appears only accidentally in the karst grasslands. The species appear for the first time at the beginning of May and finishes its season in mid-October. The species has at least two distinctive peaks one in May and second in July (Figure 9).

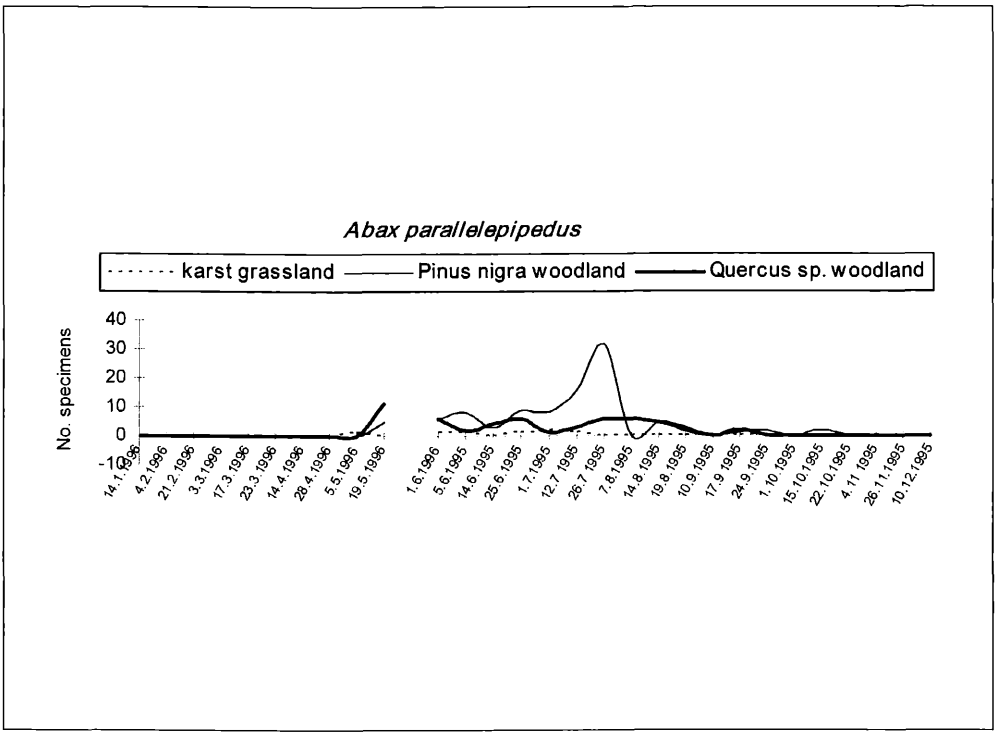

Fig. 9: *Abax parallelepipedus* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

Molops ovipennis (Chaudoir 1847)

This species lives in the montane and subalpine habitats in the southern and south-eastern Alps. It seems common on the submediterranean edge of the montane Snežnik plateau as well. Despite the literature which characterizes this beetle as a forest species my data and the results of Drovenik (1978) in Trnovski Gozd, show that it occurs in open grassland habitats too. According to the data collected in this study the species is the most common in Austrian pine forest where is classified as a dominant species. It is quite common in the calcareous karst grassland but much rarer in the oak forest. *Molops ovipennis* has two distinctive peaks in its appearance; despite this some specimens were caught in other periods also. The spring generation appears at the end of March, reaches its peak at the end of April and lasts to the end of May. We found only one specimen in July and one again in August. The second distinctive generation starts in September reaching a peak in November and December and finishes its appearance at the beginning of February. It is interesting that during the spring emergence the species was the most abundant in grassland habitats whilst in the autumn it was found most frequently in the Austrian pine woodland (Figure 10).

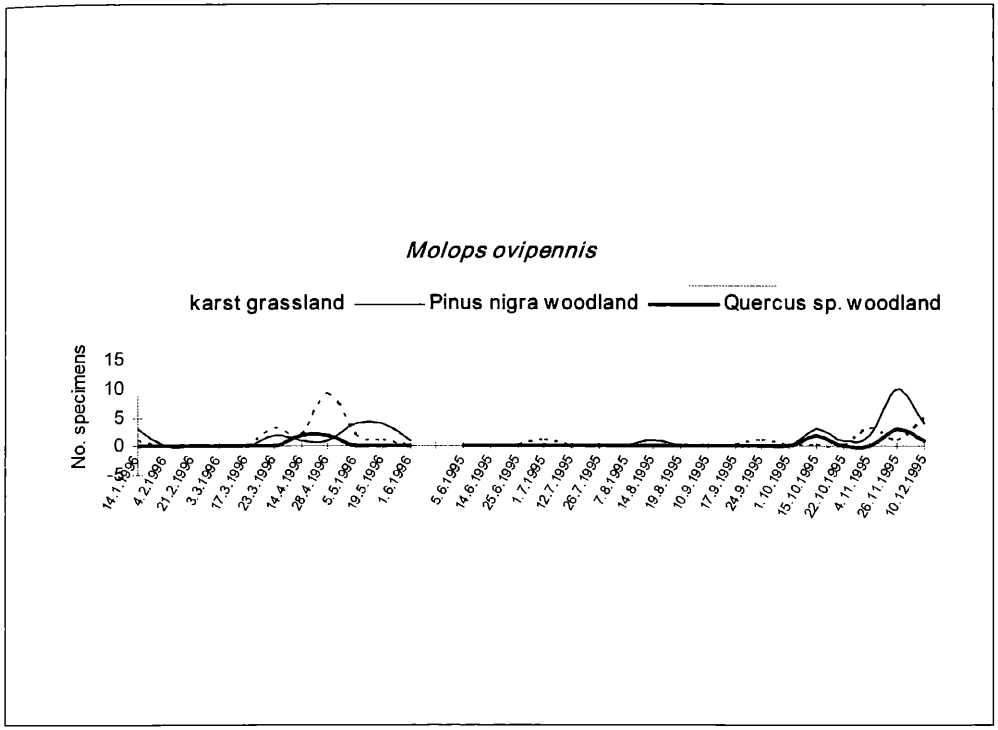

Fig. 10: *Molops ovipennis* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

Calathus fuscipes (Goeze 1777)
This genus prefers sandy soils of open habitats. Among specimens that we trapped during our investigation the 9 specimens of *Calathus fuscipes* were determined. They were present mainly in the grassland habitat but also in Austrian pine forest. Only one specimen was found in oak forest. They were caught between July and October.

Calathus cf. glabricollis
The determination of this species is not reliable so far due to the large number of similar southern European species that could appear in the region. Three specimens were caught in karst grassland, one in pine and one in oak woodland.

Synuchus nivalis (Panzer 1797)
We caught 2 specimens in September (10. 9. 1995) in the karst grassland.

Laemostenus cavicola Schaum 1858
This troglophile species is common in the underground habitats of the investigated area, but occasionally found in the surface habitats too. This is due to the fact that

the area is karstic with plenty of rock fissures and cracks so the surface appearance of the species is not a surprise. We found one in grassland habitat on 5th June and one on 26th November in the Austrian pine forest. The appearance of this species is influenced by presence of cave habitat nearby.

Harpalus marginellus (Dejean 1829)
Only two specimens were caught in the traps. On 5th July in Austrian pine woodland one specimen was traped and one on 14th July in oak forest.

Lebia clorocephala (Hoffmann 1803)
It is a species of the open landscapes with low vegetation, woodland edges and wet meadows. It occurs mostly in spring. We obtained only one specimen in the trap on 23th March in the karst grassland area.

Dromius notatus (Stephens 1827)
It is a soil-loving species of dry and sunny exposed sites. We found 8 specimens mainly in the karst grassland in the period of February through to the end of March.

Microlestes sp.
There are about 20 species of this genus in Europe. The karst dry grassland is a similar habitat to that described in literature such as sandy or clay soils which are exposed to sunlight and little vegetation. One specimen of this genus was found on 28th April and the second one on 5th June.

Aptinus bombarda (Illiger 1800)
This is an eastern Alpine and central-Balkan species that lives mostly in the montane and subalpine forests. The investigations showed that the species is eudominant in the Austrian pine forest and subdominante in the rather more thermophilic oak forest. This is distinctive and active summer species. It starts to emerge at the end of May and soon reaches its maximum of occurrence in the middle of June. The next distinctive peak is in August. The last 4 females were caught on 19th August. The sparse occurrence of this species in oak woodland and grassland could be due to post breeding dispersal (Figure 11).

Brachinus explodens Duftschmidt 1812
This species lives in the open habitats usually on sandy and clay ground. The only specimen was trapped on 19. 5. 1996 in the rocky grassland habitat.

Discussion and conclusions

Amongst the three investigated vegetational succession stages in the area, the highest number of Carabid beetle species (21) was found in the Austrian pine woodland, followed by karst grassland (20) and oak woodland (17). The possibility that some species may have been overlooked is almost identical in all three investigated

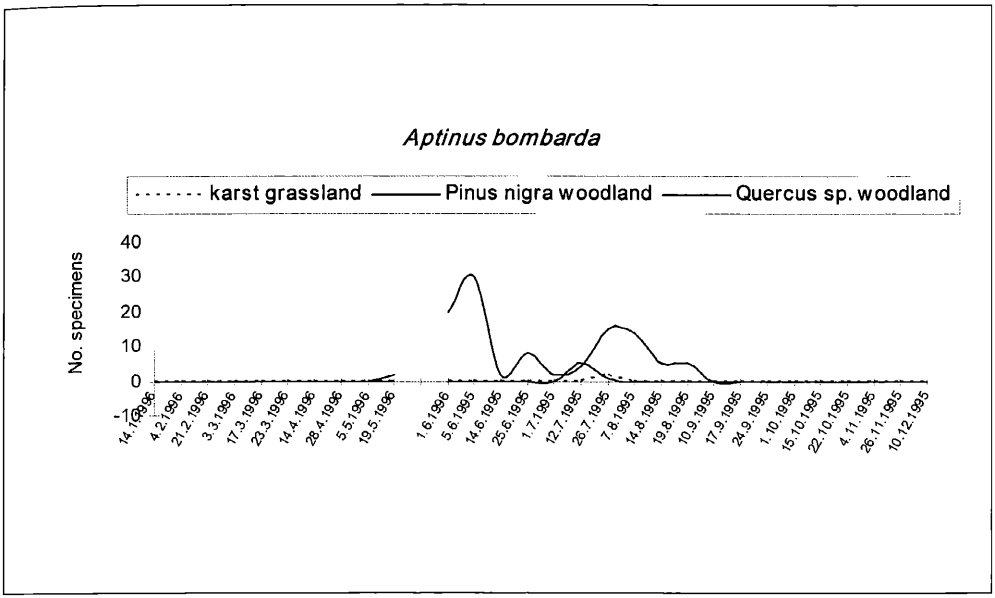

Fig. 11: *Aptinus bombarda* phenology and habitat preference in Upper Pivka karst (SW Slovenia).

habitats, each of which contained roughly the same number of species. The results were surprising; we expected some significant differences between the three areas.

The number of trapped Carabid beetle individuals was significantly the highest (573 ind.) in the Austrian pine woodland too. The total number of collected individuals was followed in the oak forest (299 ind.). Investigated karst grassland in the first stage of vegetational succession was poor in the number (171 ind.) of trapped individuals of Carabid beetles.

Despite the relatively low number of species by far the lowest number of Carabid beetle individuals, the dry, calcareous grasslands are rich in species that seem to be rare and highly endangered given the high rate of afforestation and the loss of this habitat. Only 6 years after the field work, the investigated dry karst grassland area has been invaded by Austrian pine to such an extent, that the heliophilic species such as *Panageus bipustulatus*, *Notiophilus bipustulatus*, *Poecilus koyi*, *Synuchus nivalis*, *Lebia clorocephala*, *Microlestes sp.*, and *Brachinus explodens* (and probably many others) are probably extinct in the area. The same thing is undoubtedly happening all over Slovene and Italian high and littoral karst grassland areas.

Carabid beetles as a group can be used as indicators for nature conservation area evaluation, but the species richness and the total individual Carabid beetle abundance seems inappropriate for detecting areas of high conservation priority. A list of endangered Carabid beetle species, made on the basis of estimated threats to their optimal habitats needs to be done and a 'threatened species' approach used for the area evaluation.

Acknowledgements

I would like to thank Savo Brelih and Božidar Drovenik for their help in the determination on some Carabid beetle taxa and Paul Tout for his help with the correction of the English text of this paper.

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