Original scientific article
Received: 2013-08-13

UDK 599.363:591.531.257:595.2(497.4)

# NOTES ON INVERTEBRATES PREYED BY SHREWS (MAMMALIA: INSECTIVORA: SORICIDAE) IN SLOVENIA

*Tina KLENOVŠEK, Franc JANŽEKOVIČ & Tone NOVAK*
Department of Biology, Faculty of Natural Sciences and Mathematics, University of Maribor,
SI-2000 Maribor, Koroška cesta 160, Slovenia
E-mail: tina.klenovsek@uni-mb.si

*Miran ČAS*
Department of Forest Ecology, Slovenian Forestry Institute, SI-1000 Ljubljana, Večna pot 2, Slovenia

*Tomi TRILAR*
Slovenian Museum of Natural History, SI-1000 Ljubljana, Prešernova 20, Slovenia

*Tina POŠTRAK*
Ekos, SI-2341 Limbuš, Antona Godca 8, Slovenia

## *ABSTRACT*

*Until recently in Slovenia, the presence of invertebrates in the shrew diet had not been investigated. Here we present a list of invertebrates and other ingested items in five shrew species:* Sorex alpinus, S. araneus, S. minutus, Crocidura suaveolens *and* Neomys fodiens *in Slovenia. These shrews fed mostly on arthropods and earthworms. Among the arthropods, Araneae, Opiliones, Lithobiomorpha and Insecta were found. Oniscoidea and Diplopoda, generally abundant in the shrews' habitats, were not found. Among the identified species,* Amaurobius ferox, Mitopus morio, Aptinus bombarda *and* Apterygida media *were the most common prey.*

**Key words:** shrew prey, Soricidae, Arthropoda, Slovenia

# NOTE SU INVERTEBRATI PREDATI DA TOPORAGNI (MAMMALIA: INSECTIVORA: SORICIDAE) IN SLOVENIA

*SINTESI*

*Solo recentemente è stata indagata la presenza di invertebrati nella dieta del toporagno in Slovenia. Gli autori presentano l'elenco degli invertebrati e di altri oggetti ingeriti da cinque specie di toporagno:* Sorex alpinus, S. araneus, S. minutus, Crocidura suaveolens e Neomys fodiens *in Slovenia. Questi toporagni si nutrono per lo più di artropodi e lombrichi. Tra gli artropodi sono stati trovati rappresentanti di ragni (Araneae), opilionidi (Opiliones), centopiedi (Lithobiomorpha) e insetti (Insecta). Non sono state rinvenute invece specie di onisicidi (Oniscoidea) e diplopodi (Diplopoda), generalmente abbondanti negli habitat dei toporagni. Tra le specie identificate le prede più comuni sono:* Amaurobius ferox, Mitopus morio, Aptinus bombarda e Apterygida media.

**Parole chiave:** prede di toporagni, Soricidae, Arthropoda, Slovenia

## INTRODUCTION

Shrews (Soricidae) are small insectivorous mammals that occupy relatively small territories, are active many times a day throughout the year and are opportunistic feeders (Churchfield, 1994; Churchfield & Rychlik, 2006). They prey mostly on invertebrates, like arthropods, lumbricids, slugs and others. So far, their prey has rarely been determined on the species level (Denneman, 1990; Mitov, 1995; Novak *et al.,* 2006; Klenovšek *et al.,* 2013), as studies on the shrew diet have focused mostly on the quantity of the prey consumed. Such papers usually list families and higher taxa, along with the prey body length classes (*e.g.*, Churchfield, 1994; Churchfield & Rychlik, 2006) or volume (Whitaker & Ruckdeschel, 2006), which are indicative of the prey body mass or its energy value to the predator. Besides consuming them, shrews cause injuries to living invertebrates, like the litter-dwelling opilionid *Trogulus nepaeformis*, where the legs of up to one-third of individuals in some populations have been damaged (Novak *et al.,* 2006). Such knowledge highlights the complexity of the impact of shrews on the syntopic invertebrates. Although shrews are opportunistic feeders, they are known to avoid Diplopoda (*e.g.*, Churchfield & Rychlik, 2006), which are abundant in most habitats, and shrews presumably do not eat invertebrates living above the ground (Churchfield, 2002). Thus, they are not expected to eat all invertebrates within a territory, and in this way exert an unequal impact on the invertebrate population.

The aim of this paper is to present a list of invertebrate prey species and other consumed material based on food remnants found in the stomachs of five shrew species in Slovenia (*Sorex alpinus, S. araneus, S. minutus, Crocidura suaveolens* and *Neomys fodiens*). Selected photographs of recognized prey and other ingested items – such as those provided for neuropterans (Devetak & Duelli, 2007) – are included as indispensable for the recognition and determination of prey species. We also discuss the role of some invertebrate species as the shrews' prey and the role of shrews as natural predators of some invertebrates in Slovenia.

## MATERIAL AND METHODS

In total, the stomach contents of 204 shrews belonging to five species were considered: 124 specimens of *Sorex araneus* Linnaeus, 1758, 60 specimens of *S. minutus* Linnaeus, 1766, 18 specimens of *S. alpinus* Schinz, 1837, one specimen of *Crocidura suaveolens* (Pallas, 1811) and one specimen of *Neomys fodiens* (Pennant, 1771). Most of the stomachs accrued from investigations on Mt. Snežnik and Mts. Peca, Smrekovec and Olševa (in the following: the Koroška Mts.), in which small mammals and invertebrates were systematically sampled (Trilar, 1991; Kos *et al.,* 2000; Drovenik, 2001; Janžekovič & Čas, 2001). Nearly all of these stomachs were used for a trophic niches comparison of the three syntopic *Sorex* species in a montane habitat (Klenovšek *et al.,* 2013). The rest of the shrews were from other localities (Tab. 1).

The stomachs were dissected, and their contents transposed into 70% ethanol and inspected for major food remnants. Afterwards, the contents were heated in 10% NaOH at 80 °C for 4 hrs (Sommer & Sommer, 1997) to dissolve soft tissues. Undissolved remnants, like chitinous, cellulose and other similar particles, were examined under a Nikon Eclipse E800 compound microscope with a mounted digital Net camera DN100, and processed with Eclipse Net software. The photographed prey remains were identified by comparison to invertebrate specimens collected at the same time and in the same locality as the shrews. Most frequently small fragments of antennae, legs, elytrae, heads, chelicerae etc. were found, which enabled unambiguous comparison and determination.

## RESULTS

In 204 stomachs of five shrew species, a total of 180 animal prey items from 21 taxa were identified. In addition, we found soil and wood particles, rootlets and animal prey remnants, which could not be identified. The list of food items found is presented in Table 2, and selected

***Tab. 1: Locality, altitude, collection date, shrew species and the number of specimens investigated.***
***Tab. 1: Lokaliteta, nadmorska višina, datum ulova, vrsta in število pregledanih osebkov***

| Locality, altitude | Date | Shrew species | No of individuals |
|---|---|---|---|
| Mt. Snežnik, 1150–1350 m | 1988–1990 | *Sorex araneus* | 65 |
| | | *S. alpinus* | 1 |
| Mts. Peca, Smrekovec and Olševa, 1030–1500 m | MayOctober 1999–2000 | *S. araneus* | 59 |
| | | *S. minutus* | 58 |
| | | *S. alpinus* | 14 |
| Idrija, 520 m | 13. 7. 2001 | *S. alpinus* | 3 |
| Postojna, 530 m | 13. 7. 2001 | *S. minutus* | 2 |
| Dragonja, 60 m | 13. 7. 2001 | *Crocidura suaveolens* | 1 |
| Slovenj Gradec, 430 m | 23. 6. 2000 | *Neomys fodiens* | 1 |

***Tab. 2: List of invertebrates and plant material found in the stomachs of five shrew species.***
***Tab. 2: Seznam nevretenčarjev in rastlinskega materiala, najdenega v želodcih petih vrst rovk***

| **Food items** | | | ***Sorex araneus* (n=124)** | ***S. minutes* (n=60)** | ***S. alpines* (n=18)** | ***Crocidura suaveolens* (n=1)** | ***Neomys fodiens* (n=1)** |
|---|---|---|---|---|---|---|---|
| Wood particles | | | + | | + | | |
| Rootlets | | | + | | | | |
| Prey | | | | | | | |
| Higher taxon | Family | Species | | | | | |
| Gastropoda indet. (slugs) | | | + | | | | |
| Lumbricidae indet. | | | + | + | + | | |
| Araneae indet. | | | + | + | + | | + |
| | Amaurobiidae | | | | | | |
| | | *Amaurobius ferox* (Walckenaer 1830) | + | + | + | | |
| Opiliones | | | | | | | |
| | Phalangiidae | | | | | | |
| | | *Lacinius ephippiatus* (C. L. Koch 1835) | + | | | | |
| | | *Opilio dinaricus* Šilhavý 1938 | | | | + | |
| | | *Rilena triangularis* (Herbst 1799) | | + | | | |
| | | *Mitopus morio* (Fabricius 1799) | + | + | + | | |
| | Trogulidae | | | | | | |
| | | *Trogulus nepaeformis* (Scopoli 1763) | + | | | | |
| Lithobiomorpha indet. | | | + | | + | | |
| Insecta indet. | | | + | + | | | |
| Dermaptera | | | | | | | |
| | Forficulidae | *Apterygida media* (Hagenbach 1822) | + | + | + | | |
| Coleoptera indet. | | | + | + | + | | |
| | Carabidae | | + | | | | |
| | | *Aptinus* (*Aptinus*) *bombarda* (Illiger 1800) | + | + | + | | |
| | | *Carabus* (*Megadontus*) *violaceus* Linnaeus 1758 | + | | | | |
| | | *Nebria dahlii* (Duftschmid 1812) | + | | | | |
| | Staphylinidae | *Philonthus* sp. | + | | | | |
| | Curculionidae | *Tropiphorus elevatus* (Herbst 1795) | + | | | | |
| | Pselaphidae | | | + | | | |
| Hymenoptera | | | | | | | |
| | Myrmicidae | | + | | | | |
| Diptera | | | | | | | |
| | Cecidomyiidae | *Mikiola fagi* (Hartig 1839) | + | | | | |

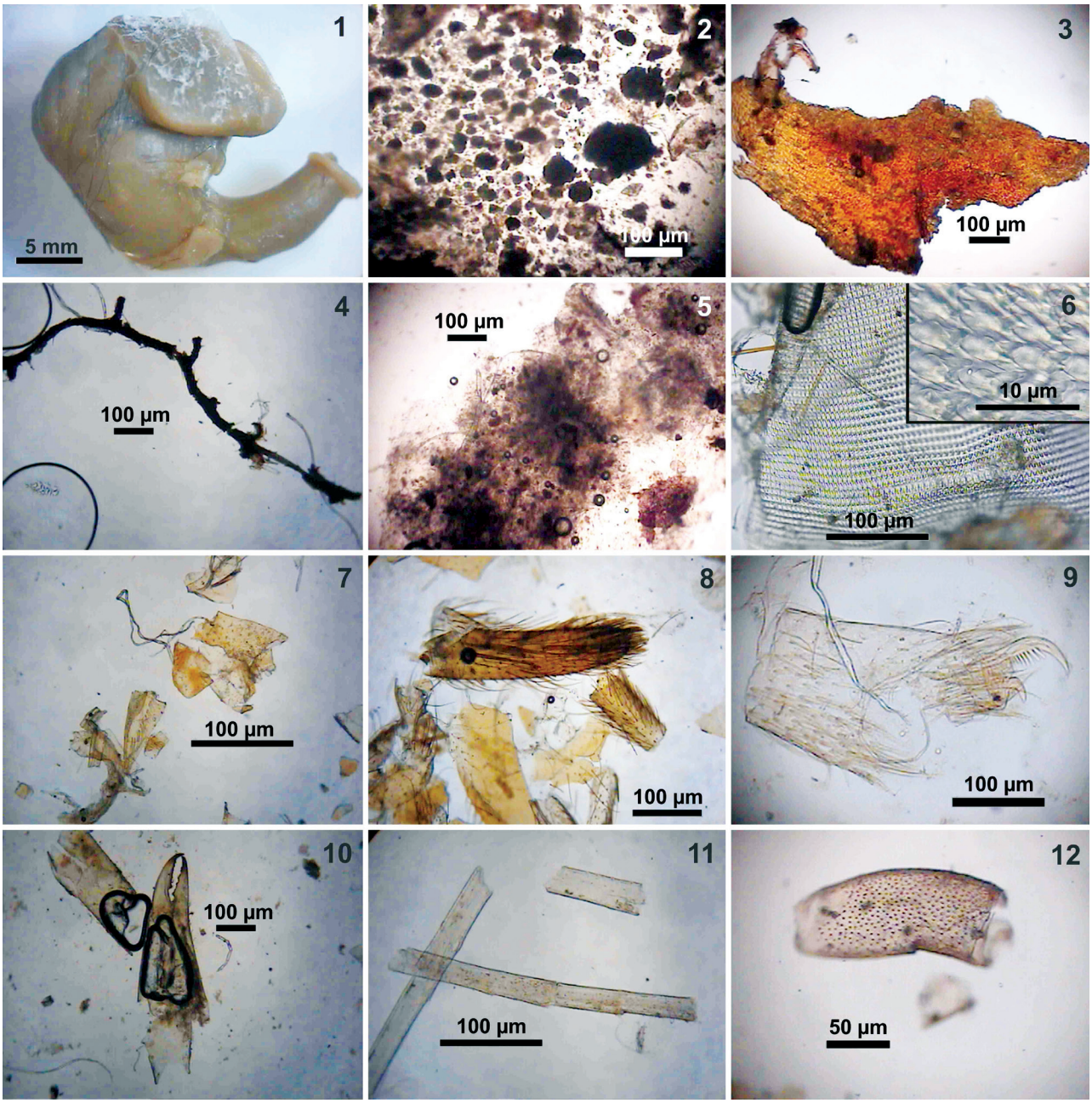


***PLATE I: Shrew stomach and selected remnants of food items. Fig. 1: stomach of*** *Sorex araneus****; Fig. 2: soil particles; Fig. 3: wood particle; Fig. 4: rootlet; Fig. 5: earthworm residuals; Fig. 6: slug radula; Fig. 7: arthropod chitinous remains; Fig. 8: spider remains; Fig. 9:*** *Amaurobius ferox* ***tarsus; Fig. 10:*** *Rilaena trinagularis* ***chelicerae; Fig. 11:*** *Lacinius ephippiatus* ***legs; Fig. 12:*** *Mitopus morio* ***pedipalpal patella.***
***TABLA I: Želodec rovke in izbrani preostanki hrane. Sl. 1: želodec vrste*** *Sorex araneus****; Sl. 2: delci prsti; Sl. 3: delci lesa; Sl. 4: koreninica; Sl. 5: ostanki deževnika; Sl. 6: strgača polža; Sl. 7: hitinski ostanki členonožca; Sl. 8: ostanki pajka; Sl. 9: tarzus vrste*** *Amaurobius ferox****; Sl. 10: helicera vrste*** *Rilaena trinagularis****; Sl. 11: noge vrste*** *Lacinius ephippiatus****; Sl. 12: patela pedipalpa vrste*** *Mitopus morio*

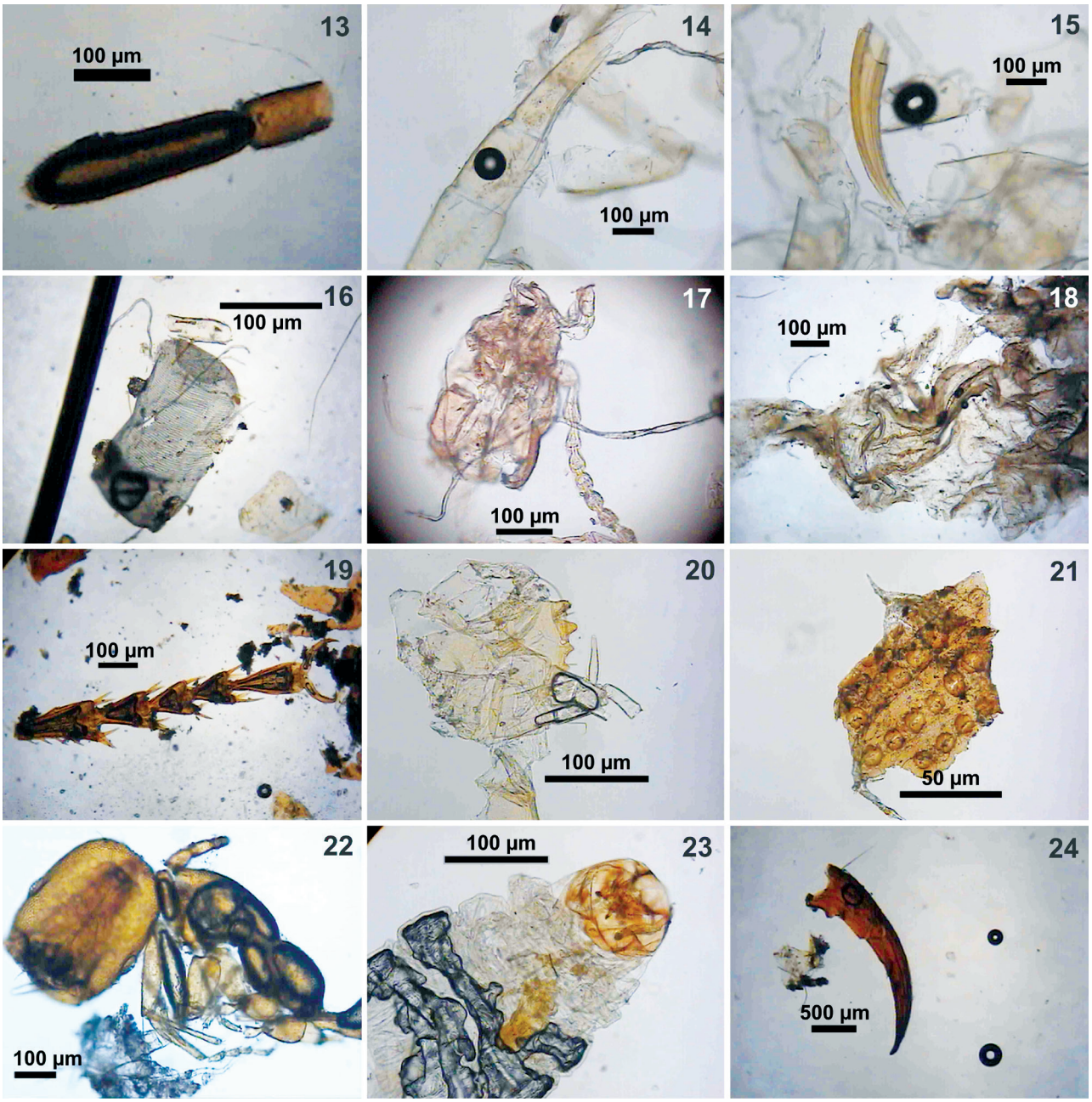


***PLATE II: Selected remnants of food items. Fig. 13:*** *Trogulus nepaeformis* ***2nd leg tarsus; Fig. 14: leg of lithobiomorphous; Fig. 15: lithobiomorphous maxillipede; Fig. 16: insect trachea; Fig. 17:*** *Aptinus bombarda* ***head; Fig. 18:*** *Carabus violaceus* ***proventricle chitinous inner covering; Fig. 19:*** *Nebria dahli* ***tarsus; Fig. 20:*** *Tropiphorus elevatus* ***maxilla; Fig. 21:*** *T. elevatus* ***fore-wing; Fig. 22: Myrmicid ant; Fig. 23:*** *Michiola fagi* ***larva; Fig. 24:*** *Apterygida media* ***cercus.***

***TABLA II: Izbrani preostanki hrane. Sl. 13: vrsta*** *Trogulus nepaeformis* ***– tarzus druge noge; Sl. 14: noga strige; Sl. 15: maksiliped strige; Sl. 16: traheja žuželke; Sl. 17: glava vrste*** *Aptinus bombarda****; Sl. 18: hitinska notranja plast proventrikla vrste*** *Carabus violaceus****; Sl. 19: tarzus vrste*** *Nebria dahli****; Sl. 20: maksila vrste*** *Tropiphorus elevatus****; Sl. 21: prednje krilo vrste*** *T. elevatus****; Sl. 22: mirmicidna mravlja; Sl. 23: larva vrste*** *Michiola fagi****; Sl. 24: cerk vrste*** *Apterygida media*

photos of ingested items in Plates I and II. The majority of the preyed animals belonged to arthropods, and among the others we recognized slug and earthworm remnants. The most frequent determinable taxa were Insecta, Araneae, Lumbricidae and Opiliones, while Oniscoidea and Diplopoda were not found. Among the insects, Coleoptera were the most frequent prey.

## DISCUSSION

Shrews are opportunistic feeders that forage on various soil-, litter-, and water-dwelling invertebrates and small vertebrates (Churchfield & Rychlik, 2006; Churchfield, 2008). The shrews studied in our investigation fed mostly on earthworms, spiders, harvestmen and insects. Some prey remnants were determined to the species level, a process which was time consuming, but it did yield evidence of the impact of shrew predation on particular invertebrate species. Species-level determination is also indispensible in detailed comparative analysis of the shrew diet niches (Klenovšek *et al.,* 2013).

Earthworms are usually a common shrew prey (Churchfield & Rychlik, 2006). In our study they were found in all three *Sorex* species and were probably frequently eaten because of their large size, slow movement and abundance. Oniscoidea were reported in other *Sorex* species (Churchfield, 2002), but absent in our shrews.

Another frequent prey were spiders, from which only *Amaurobius ferox* was identified to the species level. This relatively large and, in woodlands widespread, ground-dwelling spider was obviously a profitable prey.

Mitov (1995) reported on five slow moving, hygrophilous opilionid species found in 33 shrew stomachs on Vitosha Mountain, Bulgaria. Novak *et al.* (2006) reported of leg damages in the opilionid *Trogulus nepaeformis* caused by shrews. In contrast to these reports, we found relatively rapidly moving species as prey, which search for daily refuge under stones, wood, bark, and similar microhabitats on the ground. Moreover, preying on the fast moving opilionid *Opilio dinaricus*, which mostly lives in the understory, demonstrates that shrews may also influence above-ground species.

Among the Myriapoda, only Lithobiomorpha were found. Diplopoda have been reported as being avoided by shrews (Grainger & Fairley, 1978; Klenovšek *et al.*, 2013), probably on account of their scent gland exudates. Such glands are also characteristic of harvestmen, but the chemical composition of their defence compounds (*e.g.*, Raspotnig *et al.,* 2010) is obviously not as unpleasant to shrews as in Diplopoda. Beetles from the Carabidae family also produce defensive secretions, and some have been reported to be avoided by shrews (Bonacci *et al.,* 2011). Surprisingly, *Aptinus bombarda*, which produces chemical repellents and popping sounds, was commonly preyed by the *Sorex* species.

Shrews prefer more profitable prey, but abundance may influence the predation of smaller prey. They probably become habituated to its availability. This could be the case when *S. araneus* was found to be feeding extensively on relatively small *Mikiola fagi* larvae on Mt. Snežnik in 1989 when *M. fagi* appeared in abundance (Trilar, 1991). In this way, shrews importantly regulated the population of *M. fagi*.

Since invertebrates in shrews' diet have seldom been identified on the species level, we believe that such studies can valuably contribute to the understanding of the shrew's impact on particular invertebrate species.

## ACKNOWLEDGEMENTS

We thank Mojca Potočnik, Metka Tajzel, Karl Dretnik, Aleksander Zupanc, Alojz Klemenšek and Barbara Bertoncelj for help with the work. Božo Drovenik helped with the determination of Coleoptera remains. We are indebted to Michelle Gadpaille for valuable improvement of the language. This research was supported by the Slovenian Research Agency within the Biodiversity Research Programme (Grant No. P1-0078), Forest Biology, Ecology and Technology (Grant No. P4-0107) and Integrated Development Project (CRP; V4 0175109): Conservation of Habitats of Endangered Species of Wild Game and Other Wildlife in the Forest Ecosystems and Landscapes, Forest Grouse-Capercaillie, also funded by the Slovene Ministry of Agriculture, Forestry and Food.

# ZAPISKI O NEVRETENČARJIH KOT PLENU ROVK (MAMMALIA: INSECTIVORA: SORICIDAE) V SLOVENIJI

*Tina KLENOVŠEK, Franc JANŽEKOVIČ & Tone NOVAK*
Oddelek za biologijo, Fakulteta za naravoslovje in matematiko,Univerza v Mariboru, SI-2000 Maribor, Koroška cesta160
E-mail: tina.klenovsek@uni-mb.si

*Miran ČAS*
Oddelek za gozdno ekologijo, Gozdarski inštitut Slovenije, SI-1000 Ljubljana, Večna pot 2

*Tomi TRILAR*
Prirodoslovni muzej Slovenije, SI-1000 Ljubljana, Prešernova 20

*Tina POŠTRAK*
Ekos, SI-2341 Limbuš, Antona Godca 8

*POVZETEK*

*Rovke (Soricidae) so majhni žužkojedi sesalci, ki se prehranjujejo predvsem s členonožci, z deževniki, s polži in z drugimi nevretenčarji. V študijah o prehrani rovk avtorji običajno navajajo plen, določen do nivoja družin ali višjih taksonov, medtem ko je plen redko določen do vrste. V prispevku predstavljamo seznam uplenjenih vrst in druge želodčne vsebine pri petih vrstah rovk:* Sorex alpinus, S. araneus, S. minutus, Crocidura suaveolens *in* Neomys fodiens *v Sloveniji. Pregledali smo vsebino želodcev 204 rovk. S primerjavo ostankov zaužitega plena z zbirko nevretenčarjev, ulovljenih skupaj z rovkami, smo prepoznali 180 osebkov plena iz 21 taksonov. Preostanke plena in drugo vsebino želodcev smo fotografirali. Rovke so jedle predvsem členonožce in deževnike. Od členonožcev so bili najpogostejši plen pajki, suhe južine, strige in žuželke ter med slednjimi hrošči. Od prepoznanih vrst so bile najpogostejše* Amaurobius ferox, Mitopus morio, Aptinus bombarda *in* Apterygida media. *Kočičev in dvojnonog, sicer pogostih v habitatih rovk, nismo našli. Rovke običajno plenijo endogejične in epigejične nevretenčarje, zato je najdba suhe južine* Opilio dinaricus*, ki živi pretežno v podrasti, nakazala, da lahko rovke vplivajo na širši razpon nevretenčarjev, kot običajno pričakujemo. Rovke se navadno hranijo z večjim plenom, a če so manjši nevretenčarji, kakršne so ličinke* Mikiola fagi, *pogosti, iščejo in jedo tudi tak plen. Raziskave prehrane rovk z identifikacijo plena do vrste lahko pomembno prispevajo k poznavanju vpliva rovk na posamezne vrste nevretenčarjev.*

**Ključne besede:** plen rovk, Soricidae, Arthropoda, Slovenija

## REFERENCES

**Bonacci, T., P. Brandmayr & T. Z. Brandmayr (2011):** Predator feeding choice on conspicuous and non-conspicuous carabid beetles: first results. Zookeys, 100, 171–179.

**Churchfield, S. (1994):** Foraging strategies of shrews, and the evidence from field studies. Carnegie Mus. Nat. Hist. Spec. Publ., 18, 77–87.

**Churchfield, S. (2002):** Why are shrews so small? The costs and benefits of small size in northern temperate *Sorex* species in the context of foraging habits and prey supply. Acta Theriol., 47 (Suppl. 1), 169–184.

**Churchfield, S. (2008):** The feeding ecology of the European water shrew. Mammal Rev., 15 (1), 13–21.

**Churchfield, S. & L. Rychlik (2006):** Diets and coexistence in *Neomys* and *Sorex* shrews in Białowieża forest, eastern Poland. J. Zool., 269, 381–390.

**Denneman, W. D. (1990):** A comparison of the diet composition of two *Sorex araneus* populations under different heavy-metal stress. Acta Theriol., 35, 25–38.

**Devetak, D. & P. Duelli (2007):** Intestinal contents of adult *Osmylus fulvicephalus* (Scop.) (Neuroptera, Osmylidae). Annales, Ser. Hist. Nat., 17 (1), 93–98.

**Drovenik, B. (2001):** Hrošči (Coleoptera) v gozdovih in ohranjenost na rastiščih divjega petelina. Gozd. vestn., 59, 314–316.

**Grainger, J. P. & J. S. Fairley (1978):** Studies on the biology of the Pygmy shrew *Sorex minutus* in the West of Ireland. J. Zool., 186, 109–141.

**Janžekovič, F. & M. Čas (2001):** Small mammals in the woodland and their association diversity in Alpine forest on Mt. Smrekovec and Mt. Peca. Gozd. vestn., 59 (78), 322–327.

**Klenovšek, T., T. Novak, M. Čas, T. Trilar & F. Janžekovič (2013):** Feeding ecology of three sympatric *Sorex* shrew species in montane forests of Slovenia. Folia Zool., 62 (3), 193–199.

**Kos, I., T. Grgič, H. Potočnik, F. Kljun & M. Čas (2000):** Pestrost pedofavne – strig (Chilopoda) in deževnikov (Lumbricidae) na vzorčnih ploskvah na rastiščih divjega petelina (*Tetrao urogallus* L.) v gozdnih tipih vzhodnih Karavank in vzhodnih Kamniško-Savinjskih Alp na Koroškem in Štajerskem. Končno poročilo o raziskovalnem delu. Gozdarski inštitut Slovenije, Biotehniška fakulteta, Oddelek za biologijo, Ljubljana, 14 str.

**Mitov, P. (1995):** Opiliones (Arachnida) as a component of the food stuffs of some animals. Ann. Univ. Sofia, Zool., 1 (8687), 67–74.

**Novak, T., A. Alatič, J. Poterč, B. Bertoncelj & F. Janžekovič (2006):** Regenerational leg asymmetry in damaged *Trogulus nepaeformis* (Scopoli 1763) (Opiliones, Trogulidae). J. Arachnol., 34, 524–531.

**Raspotnig, G., V. Leutgeb, M. Schaider & C. Komposch (2010):** Naphthoquinones and Anthraquinones from Scent Glands of a Dyspnoid Harvestman, *Paranemastoma quadripunctatum*. J. Chem. Ecol., 36, 158–162.

**Sommer, R. & A. Sommer (1997):** Ergebnise zur Kotanalyse bei Teichfledermäusen, *Myotis dasycneme* (Boil, 1825). Myotis, 35, 103–107.

**Trilar, T. (1991):** Population density, biomass and reproduction of small mammals of the Dinaric beech-fir forest at Mt. Snežnik between 1988 and 1990. M. Sc. Thesis. University of Ljubljana.

**Whitaker, J. O. & C. Ruckdeschel (2006):** Food of the Southern Short-tailed Shrew (*Blarina carolinensis*) on Cumberland Island, Georgia. Southeastern Nat., 5 (2), 361–366.