ZVEZA ZA TEHNIČNO KULTURO SLOVENIJE

# NATURA SLOVENIAE

Revija za terensko biologijo • Journal of Field Biology

Letnik • Volume 13 Številka • Number 1

Ljubljana
2011

**NATURA SLOVENIAE**

**Revija za terensko biologijo • Journal of Field Biology**

**Izdaja • Published by**
Zveza za tehnično kulturo Slovenije
Lepi pot 6, SI-1111 Ljubljana
Številka žiro računa: 50101-678-51259
Tel.: (01) 251 37 43, 425 07 69; Telefax: (01) 252 24 87
http://www.zotks.si/portal/
http://www.bf.uni-lj.si/bi/NATURA-SLOVENIAE/index.php



**Naslov uredništva • Address of the Editorial Office**
NATURA SLOVENIAE, Večna pot 111, SI-1111 Ljubljana, Slovenija

Izvlečki prispevkov so zavedeni v zbirkah **ASFA, AGRIS, Biological Abstracts, Biosis Previews, COBISS in Zoological Records**

**ISSN: 1580-0814** **UDK: 57/59(051)=863=20**

**Lektorji • Language Editors**
za angleščino (for English): Henrik Ciglič
za slovenščino (for Slovene): Henrik Ciglič

**Oblikovanje naslovnice • Layout**
Daša Simčič akad. slikarka, Atelje T

**Natisnjeno • Printed in**
2011

**Tisk • Print**
Repro print d.o.o., Kranj

**Naklada • Circulation**
300 izvodov/copies

# Kazalo vsebine

Prejeto / Received: 1.4.2011
Sprejeto / Accepted: 1.6.2011

# Sprememba sestave fitobentosa po odvzemu vode za hidroelektrarne na Kokri in Selški Sori v slovenskih Alpah

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**Izvleček.** Namen naše raziskave je bil ugotoviti vpliv odvzema vode za potrebe hidroelektrarn Oljarica in Niko na reki Kokri in Selški Sori na združbo fitobentosa. Skupno smo v reki Kokri in Selški Sori določili 52 taksonov iz šestih razredov alg. Po številu določenih taksonov so prevladovale kremenaste alge. Primerjava vrstnih sestavov fitobentosa obeh rek na odvzemnih mestih pred in po odvzemu vode za hidroelektrarni je pokazala, da je prišlo v reki Selški Sori do znižanja biodiverzitete na odvzemnem mestu pod jezom, v obeh rekah pa so izginili nekateri taksoni, značilni za neonesnažene vodotoke, hkrati pa je bilo zaznati več taksonov, značilnih za vodotoke s povišanim organskim onesnaženjem. Na obeh rekah so bile vrednosti saprobnega indeksa na odvzemnih mestih pod odvzemom vode višje, kar je lahko posledica povečane organske obremenitve ali pa znižanega pretoka. Biomasa fitobentosa na reki Kokri je bila najvišja v predelih struge z nizko vodno gladino in upočasnjenim tokom.

Ključne besede: Alpe, fitobentos, hidroelektrarne, odvzem vode, reke, Slovenija

**Abstract. CHANGE IN PHYTOBENTHOS COMPOSITION AFTER WATER ABSTRACTION FOR HYDROELECTRIC POWER PLANTS ON THE KOKRA AND THE SELŠKA SORA RIVERS IN THE SLOVENIAN ALPS** – The objective of our research was to determine the impact of water abstraction for hydroelectric power plant purposes Oljarica (River Kokra) and Niko (River Selška Sora) on phytobenthos community. Altogether, 52 taxa from six algal classes were determined in both rivers. According to the number of identified taxa, diatoms prevailed. Comparison of phytobenthos species compositions on both rivers before and after water abstraction showed that in the Selška Sora River phytobenthos biodiversity was lower below the dam while in both rivers decrease of algal taxa typical for unpolluted waters and increase of algal taxa typical for organically polluted waters were noticed. On both rivers, the values of Saprobic index were higher on the sites with water abstraction, which could be the result of increased organic load or reduced flow. Phytobenthos biomass in the Kokra River was the highest in the areas with low water level and low water velocity.

Key words: Alps, phytobenthos, hydroelectric power plants, water abstraction, rivers, Slovenia

# Uvod

Do odvzemov vode iz vodotokov prihaja zaradi uporabe vode v energetske ali ribogojne namene, za namakanje, pitno vodo, tehnološke namene ter za potrebe turizma in rekreacije. Zaradi odvzema vode so pogosto najbolj prizadeti pritrjeni organizmi (primarni producenti), kar se kaže v spremembi razmerja primarni in sekundarni producenti ter v bioprodukciji vodotoka. Najbolj je prizadet litoralni del vodotoka, ki je biološko najproduktivnejši in ima neposredni vpliv na samočistilno sposobnost vodotoka (Bergey et al. 2010). Zaradi osušenosti struge ali zmanjšanja globine vode je preprečena migracija nevretenčarjev in rib po toku navzgor in navzdol, kar prekine prehranjevalne verige in povezave med organizmi. Npr., pod pregradami je pogosto opažena sprememba starostne strukture in zmanjšanja gostote ribje populacije (Bundi & Eichenberger 1989). Pod pregrado lahko nastanejo spremembe v dotoku hranilnih snovi, svetlobnih razmer in aktivnosti nevretenčarjev, ki se hranijo s fitobentoškimi algami (Stevenson 1984). Z odvzemom vode iz vodotoka se zmanjša količina drifta (Biggs & Close 1989) in pride do spremenjene razporeditve organizmov ter porušitve zgradbe in funkcije združbe (Gore 1994). Zmanjšanje pretoka vode vpliva tudi na obvodne živali, ki žive na bregu, in tiste, ki žive v tleh na vplivnem območju podtalnice.

Umetno zmanjšanje pretoka vode pod pregrado ustvarja fizikalne in kemijske razmere, ki povzročajo povečano rast bentoških alg (Mc Intire 1966, Lowe 1979, Valentin et al. 1995, Biggs 1996) in porušijo zgradbo ter funkcijo fitobentoške združbe (Lowe 1979).

Biomasa in vrstni sestav bentoških alg sta pogosto neposredno povezani s hidrološkimi značilnostmi vodotoka (Biggs 1996). Bentoške alge se v določenih razmerah lahko močno razrastejo in postanejo škodljive za živalske združbe. V slabo puferiranih vodotokih lahko močna razrast alg povzroči porast pH, zmanjšanje vsebnosti raztopljenega kisika (dihanje alg v nočnem času in propad alg v jesenskem času), spremembo v hrapavosti dna vodotoka in spremembo v združbi vodnih nevretenčarjev (Moreno *et* al. 2010). Rast alg ima velik vpliv na populacijo nevretenčarjev in rib, energijska razmerja in kompeticijo v vodotokih (Biggs 1996). S spremembo hitrosti vodnega toka pa lahko nastanejo spremembe v vrstni sestavi bentoških alg. Povečana hitrost vodnega toka pospešuje naseljevanje pritrjenih organizmov, z manjšanjem hitrosti pa se poveča število organizmov, živečih na mulju (epipelični organizmi) (Rolland et al. 1997, Yamada & Nakamura 2002). Pri nižjem pretoku se v vodotoku povišajo vrednosti hranilnih in strupenih snovi. S povečanjem količine hranilnih snovi se poveča biomasa alg, bakterij in drugih mikroorganizmov, ob povečani strupenosti pa vrstno osiromašijo ali celo izginejo. Odvzem vode iz vodotokov in porast koncentracije hranilnih snovi v vodotoku ima podoben vpliv, saj se v obeh primerih spremeni vrstna diverziteta (Rott & Pfister 1988). Zmanjšanje vodne površine v strugi lahko onemogoča obstoj združbe bentoških alg (Bergey et al. 2010).

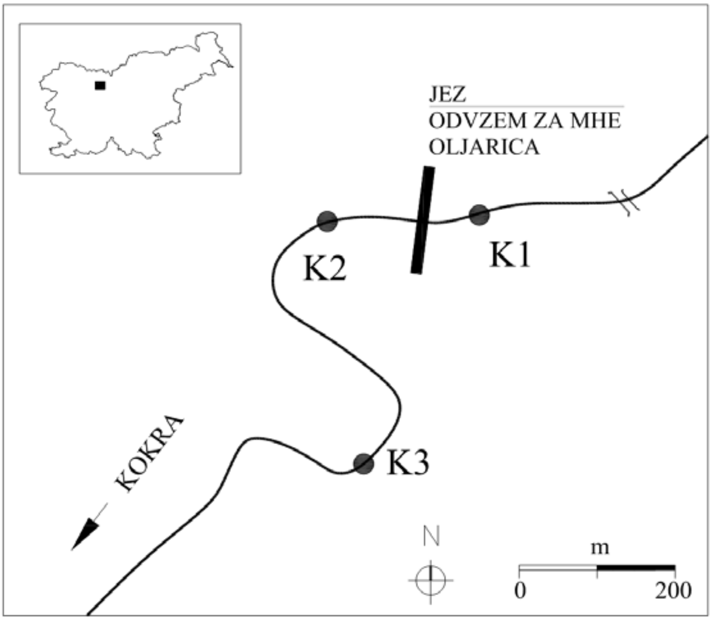
Namen naše raziskave je bil ugotoviti vpliv odvzema vode za potrebe hidroelektrarn Oljarica in Niko na reki Kokri in Selški Sori na združbo fitobentosa v kvalitativnem in kvantitativnem smislu ter vpliv na biomaso alg.

## Mesto raziskav

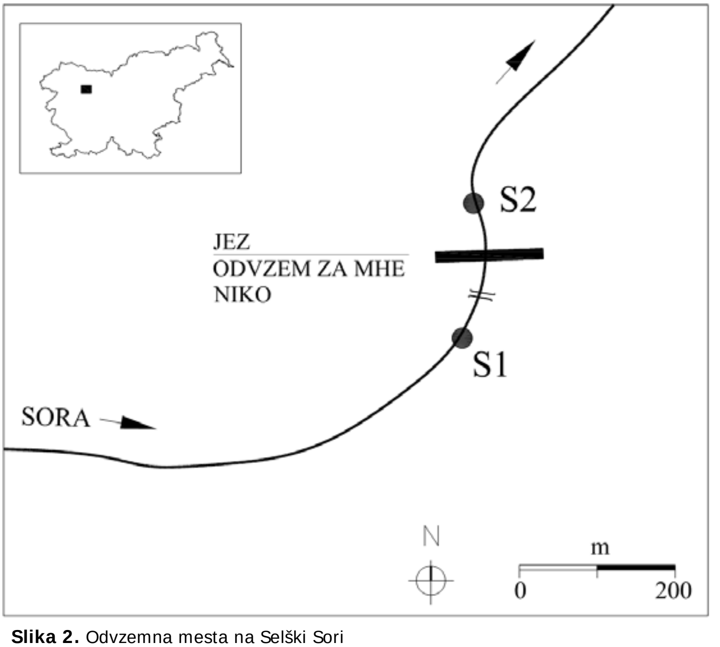
### Reka Kokra

Reka Kokra izvira na nadmorski višini 1640 m. Dolžina vodotoka je 30 km, povprečni strmec 17 ‰ in zbirna površina 236 $km^2$. Osnovo hidrografskega omrežja sestavljata Kokra in Jezernica, ki se Kokri pridruži na Spodnjem Jezerskem, izvira pa v Ravenski Kočni. Tudi v nadaljnjem toku pritekajo v Kokro številni krajši in daljši pritoki z obeh bregov. V zgornjem in srednjem delu je dolina ozka. Od spodnjega Jezerskega navzdol se je tako reka globoko zajedla v apneno-dolomitni pokrov Kamniških Alp. Značaj Kokre je opazen tudi v njenem padcu, saj na razdalji 20 km od izvira do Preddvora premaga nad 800 m višinske razlike. Pri Preddvoru se tok reke umiri in počasi teče po vršaju, ki ga je nasula daleč na ravnino, ter se v Kranju izliva v Savo. Tu lahko zasledimo tudi 10 pleistocenskih rečnih teras, ki jih je ustvarila Kokra v ledenih in medledenih dobah (Ajdič et al.1998).

Za Kokro velja varstveni režim za hidrološko, geomorfološko površinsko in botanično naravno dediščino, varstvena namembnost pa je spomeniška in rekreacijska. Pretežni del vodnih količin reke Kokre prihaja iz alpskega področja, ki je spomladi pod vplivom taljenja snega. Najnižje vode so avgusta in septembra, takrat Kokra do Kranja na posameznih odsekih povsem presuši (Ajdič et al.1998). Zaradi nepovratnih odvzemov za vodovode na območju občin Preddvor in Jezersko in odvzema za protokolarni objekt Brdo je postal vodonosnik od Preddvora do Kranja »lačen« vode. Odvzem vode za malo hidroelektrarno (MHE) Oljarica je v naselju Britof, ki je blizu izliva in kjer so razmere v obdobju nizkih voda zelo kritične. Odvzem vode je na 720 m dolgem odseku struge, ki ga tvori dvojni meander. Vrh prodne terase okoli obravnavanega odseka reke Kokre je pozidan na obeh straneh (naselja: Britof, Predoslje, Orehovlje in Suha). V Kokro in njen pritok Belo gravitira določen delež odpadnih voda. Meteorni dotoki prinašajo s seboj tudi nekaj odplak iz gospodinjstev. To se zaradi odvzema vode precej pozna, posebno v desni obrežni konkavi pod jezom. Za namen raziskave smo na reki Kokri izbrali tri odvzemna mesta: i) odvzemno mesto K1 leži 70 m nad odvzemom vode za MHE Oljarica, ii) odvzemno mesto K2 leži 120 m pod odvzemom vode za MHE Oljarica in iii) odvzemno mesto K3 leži 550 m pod odvzemom vode za MHE Oljarica (Sl. 1). Znotraj vsakega odvzemnega mesta smo izbrali dve vzorčni mesti (K1.1, K1.2; K2.1, K2.2 in K3.1, K3.2.) glede na širino struge, strukturo habitatov, globino vode in hitrosti vodnega toka.




**Slika 1.** Odvzemna mesta na reki Kokri




**Slika 2.** Odvzemna mesta na Selški Sori

### Reka Selška Sora

Reka Selška Sora nad Železniki ima obširno in gorato prispevno območje. Na levi se razprostira pogorje Ratitovca ter naprej Možica in Lajnarja, ki se prevešata v dolino Bače. Na desni strani spremljajo dolino Selške Sore grebeni Porezna. Krovne površine teh pogorij so sestavljene iz apnenca in dolomita. Med kamninami se najpogosteje pojavljajo glinovci, rdeči lapor in peščenjak (Geološki zavod Slovenije 2004). Prispevno območje je močno poraščeno, kljub temu pa ima reka močan hudourniški značaj. Čeprav je prispevno območje obkroženo z visokimi gorami, se vpliv taljenja snega ne pozna pozno v pomlad. Selška Sora ima na obravnavanem območju v kraju Železniki spremenjen režim pretakanja nizkih in srednjih voda. Poleg manjše onesnaženosti in odvzema vode so v veliki meri opazne tudi regulacijske ureditve. Hidroelektrarna (HE) Niko leži na jezu pod vtokom Prednje Smoleve v kraju Železniki. Odvzem vode je na dolgem odseku struge, kjer se morfološke karakteristike struge ne menjavajo. Odvzem, onesnaženje in regulacije vplivajo na naravno podobo vodotoka. Odvzem vode za HE Niko je na dolžini 990 m. Del zajete vode se lahko 340 m pod jezom prek bočnega izpusta vrača v strugo. Pri cerkvi, to je 480 m pod jezom, doteka z leve stranski pritok, ki v sušnem obdobju na pretok v Selški Sori nima vpliva. Jez odvaja vodo na desno v odprto mlinščico, ki ima na začetku površinski tok, sledi zajezitev, od koder gre voda po zaprtem kanalu do strojnice HE. Za namen raziskave smo na reki Selški Sori izbrali dve odvzemni mesti: i) odvzemno mesto S1 leži 60 m gorvodno od mostu, pred odvzemom vode za HE Niko, ii) odvzemno mesto S2 leži 50 m pod jezom, na vplivnem območju odvzema vode za HE Niko (Sl. 2). Znotraj vsakega odvzemnega mesta smo izbrali dve vzorčni mesti (S1.1, S1.2 in S2.1, S2.2) glede na širino struge, strukturo habitatov, globino vode in hitrosti vodnega toka.

## Materiali in metode dela

### Hidrološki dejavniki

Na reki Kokri smo za vsako izbrano vzorčno mesto izmerili lokalne hitrosti vodnega toka s hidrometričnim krilom SEBA Mini Current Meter MI, Nemčija. Za meritve različnih hitrosti smo uporabljali različna krila. Na vseh vzorčnih mestih smo merili hitrost vodnega toka 3 cm nad dnom, odvisno od globine vode smo merili hitrost vodnega toka v vertikalah nad vzorčnim mestom na treh do petih točkah. Povprečno hitrost v merskih vertikalah nad vzorčnimi mesti smo izmerili na 0,4 m globine vode, merjeno od dna struge. Čas meritve v posamezni točki je bil eno minuto. Na Selški Sori smo hitrosti vodnega toka na posameznih vzorčnih mestih le ocenili. Na obeh rekah smo na vseh odvzemnih mestih s hidrometričnim krilom (SEBA Mini Current Meter MI, Nemčija) izmerili tudi pretok.

## Fizikalni in kemijski dejavniki

Meritve osnovnih fizikalnih in kemijskih dejavnikov smo opravili na izbranih odvzemnih mestih na reki Kokri dne 10.9.2008 in na izbranih odvzemnih mestih na reki Selški Sori dne 6.8.2008. Merili smo specifično električno prevodnost, temperaturo vode, pH, vsebnost raztopljenega kisika v vodi in nasičenost vode s kisikom s pomočjo prenosnega multimetra (WTW Multiline/F, Nemčija) po metodologiji APHA (1992).

## Biološki dejavniki

Vzorce fitobentosa smo na obeh rekah pobirali tako, da smo postrgali površino prodnikov, kamnov, skal, peska, makrofitov in potopljenega lesa na območju odvzema. Vzorce smo že na terenu fiksirali s formalinom, tako da je bila končna koncentracija formalina v vzorcih 4 %. V laboratoriju smo vzorce fitobentosa pregledali pod svetlobnim mikroskopom, s fazno kontrastno optiko pri povečavah do 1000× (Nikon Eclipse E400). Pri pregledu vzorcev smo ocenili pogostost posameznih taksonov (vrst) fitobentosa s pomočjo lestvice: 1 = redko, 3 = pogosto, 5 = množično (Pantle & Buck 1955). Fitobentos smo določali s pomočjo sledečih določevalnih ključev: Starmach (1966, 1972, 1980), Krammer & Lange-Bertalot (1997a, b, 2004a, b), Hindák (1996).

V reki Kokri smo opravili tudi kvantitativno analizo fitobentoške združbe, v ta namen smo s krtačko postrgali določeno površino prodnika in jo razredčili z vodo. V laboratoriju smo ovrednotili suho težo in organsko snov po metodiki APHA (1992) in koncentracijo klorofila *a* s filtriranjem skozi Watman GF/C filtre ter z ekstrahiranjem z vročim metanolom (Vollenweider 1974).

## Biostatistične metode

Primerjavo združb fitobentosa med vzorčnimi mesti in med območji odvzema smo napravili s pomočjo podatkov vrstnega sestava in relativne pogostosti obstoječih vrst. Podobnost oziroma različnost združb fitobentosa smo vrednotili z Bray-Curtisovim koeficientom podobnosti (Clarke & Warwick 2001). Saprobni indeks smo izračunali po Pantle & Buck (1955) z modifikacijo po Zelinka & Marvan (1961).

# Rezultati in razprava

## Hidrološki dejavniki

Pretoki, srednja hitrost in padec na posameznih odvzemnih mestih reke Kokre so prikazani v tabeli 1. Pod jezom se je zmanjšal pretok vode. Na odvzemnem mestu K3 je pretok manjši, kar je posledica pretakanja skozi prodnato podlago. Hitrost vodnega toka je zelo nizka, kar je posledica raztečenosti, vendar je kljub temu premajhna za obravnavani odsek, ker je padec bistveno večji. Izmerjene lokalne hitrosti vodnega toka na posameznih točkah odvzema fitobentosa so bile sledeče: K1.1: 0,40 m/s, K1.2: 0,33 m/s, K2.1: 0,08 m/s, K2.2: 0,58 m/s, K3.1: 0,04 m/s in K3.2: 0,03 m/s.

**Tabela 1.** Pretok, srednja hitrost vodnega toka in padec na posameznih odvzemnih mestih reke Kokre dne 10.9.2008

| dejavnik | odvzemno mesto | | |
|---|---|---|---|
| | K1 | K2 | K3 |
| pretok Q [$m^3$/s] | 1,57 | 0,19 | 0,19 |
| srednja hitrost [m/s] | 0,50 | 0,30 | 0,14 |
| padec [‰ ] | 8,11 | 5,50 | 11,60 |

Pretoki Selške Sore so za obe odvzemni mesti za dan 6.8.2008 prikazani v tabeli 2. Na odvzemnem mestu S2, ki leži na vplivnem območju HE Niko, se je pretok znižal z 1,38 $m^3$/s, kolikor je znašal na odvzemnem mestu S1, ki leži nad odvzemom vode za HE Niko, na 0,22 $m^3$/s.

**Tabela 2.** Pretoki reke Selške Sore dne 6.8.2008

| dejavnik | odvzemno mesto | |
|---|---|---|
| | S1 | S2 |
| pretok Q [$m^3$/s] | 1,38 | 0,22 |

## Fizikalni in kemijski dejavniki

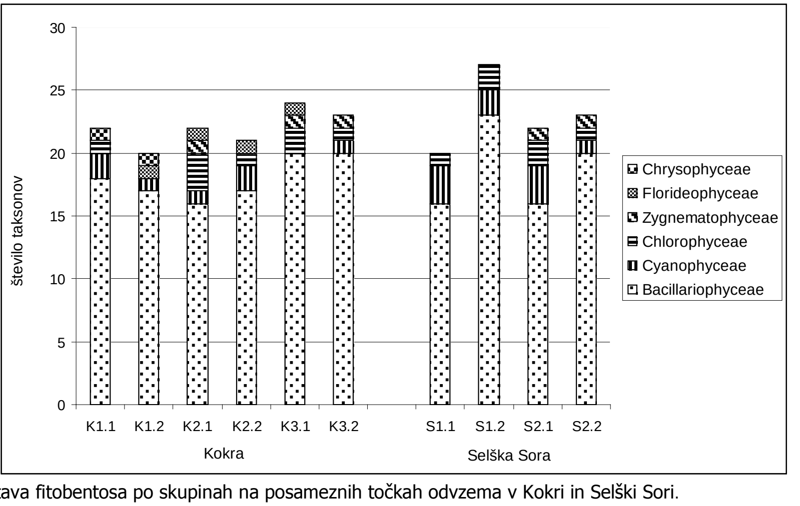
Vrednosti izmerjenih fizikalnih in kemijskih dejavnikov so bile v Kokri in v Selški Sori podobne pred odvzemom vode in na vplivnem območju odvzema oziroma po vrnitvi vode v vodotok (Tab. 3). Temperature reke Kokre v poletnem obdobju so bile letnemu času primerne, temperatura vode je vzdolž toka naraščala. Na vseh odvzemnih mestih so bile koncentracije raztopljenega kisika v vodi ter nasičenosti vode s kisikom dovolj visoke (nasičenost s kisikom okoli 100 %) za ohranjanje naravne strukture in funkcije vodotoka.

**Tabela 3.** Vrednosti fizikalnih in kemijskih dejavnikov na odvzemnih mestih reke Kokre in Selške Sore, dne 10.9.2008 in 6.8.2008

| odvzemno mesto | T [°C] | $O_2$ [mg/l] | saturacija [%] | prevodnost [µS/cm] | pH |
|---|---|---|---|---|---|
| K1 | 12,2 | 11,2 | 103 | 320 | 8,0 |
| K2 | 12,8 | 10,8 | 102 | 320 | 7,8 |
| K3 | 14,2 | 11,4 | 109 | 325 | 7,8 |
| S1 | 15,8 | 10,0 | 98 | 315 | 7,9 |
| S2 | 15,4 | 10,0 | 98 | 307 | 7,9 |

## Biološki dejavniki

Skupaj smo na vseh mestih odvzema v Kokri in Selški Sori identificirali 52 različnih taksonov iz šestih razredov alg. Sestava fitobentosa po razredih na posameznih odvzemih mestih je za obe reki prikazana na sliki 3. Na vseh točkah odvzema so po številu določenih taksonov prevladovale kremenaste alge, podobno kot pri drugih raziskavah alg v slovenskih rekah (npr. Krivograd Klemenčič 2004, Krivograd Klemenčič & Vrhovšek 2003, Krivograd Klemenčič & Vrhovšek 2004, Krivograd Klemenčič et al. 2003, Krivograd Klemenčič et al. 2009). Na točkah K1.1, K2.2, S1.1 in S2.1 so po številu identificiranih taksonov kremenastim algam sledile Cyanophyceae, na točkah K2.1 in K3.1 pa Chlorophyceae. Razredi Chrysophyceae, Zygnematophyceae in Florideophyceae so bili na določenih točkah odvzema zastopani le s posameznimi taksoni. Vrsta *Hydrurus foetidus* iz razreda Chrysophyceae je bila zabeležena le na odvzemnem mestu K1 v Kokri, tudi predstavnica razreda Florideophyceae *Audouinella chalybea* je bila ugotovljena le v Kokri (vsa tri odvzemna mesta). *Hydrurus foetidus* je vrsta, ki je značilna za bistre in hladne potoke in reke, masovno se razvije konec zime, ko voda doseže temperaturo okoli 14 °C (Starmach 1980). Traaen in Lindstrom (1983) sta opazovala razširjenost nekaterih vrst alg v treh norveških rekah, ugotovila sta, da je bilo 90 % kolonij vrste *Hydrurus foetidus* zabeleženih pri hitrostih vodnega toka nad 0,8 m/s.




**Slika 3.** Sestava fitobentosa po skupinah na posameznih točkah odvzema v Kokri in Selški Sori.

## Kokra

V reki Kokri smo na vseh točkah odvzema skupaj določili 43 različnih taksonov iz šestih razredov alg (Tab. 4).

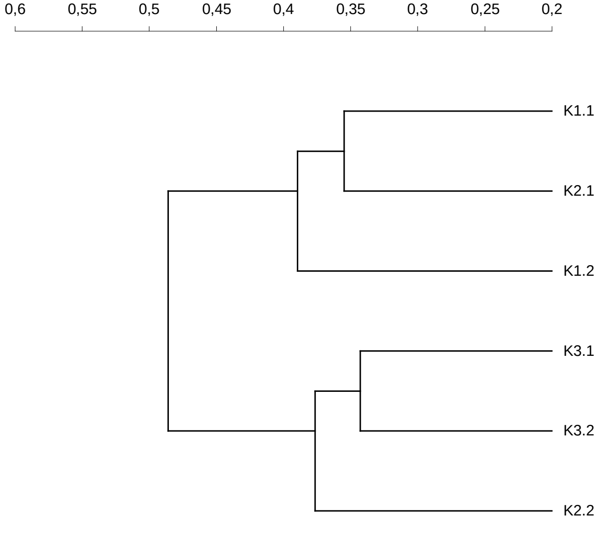
**Tabela 4.** Vrstni sestav in relativna pogostost fitobentosa v Kokri dne 10.09.2008.

| **Takson** | **Saprobna st.** | **K1** | | **K2** | | **K3** | |
|---|---|---|---|---|---|---|---|
| | | **K1.1** | **K1.2** | **K2.1** | **K2.2** | **K3.1** | **K3.2** |
| **PROKARYOTA** | | | | | | | |
| **CYANOPHYTA** | | | | | | | |
| CYANOPHYCEAE | | | | | | | |
| *Chamaesiphon incrustans* Grunow | o-b | | | | 1 | | |
| *Homoeothrix varians* Geitler | o | 1 | 3 | 1 | 1 | | 1 |
| *Pleurocapsa* sp. Thuret | o-b | 1 | | | | | |
| **EUKARYOTA** | | | | | | | |
| **HETEROKONTOPHYTA** | | | | | | | |
| CHRYSOPHYCEAE | | | | | | | |
| *Hydrurus foetidus* (Villars) Kirchner | o-b | 1 | 1 | | | | |
| BACILLARIOPHYCEAE | | | | | | | |
| *Achnanthes minutissima* Kützing | b | 1 | 3 | 1 | 1 | 1 | 1 |
| *Achnanthes* sp. Bory | b | 3 | 3 | 3 | 3 | 3 | 3 |
| *Amphora pediculus* (Kützing) Grunow | o-b | | | | 1 | 1 | 1 |
| *Cocconeis pediculus* Ehrenberg | b | 1 | 1 | 1 | 3 | 3 | 1 |
| *Cocconeis placentula* Ehrenberg | o | 1 | 1 | 1 | 1 | 1 | 3 |
| *Cymbella affinis* Kützing | o | 1 | 1 | 1 | | | |
| *Cymbella lanceolata* (Ehrenberg) Kirchner | o-b | | | 1 | | | |
| *Cymbella silesiaca* Bleisch | o-b | 3 | 1 | 1 | 1 | 1 | 3 |
| *Cymbella sinuata* Gregory | o-b | 1 | | 1 | 1 | 1 | 1 |
| *Denticula tenuis* Kützing | o | | 1 | | | | |
| *Diatoma vulgaris* Bory | b | 3 | 1 | 1 | 3 | | 1 |
| *Fragilaria arcus* (Ehrenberg) Cleve | o | 1 | 1 | | | | |
| *Fragilaria capucina* Desmazières | o-b | | 1 | | 1 | | |
| *Fragilaria ulna* (Nitzsch) Lange-Bertalot | b | 1 | 1 | 1 | 1 | 1 | 1 |
| *Gomphonema angustatum* (Kützing) Rabenhorst | b | 3 | 1 | 3 | 1 | 1 | 1 |
| *Gomphonema angustum* Agardh | o | 1 | 3 | 3 | 1 | 1 | |
| *Gomphonema olivaceum* (Hornemann) Brébisson | b | 3 | 1 | 1 | 1 | | |
| *Melosira varians* Agardh | o-b | | 1 | | | | |
| *Meridion circulare* (Greville) C. A. Agardh | o | 1 | | | | | |
| *Navicula cryptocephala* Kützing | b-a | | | | | 3 | 3 |

| **Takson** | **Saprobna st.** | **K1** | | **K2** | | **K3** | |
|---|---|---|---|---|---|---|---|
| | | **K1.1** | **K1.2** | **K2.1** | **K2.2** | **K3.1** | **K3.2** |
| *Navicula dicephala* (Ehrenberg) W. Smith | o | | | | | 1 | |
| *Navicula lanceolata* (Agardh) Ehrenberg | b | | | | | 1 | 1 |
| *Navicula menisculus* Schumann | b | | | | | 1 | |
| *Navicula pupula* Kützing | b | | | | | | 1 |
| *Navicula radiosa* Kützing | o-b | 1 | | 1 | 1 | 1 | 1 |
| *Navicula* sp. Bory | b | 1 | 1 | 1 | 1 | 1 | 1 |
| *Navicula tripunctata* (O. F. Müller) Bory | o-b | 1 | 1 | | 1 | 3 | 1 |
| *Navicula veneta* Kützing | a | | | | | 3 | 1 |
| *Nitzschia dissipata* (Kützing) Grunow | o | 1 | 1 | 1 | | | |
| *Nitzschia fonticola* Grunow | o | | | | | 1 | 1 |
| *Nitzschia linearis* (Agardh) W. Smith | o-b | 1 | | | | | |
| *Nitzschia palea* (Kützing) W. Smith | b-a | | | 1 | 1 | 3 | 1 |
| *Surirella angusta* Kützing | o-b | | | | | | 1 |
| **CHLOROPHYTA** | | | | | | | |
| CHLOROPHYCEAE | | | | | | | |
| *Cladophora* sp. Kützing | b-a | | | | 3 | 3 | 1 |
| *Oedogonium* sp. Link | o-b | | | 1 | | 1 | |
| *Ulothrix* sp. Kützing | b | | | 1 | | | 1 |
| *Ulothrix zonata* Kützing | o | 1 | | 3 | | | |
| ZYGNEMATOPHYCEAE | | | | | | | |
| *Closterium moniliferum* (Bory) Ehrenberg | b | | | 1 | | 1 | 1 |
| **RHODOPHYTA** | | | | | | | |
| FLORIDEOPHYCEAE | | | | | | | |
| *Audouinella chalybea* (Lyngbye) Fries | b-a | | 1 | 1 | 1 | 1 | |
| **Skupno število taksonov** | | 22 | 20 | 22 | 21 | 24 | 23 |
| | | 26 | | 27 | | 29 | |
| **Saprobni indeks** | | 1,47 | | 1,63 | | 1,74 | |

S 33 taksoni so prevladovale kremenaste alge, sledile so Chlorophyceae s štirimi in Cyanophyceae s tremi taksoni, razredi Chrysophyceae, Zygnematophyceae in Florideophyceae so bili zastopani s po enim taksonom. Po številu določenih taksonov se posamezne točke odvzema med seboj niso bistveno razlikovale. Najvišje število taksonov je bilo zabeleženo na odvzemnem mestu K3 (29), najnižje pa na odvzemnem mestu K1 (26). Na vseh šestih točkah odvzema so bile ugotovljene sledeče vrste: *Achnanthes minutissima*, *Achnanthes* sp., *Cocconeis pediculus*, *Cocconeis placentula*, *Cymbella silesiaca*, *Gomphonema angustatum*, *Navicula* sp. in *Fragilaria ulna*. *Achnanthes* sp. je bila najštevilčneje zastopana vrsta, v vseh vzorcih se je pojavljala z oceno 3 (pogosta). Med posameznimi mesti odvzema so opazne razlike glede na vrstni sestav. Na odvzemnem mestu K1 zasledimo veliko vrst, značilnih za neonesnažene oligosaprobne vodotoke: *Homoeothrix varians*, *Fragilaria arcus*, *Cocconeis* *placentula*, *Cymbella affinis*, *Denticula tenuis*, *Gomphonema angustum*, *Meridion circulare*, *Nitzschia dissipata* in *Ulothrix zonata* (Hindak et al. 1978; Krammer 1997a,b, 2004a,b, Komarek & Anagnostidis 2005). Na odvzemnem mestu K2 nismo zaznali večjih sprememb v vrstnem sestavu, v večjem številu pa sta bili zabeleženi zeleni algi *Cladophora* sp. in *Ulothrix zonata*. Na odvzemnem mestu K3 so nekateri predstavniki čistih voda izginili (npr. *Fragilaria arcus*, *Cymbella affinis*, *Denticula tenuis*, *Meridion circulare*, *Nitzschia dissipata*, *Ulothrix zonata*), pojavili pa so se predstavniki močnejšega organskega onesnaženja (npr. *Navicula cryptocephala*, *Navicula lanceolata*, *Navicula menisculus*, *Navicula pupula*, *Navicula veneta*). Z odvzemom vode pride v večini primerov do zmanjšanja biodiverzitete vodne in obvodne flore, spremenjene lokalne razmere pa lahko omogočajo povečevanje biomase posameznih vrst, ki lahko povzročijo okoljske probleme (Nilsson & Brittain 1996), kot so pogini rib, zmanjšanje rekreacijske privlačnosti. Vrednosti saprobnega indeksa so bile na odvzemnem mestu K1 1,47, na odvzemnem mestu K2 1,63 in na odvzemnem mestu K3 1,74. Glede na rezultate saprobnega indeksa lahko uvrstimo reko Kokro na odvzemnem mestu K1 v oligosaprobno (neonesnaženo), na odvzemnih mestih K2 in K3 pa med oligosaprobno (neonesnaženo) in ß-mezosaprobno (srednje onesnaženo). Poslabšanje kakovosti vode na drugem in tretjem odvzemnem mestu je lahko posledica povečane obremenitve vode ali pa zmanjšanega pretoka.

Bray-Curtisov koeficient podobnosti (Sl. 4) je pokazal dva ločena dendrograma. Točka odvzema K2.1 je bila bolj podobna točkama na odvzemnem mestu K1 kot točki odvzema K2.2. Podobno velja za točko odvzema K2.2, ki je bila bolj podobna točkama na odvzemnem mestu K3 kot točki odvzema K2.1.




**Slika 4.** Dendrogram: Bray-Curtisov koeficient podobnosti za fitobentos v reki Kokri.

## Biomasa fitobentosa

V tabeli 5 so podane vrednosti suhe teže, organske snovi in klorofila *a* v reki Kokri dne 10.9.2008. Povprečne vrednosti dejavnikov biomase perifitona v Kokri (organska snov, suha teža in klorofil *a*) so bile najvišje na odvzemnem mestu K3. Nizki pretoki vode, ugodne svetlobne razmere in struktura usedlin so bili dejavniki, ki so omogočali veliko rast alg.

**Tabela 5.** Vrednosti suhe teže, organske snovi in klorofila *a* v Kokri dne 10.9.2008.

| Odvzemno mesto | | Suha teža [g/m$^2$] | Organska snov [g/m$^2$] | klorofila *a* [mg/m$^2$] |
|---|---|---|---|---|
| **K1** | **K1.1** | 14 | 7 | 21 |
| | **K1.2** | 13 | 5 | 33 |
| | povprečje | 13,5 | 6 | 27 |
| **K2** | **K2.1** | 56 | 12 | 37 |
| | **K2.2** | 19 | 9 | 73 |
| | povprečje | 37,5 | 10,5 | 55 |
| **K3** | **K3.1** | 121 | 25 | 113 |
| | **K3.2** | 22 | 10 | 25 |
| | povprečje | 71,5 | 17,5 | 69 |

Maksimalne vrednosti biomase perifitona so bile v Savi Bohinjki vselej zabeležene v obdobju minimalne višine vode v zimskem času (Kosi 1988), v reki Soči v pozno poletnem oz. zgodnje jesenskem obdobju v predelih z manjšimi hitrostmi vodnega toka (Smolar-Žvanut et al. 2010). Vrednosti biomase v reki Kokri se ujemajo s podatki podobnih raziskav na drugih vodotokih v Sloveniji (Peroci et al. 2009). Če je vsebnost hranilnih snovi v vodi velika, hitrost vodnega toka pa nizka, lahko pride do zelo velikih vrednosti biomase perifitona (Biggs 1996). Največja biomasa perifitonskih alg pa je navadno pri srednjih hitrostih vodnega toka (Stevenson 1996). Na rekah Okuku v Novi Zelandiji in Sokna na Norveškem so ugotavljali odvisnost med hitrostjo vodnega toka in perifitonsko biomaso v določenih časovnih razmikih po poplavah. V začetnih fazah naseljevanja perifitonskih alg na rečno dno niso ugotovili razlik v perifitonski biomasi med habitati z nizkimi, srednjimi in visokimi hitrostmi vodnega toka. V kasnejših fazah razvoja perifitonske združbe pa so izmerili najvišjo perifitonsko biomaso pri nizkih hitrostih vodnega toka (< 0,3 m/s) ter najnižjo perifitonsko biomaso pri najvišjih hitrostih vodnega toka (> 0,7 m/s) (Biggs & Stokseth 1996).

V onesnaženih vodah so sestavni del organske teže perifitona organski sedimenti, heterotrofne bakterije, glive, praživali in majhni mnogoceličarji. Ocena biomase s pigmenti je le približek dejanski vrednosti zato, ker na vsebnost pigmentov v algah v določenem okolju vplivajo različni dejavniki (življenjski cikel, svetloba, temperatura, dušik, fosfor, magnezij, železo itd.) (Uehlinger 1991). Zaradi vpliva drugih ekoloških dejavnikov pa je rast alg nemogoče pojasniti le z nizkimi pretoki vode, pomembni so tudi količina nutrientov, svetloba in struktura usedlin (Uehlinger 1991). Umetno zmanjšanje pretoka vode pod pregrado ustvarja fizikalne in kemijske razmere, ki povzročajo rast fitobentosa (Mc Intire 1966, Lowe 1979, Valentin et al. 1995, Biggs 1996) in porušijo zgradbo in funkcijo fitobentoške združbe (Lowe 1979). Biomasa in vrstni sestav perifitonskih alg sta pogosto neposredno povezana s hidravličnimi značilnostmi vodotoka (Biggs 1996). Bentoške alge se v določenih okoliščinah lahko močno razrastejo in postanejo škodljive za živalske združbe. Zaradi obratovanja hidroelektrarn in odvzema vode so bentoške alge pogosto izpostavljene izsuševanju, kar lahko privede do fizioloških in morfoloških sprememb alg.

## Selška Sora

V Selški Sori smo na vseh štirih točkah odvzema skupaj določili 39 različnih taksonov iz štirih razredov alg (tabela 6). Po številu določenih taksonov (31) so prevladovale kremenaste alge, sledile so Cyanophyceae s štirimi, Chlorophyceae z dvema in Zygnematophyceae z enim taksonom. Na odvzemnem mestu S1 (nad jezom) smo določili višje število taksonov (32) kot na odvzemnem mestu S2 (pod jezom) (28). Najvišje število vrst (27) smo določili na točki odvzema S1.2 (nad jezom počasen tok), najnižje (20) pa na točki odvzema S1.1 (nad jezom hiter tok). Na odvzemnem mestu S2 sta se točki S2.1 in S2.2 po številu določenih taksonov razlikovali le za en takson.

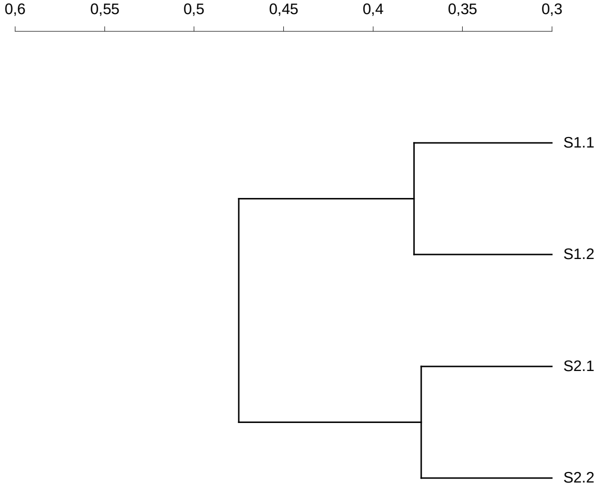
**Tabela 6.** Vrstni sestav fitobentosa in relativna abundanca v Selški Sori dne 6.8.2008.

| **Takson** | **Saprobna st.** | **S1** | | **S2** | |
|---|---|---|---|---|---|
| | | **S1.1** | **S1.2** | **S2.1** | **S2.2** |
| **PROKARYOTA** | | | | | |
| **CYANOPHYTA** | | | | | |
| CYANOPHYCEAE | | | | | |
| *Chamaesiphon incrustans* Grunow | o-b | 3 | | 1 | |
| *Lyngbya kuetzingiana* Kirchner | - | 1 | | 1 | |
| *Pleurocapsa* sp. Thuret | o-b | | 1 | | |
| *Phormidium* sp. Kützing | o-a | 1 | 1 | 1 | 1 |
| **EUKARYOTA** | | | | | |
| **HETEROKONTOPHYTA** | | | | | |
| BACILLARIOPHYCEAE | | | | | |
| *Achnanthes lanceolata* (Brébisson) Grunow | o | | 1 | | |
| *Achnanthes minutissima* Kützing | b | 1 | 1 | | |
| *Achnanthes* sp. Bory | b | 3 | 3 | 1 | 1 |
| *Amphora pediculus* (Kützing) Grunow | o-b | 1 | | | |
| *Fragilaria arcus* (Ehrenberg) Cleve | o | 1 | 1 | | |
| *Fragilaria capucina* Desmazières | o-b | | 1 | | |
| *Fragilaria ulna* (Nitzsch) Lange-Bertalot | b | 1 | 1 | 1 | 3 |
| *Cocconeis pediculus* Ehrenberg | b | 3 | 3 | 1 | 3 |
| *Cocconeis placentula* Ehrenberg | o | 1 | 1 | 1 | 3 |
| *Cymbella affinis* Kützing | o | | 1 | | 1 |
| *Cymbella microcephala* Grunow | o | | | | 1 |
| *Cymbella silesiaca* Bleisch | o-b | 1 | 1 | 1 | 1 |
| *Cymbella sinuata* Gregory | o-b | 1 | 1 | 1 | 1 |
| *Diatoma mesodon* (Ehrenberg) Kützing | o | | 1 | | |
| *Diatoma vulgaris* Bory | b | 1 | 3 | 1 | 3 |
| *Gomphonema angustum* Agardh | o | | 1 | | |

| **Takson** | **Saprobna st.** | **S1** | | **S2** | |
|---|---|---|---|---|---|
| | | **S1.1** | **S1.2** | **S2.1** | **S2.2** |
| *Gomphonema olivaceum* (Hornemann) Brébisson | b | 1 | 1 | 1 | 1 |
| *Gomphonema* sp. Ehrenberg | b | | | | 1 |
| *Melosira varians* Agardh | o-b | | | 1 | 3 |
| *Navicula pupula* Kützing | b | | 1 | | 1 |
| *Navicula radiosa* Kützing | o-b | | 1 | 1 | |
| *Navicula* sp. Bory | b | 1 | 1 | | 1 |
| *Navicula tripunctata* (O. F. Müller) Bory | o-b | 1 | | 1 | |
| *Nitzschia acicularis* (Kützing) W. Smith | a | 1 | 1 | 3 | 3 |
| *Nitzschia dissipata* (Kützing) Grunow | o | | 1 | | |
| *Nitzschia fonticola* Grunow | o | | | 1 | 1 |
| *Nitzschia linearis* (Agardh) W. Smith | o-b | 1 | 1 | 1 | 1 |
| *Nitzschia palea* (Kützing) W. Smith | a | | 1 | 1 | 3 |
| *Rhoicosphaenia abbreviata* (C. Agardh) Lange-Bertalot | b | 1 | | | |
| *Surirella angusta* Kützing | o-b | | 1 | | 1 |
| *Surirella brebissonii* var. *kuetzingii* Krammer & Lange-Bertalot | o-b | | | 1 | 1 |
| **CHLOROPHYTA** | | | | | |
| CHLOROPHYCEAE | | | | | |
| *Cladophora* sp. Kützing | b-a | 3 | 1 | 3 | |
| *Ulothrix zonata* Kützing | o | | 1 | 3 | 3 |
| ZYGNEMATOPHYCEAE | | | | | |
| *Closterium moniliferum* (Bory) Ehrenberg | b | | | 1 | 1 |
| **Skupno število taksonov** | | 20 | 27 | 22 | 23 |
| | | 32 | | 28 | |
| **Saprobni indeks** | | 1,65 | | 1,77 | |

Na vseh štirih točkah odvzema so bile zabeležene sledeče vrste: *Phormidium* sp., *Achnanthes* sp., *Cocconeis pediculus*, *Cocconeis placentula*, *Cymbella sinuata*, *Cymbella silesiaca*, *Diatoma vulgaris*, *Fragilaria ulna*, *Gomphonema olivaceum*, *Nitzschia acicularis* in *Nitzschia linearis*. Najštevilčneje so se pojavljale vrste *Achnanthes* sp., *Cocconeis pediculus*, *Diatoma vulgaris* in *Nitzschia acicularis*. Iz primerjave vrstnih sestavov na odvzemnih mestih S1 in S2 je razvidno, da so na vzorčnem mestu pod jezom poleg znižanega števila vrst izginile tudi nekatere vrste, značilne za čistejše vodotoke (*Achnanthes lanceolata*, *Diatoma mesodon*, *Fragilaria arcus*, *Gomphonema angustum* in *Nitzschia dissipata*) (Krammer & Lange-Bertalot 1997a, 2004a,b). O znižani biodiverziteti alg pod pregradami poročajo tudi drugi avtorji (Cazaubon & Giudicelli 1999), kot glavni razlog navajajo izginjanje številnih vodnih habitatov, primernih za bentoške alge (Gore 1994). V Selški Sori so se pod jezom pojavile nove vrste, značilne za vodotoke s povišanim organskim onesnaženjem (*Closterium moniliferum*, *Melosira varians*, *Surirella brebissonii* var. *kuetzingii*). Na odvzemnem mestu pod jezom, predvsem v predelu s počasnim tokom, se je povečala relativna abundanca nekaterih indikatorskih vrst, značilnih za močno organsko onesnaženje (*Melosira varians*, *Nitzschia acicularis* in *Nitzschia* *palea*) (Krammer & Lange-Bertalot 1997a, 2004a). Na zgoraj opisane spremembe kažejo tudi izračunane vrednosti saprobnega indeksa, ki so bile nad jezom nižje (1,65) kot pod jezom (1,77), vendar nikjer niso dosegle ß-mezosaprobne stopnje onesnaženja. Glede na rezultate saprobnega indeksa lahko uvrstimo Selško Soro na odvzemnih mestih S1 in S2 med oligosaprobno (neonesnaženo) in ß-mezosaprobno (srednje onesnaženo) stopnjo.

Iz Bray-Curtisovega koeficienta podobnosti (Sl. 5) je razvidno, da sta si bili med seboj bolj podobni točki odvzema na odvzemnem mestu S1 in točki odvzema na odvzemnem mestu S2.




**Slika 5.** Dendrogram: Bray-Curtisov koeficient podobnosti za fitobentos v Selški Sori dne 6.8.2008.

Tudi v raziskavi alg v reki Dragonji (Krivograd Klemenčič et al. 2003) je bilo v predelih reke s počasnim vodnim tokom bistveno višje število vrst kot v predelih reke s hitrim vodnim tokom. Naseljevanje fitobentoških alg je hitrejše pri nizkih hitrostih vodnega toka, do rasti alg in povečevanja organske snovi pa pride pri srednjih hitrostih vodnega toka. Visoke hitrosti vodnega toka ovirajo naseljevanje fitobentoških alg in prirast organske snovi (Biggs 1996). Povečanje hitrosti toka stimulira rast alg, zato je reprodukcija večja pri višjih hitrostih vodnega toka (Peterson & Stevenson 1989). Privzem hranilnih snovi in fotosinteza se povečata pri višjih hitrostih vodnega toka (Stevenson, 1996). V vseh vodotokih nastopajo spremembe hitrosti vodnega toka v času in prostoru in fitobentoške alge so izpostavljene tem nihanjem. Naraščanje hitrosti vodnega toka poveča strižno napetost in pride do odstranjevanja alg (Ghosh & Gaur 1998). Vpliv je očiten v alpskih vodotokih, kjer se hitro menja višina vode in nastajajo spremembe v hitrosti vodnega toka. Pri hitrem toku lahko pride do popolnega uničenja fitobentosa. Tok vode namreč odtrga alge od podlage, mehansko premikanje plavin pa privede do poškodb alg (Wetzel 1983).

# Zaključki

Rezultati analiz na Kokri in Selški Sori so pokazali zmanjšan pretok vode ter zmanjšanje v hitrostih vodnega toka na odsekih, kjer je prišlo do odvzema vode za potrebe hidroelektrarn, kar se je v kombinaciji z drugimi ekološkimi dejavniki pokazalo v spremembi vrstnega sestava fitobentosa in v biomasi. V obeh rekah smo na odvzemnih mestih, kjer je prišlo do odvzema vode, opazili, da ni več nekaterih taksonov alg, ki so bili zabeleženi na odvzemnih mestih pred odvzemom vode (reka Kokra: *Pleurocapsa* sp., *Hydrurus foetidus*, *Fragilaria arcus*, *Meridion circulare*, *Melosira varians*; reka Selška Sora: *Pleurocapsa* sp., *Achnanthes lanceolata*, *Amphora pediculus*, *Gomphonema angustum*, *Rhoicosphaenia abbreviata*). Za natančnejšo analizo ocena vpliva odvzema vode na fitobentos bi bilo treba o opraviti analize velikosti in gibljivosti substrata, svetlobnih razmer, strižnih hitrosti, globine vode, izbranih fizikalno – kemijskih parametrov ter opraviti vzorčevanje v različnih letnih časih. Vsekakor pa lahko na podlagi rezultatov predlagamo, da je za zagotavljanje združbe fitobentosa v vodotokih potrebno zagotavljanje ustreznih pretokov vode na odsekih, kjer prihaja do odvzemov vode iz vodotokov.

# Summary

Water is abstracted from watercourses for different purposes: hydroelectric power plants, fish farming, irrigation, drinking water, industrial purposes and for tourism and recreation. Water abstraction affects mostly the organisms that are not able to move (primary producers), this is reflected in the change of the relationship between primary and secondary producers and watercourse bio-productivity. The aim of our research was to determine the impact of water abstraction for the purpose of hydroelectric power plants Oljarica (River Kokra) and Niko (River Selška Sora) on phytobenthos community. Phytobenthos was sampled at each sampling site on two sampling points with different water velocities. At all sampling sites, flow and basic physical and chemical parameters were measured. On the River Kokra, local water velocities were also measured at single sampling points. Altogether, 52 taxa from six algal classes were determined in both rivers. According to the number of identified taxa, diatoms prevailed. In the River Kokra, diatoms followed Chlorophyceae and Cyanophyceae. In the River Selška Sora, diatoms followed Cyanophyceae, Chlorophyceae and Zygnematophyceae. Comparison of phytobenthos species compositions on both rivers before and after water abstraction showed that in the River Selška Sora phytobenthos biodiversity was lower below the dam while in both rivers decrease of algal taxa typical for clean waters and increase of algal taxa typical for organic polluted waters were noticed. On both rivers, the values of Saprobic index were higher on the sites with water abstraction, which could be the result of increased organic load or reduced flow. Phytobenthos biomass in the River Kokra was the highest in the areas with low water level and low water velocity.

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Prejeto / Received: 2.1.2011
Sprejeto / Accepted: 5.5.2011

# Spatial and temporal variability of hyporheic invertebrate community within a stream reach of the river Bača (W Slovenia)

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**Abstract.** We studied spatio-temporal distribution of hyporheic invertebrate community at the stream-reach scale in the Bača River on three sampling occasions (January, March, May) in 2005. On each sampling occasion, invertebrates were collected from the shallow hyporheic zone (RB1; depth 30-60 cm, 3 replicates), and deeper hyporheic zone (RB2; depth 60-90 cm, 2 replicates) in the river bed, and adjacent gravel bar (GB; depth 60-90 cm, 3 replicates) using Bou-Rouch piston pump. Concurrently, temperature, conductivity and oxygen were measured in the surface water and in hyporheic water at each sampling station. Differences in hyporheic community between dates and habitats were analysed by using two-way ANOVA (dates and habitats as fixed factors) and explored by principal component analysis (PCA). Altogether, 21,657 specimens from 63 taxa were collected. *Cyclopoida juveniles*, *Leuctra* sp. (Plecoptera), Chironomidae (Diptera), *Acanthocyclops vernalis* (Fischer, 1853) and *Diacyclops languidus* (G. O. Sars, 1863) were the most abundant in the samples. Two-way ANOVA showed significant differences between habitats (RB1 and GB), but no differences between dates when using taxonomic richness as dependent variable. No differences between habitats and dates were calculated when invertebrate densities were applied. PCA of hyporheic invertebrate data showed a gradient in community composition from shallow hyporheic zone (RB1) to deeper hyporheic zone (RB2) and gravel bar (GB). The differences were most probably due to different sediment composition in the studied habitats and less frequent disturbances due to floods in deeper layers and lateral gravel bars.

Key words: stream reach, hyporheic zone, invertebrates, distribution, community composition, spatial and temporal distribution

**Izvleček. PROSTORSKO-ČASOVNA SPREMENLJIVOST ZDRUŽBE NEVRETENČARJEV V HIPOREIKU REKE BAČE (Z SLOVENIJA)** – V letu 2005 je bila opravljena raziskava združbe nevretenčarjev v hiporeiku reke Bače, kjer smo opazovali prostorsko-časovno spremenljivost združbe nevretenčarjev v 3 vrstah habitatov. Nevretenčarje smo vzorčili iz globine 30 – 60 cm (RB1; 3 podvzorci) in iz globine 60 – 90 cm (RB2; 2 podvzorca) v rečni strugi ter v obrežnem prodišču iz globine 60-90 cm (GB; 3 podvzorci) v januarju, marcu in maju 2005. Merili smo tudi temperaturo vode, prevodnost in vsebnost kisika. Za testiranje razlik v številčnosti nevretenčarjev in številu taksonov med habitatoma (RB1, GB) in datumi smo uporabili dvosmerno analizo variance z vrsto habitata in datumom kot glavnima faktorjema. Sestavo združb med posameznimi habitati in datumi smo primerjali s pomočjo multivariatne analize glavnih komponent (PCA). V hiporeiku reke Bače smo nabrali 21.657 osebkov iz 63 taksonov. Najbolj številčni so bili predstavniki zgodnjih razvojnih stadijev rakov ceponožcev (Cyclopoida, Copepoda), ličinke vrbnic (*Leuctra* sp.) in trzač (Chironomidae) ter 2 vrsti ceponožnih rakov, *Acanthocyclops vernalis* (Fischer, 1853) in *Diacyclops languidus* (G. O. Sars, 1863). Dvosmerna analiza variance je pokazala razlike med RB1 in GB v številu taksonov, medtem ko razlik med datumi ni bilo. Številčnost nevretenčarjev ni bila značilno različna ne med habitati in ne med datumi. Analiza glavnih komponent (PCA) je pokazala gradient v sestavi združbe od plitvega hiporeika (RB1) do globljega hiporeika (RB2) in obrežnega prodišča (GB), najverjetneje zaradi različne strukture sedimenta v izbranih habitatih in bolj pogostih motenj (mešanje sedimenta) zaradi visokih voda v plitvejših slojih hiporeika.

Ključne besede: rečni odsek, hiporeik, nevretenčarji, porazdelitev, sestava združbe, prostorska spremenljivost, časovna spremenljivost

# Introduction

The term hyporheic biotope was first used in the late 50s and described as the interstitial habitat beneath a stream, bordered by the surface water above and by true groundwater below (Orghidan 1959, Schwoerbel 1961). However, investigations of fauna in sediments along the river banks have longer tradition (Karaman 1935, Chappuis 1942, Angelier 1953). Later, the hyporheic zone was more precisely defined as the saturated interstitial spaces below the stream bed and adjacent stream banks that contain some proportion of channel water (White et al. 1993). Recently, it has been shown by several authors that many rivers exchange water with their subsurface aquifers at a range of scales (Packman & Bencala 2000), both vertically into the hyporheic zone sensu stricto below the stream and laterally into the parafluvial zone below the banks and floodplain. Surface water down-wells into the sediments and travels for some distance through the saturated sediments before upwelling into the stream again. During its hyporheic journey, the downwelling water mixes with groundwater, and its chemical composition is further altered by biogeochemical processes typically mediated by microbial biofilms on sediment particles (Boulton et al. 1998).

Hyporheic zone is inhabited by a diverse array of invertebrate assemblages. In the areas where downwelling of river water occurs, the sediments are well-oxygenated, rich in labile carbon, and harbour primarily organisms from benthic origin. With increasing residence time below the riverbed, hyporheic water becomes less oxygenated, biogeochemical processes become reductive, and the hyporheic fauna becomes dominated by groundwater species (Gibert et al. 1994, Brunke & Gonser 1997). The hyporheic zone is a site of spawning and egg incubation for some salmonid species (Geist & Dauble 1998), as well as a nursery site for some insect taxa, such as Leuctridae (Plecoptera) and Heptageniidae (Ephemeroptera) (Malard et al. 2003). The hyporheic sediment pores can act as a refuge for invertebrates during periods of drought (Williams 1977, Wood et al. 2010), and can be regularly used by early instars of benthic insects as a refuge against strong currents (shear stress) (Schwoerbel 1964).

Despite the extensive faunistic research of groundwater invertebrates in Slovenia over the past decades, the ecology of interstitial habitats along the rivers remains poorly investigated, especially in comparison to those in karst aquifers. Invertebrate communities living in different groundwater habitats of the River Sava in southern Slovenia and northern Croatia were investigated from 1960-70 (Meštrov 1960, Meštrov et al. 1983). In the late 1970s, comprehensive studies of the invertebrate community from interstitial habitats were conducted in the River Sava (at Ljubljansko polje) (Sket & Velkovrh 1981). Two decades later, intensive ecological studies of interstitial habitats were performed on four rivers, tributaries of the River Sava, flowing in the south and southeastern part of Ljubljansko Barje (Mori 2004, Dole-Olivier et al. 2009). Recently, the ecology of hyporheic biofilm (Simčič & Mori 2007) and the impacts of gravel extraction on the hyporheic invertebrates of the River Bača, a tributary of the River Soča, have been studied (Simčič & Mori 2007, Mori et al. 2011).

In this paper we present the composition and spatio-temporal dynamics of hyporheic invertebrate community at the stream-reach scale in the pre-alpine gravel-bed River Bača with the aim to compare assemblages inhabiting shallow (RB1) and deeper (RB2) hyporheic zone in the river bed and those from adjacent gravel bar (GB), and discuss the importance of hydrology and river bed geomorphology in shaping the hyporheic invertebrate community.

## Materials and methods

The study was carried out within a 20 m long reach of the pre-alpine River Bača (W Slovenia, the River Soča catchment). The study site is located 2.5 km before the river confluence with the River Idrijca, where a 100 m long gravel bar is extending along the right side of the stream channel. The width of the channel was 5 m and additional 5 m belonged to the gravel bar. The River Bača has pluvio-nival discharge regime, with maximum discharge rates in autumn. The predictability of discharge rates is relatively low, especially for October and November. The mean annual discharge was 7.1 $m^3/s$ for the 1961 – 1990 period, and 6.6 $m^3/s$ for the 1991 – 2004 period (Environment Agency RS). The maximum and minimum mean daily discharges for 13 years period were 38.7 and 2.6 $m^3/s$, respectively. The substrate is highly permeable, composed mainly of gravel and pebble.

In this paper, the results of three sampling campaigns carried out at three different dates (i.e. in January, March and May 2005) are presented (Fig. 1). On each sampling occasion, a mobile steel pipe (Ø 45 mm) with a perforated distal end (apertures in a length of 30 cm, diameter of holes were 10 mm) was inserted into the river sediments at six sampling stations. Three samples were taken from the depths between 30 and 60 cm (shallow hyporheic zone - RB1) in the river bed, and three from adjacent gravel bar, from a depth between 60 and 90 cm (GB). Two samples were taken at the same sampling stations as RB1, but from the depths between 60 and 90 cm (deeper hyporheic zone – RB2). The samples from RB2 were not collected in January 2005 due to technical problems, and one of the RB2 samples was not collected in March and May because the sediments were too shallow at the most downstream RB1 station to insert the steel pipe deeper than 60 cm into the sediments. Sampling stations at RB1 were approximately 5 m apart in a line along the river flow, while stations at GB were parallel to RB1. At each sampling station (n=8), 10 litre mixtures of water, sediment and invertebrates were extracted using a piston pump fixed on a mobile steel pipe (Bou & Rouch 1967). Invertebrates and organic matter were removed from the sample by elutriating and filtering the water through a hand net (mesh size 100 µm), stored in PVC bottles in 4% formaldehyde solution and transported to the laboratory for processing. After collecting the biological samples, oxygen (WTW Multiline P4, CellOx 325), temperature and conductivity (WTW Multiline P4, TetraCon 325) of the surface water and hyporheic water in the steel pipes were measured. In the laboratory, the biological samples were sorted and invertebrates counted and identified to the species where possible (Rivosecchi 1984, Studeman et al. 1992, Einsle 1993, Janetzky et al. 1996, Graf & Waringer 1997, Meisch 2000, Zwick 2004).

Physical and chemical measurements and invertebrate densities and taxonomic richness were compared between different sampling occasions and between RB1 and GB, using two-way analysis of variance (ANOVA) with habitats (RB1, GB) and dates (January, March, May) as fixed factors. Data were normalized by log10(x+1) (T, conductivity, oxygen, invertebrate density) and by $\sqrt{(x+3/8)}$ (taxonomic richness) transformations. Data from the deeper hyporheic zone (RB2) were not included in the above analyses due to lacking data from January sampling campaign. Principal component analysis (PCA) on log (x+1) transformed invertebrate abundances was carried out to examine the variation in community composition between habitats and dates. The CANOCO software package was applied (ter Braak & Šmilauer 2002).

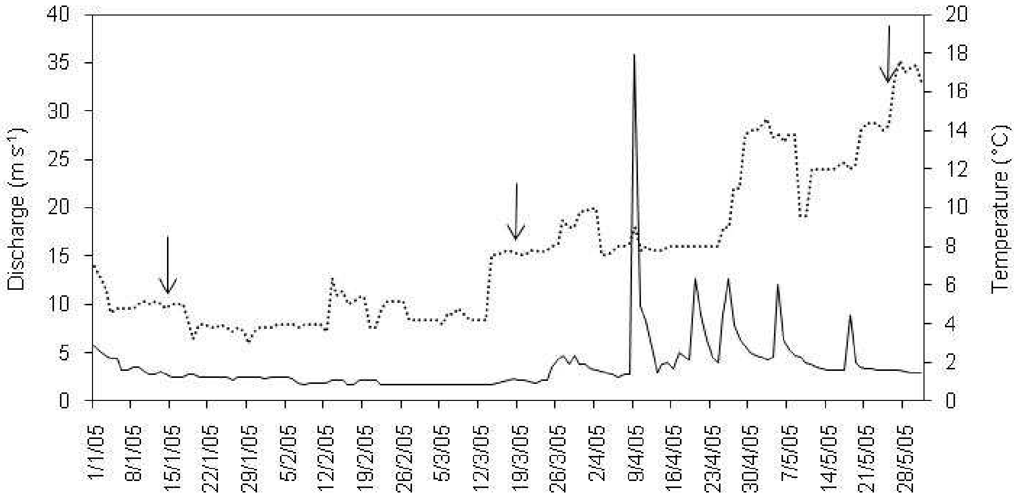


**Figure 1.** Mean daily discharge (solid line) and surface water temperatures (dashed line) in the River Bača from January to May 2005. Arrows indicate the sampling dates.

**Slika 1.** Srednji dnevni pretoki (neprekinjena črta) in temperature površinske vode (pikčasta črta) v reki Bači, merjeni od začetka januarja do konca maja 2005. Puščice označujejo datume vzorčenja.

# Results

Mean water temperatures over sampling periods were 4.8 - 14.5°C (surface), 5 - 14.4°C (RB1), 6.4 - 14°C (RB2) and 5.5 - 16°C (GB) respectively (Fig. 2a) and were significantly different between dates (two-way ANOVA; $F = 3.88$, $p < 0.001$), but not between RB1 and GB. Mean conductivity of the surface water was 265 - 279 µS/cm, of the shallow river bed (RB1) 268 – 282 µS/cm, of the deeper river bed water (RB2) 266 – 279 µS/cm, and of gravel bars (GB) 282 – 290 µS/cm (Fig. 2b). Mean oxygen concentrations were 11.7 – 13.8 mg/l in the surface water, 9.0 – 12.2 mg/l in RB1, 11.6 – 12.8 mg/l in RB2 and 8.2 – 9.8 mg/l in GB (Fig. 2c). Two-way ANOVA did not show significant differences in conductivity and oxygen concentrations between habitats RB1 and GB, and dates.

Altogether, 21,657 specimens from 63 taxa were collected (Tab. 1). Juveniles of Cyclopoida, *Leuctra* sp. (Plecoptera), Chironomidae (Diptera), *Acanthocyclops vernalis* (Fischer, 1853) and *Diacyclops languidus* (G. O. Sars, 1863) (Crustacea, Copepoda) were the most abundant taxa in the samples. Eleven groundwater taxa were collected, with *Diacyclops languidoides* (Lilljeborg, 1901) being the most abundant among them. Mean densities ($n=3$) over the sampling occasions were in RB1 556 - 650 specimens 10 $l^{-1}$, in RB2 1,316 - 2,960 specimens 10 $l^{-1}$, and in GB 479 - 1,308 specimens 10 $l^{-1}$ (Fig. 3a). Mean taxonomic richness ($n=3$) varied from 8.7 – 14.3 taxa 10 $l^{-1}$ in RB1, from 14.0 – 17.5 taxa 10 $l^{-1}$ in RB2, and from 18.0 – 21.7 taxa 10 $l^{-1}$ in GB (Fig. 3b). Two-way analysis of variance revealed significant difference in taxonomic richness between RB1 and GB ($p < 0.001$, $F = 4.74$), but not in density, as well as there was no impact of sampling dates on taxonomic richness or density.

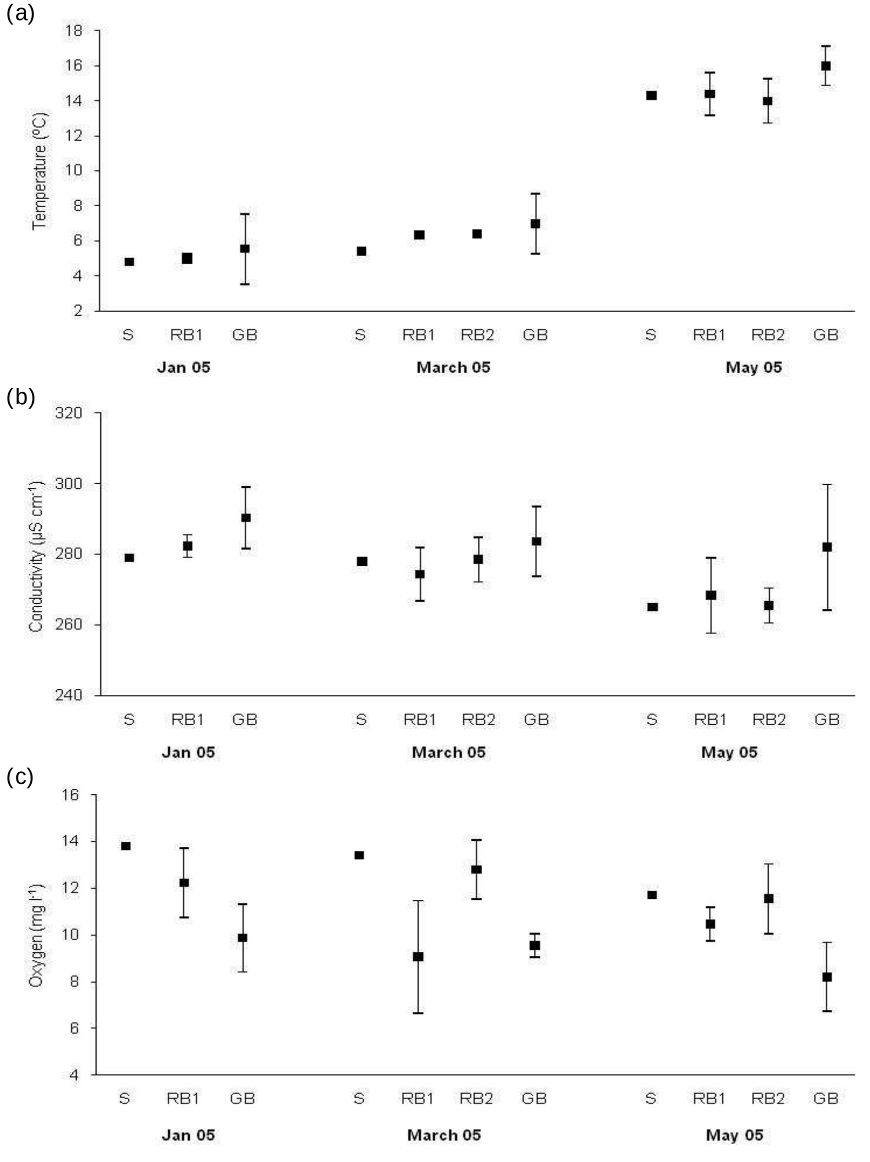


**Figure 2.** Mean temperatures **(a)**, conductivity **(b)** and oxygen concentrations **(c)** (± SE) of surface and hyporheic water measured during invertebrate sampling. RB1 – shallow hyporheic zone (30 – 60 cm); RB2 – deeper hyporheic zone (60 – 90 cm); GB – gravel bars (60 – 90 cm). RB1, GB, n=3; RB2, n=2.

**Slika 2.** Srednje vrednosti temperature (a), prevodnosti (b), in vsebnosti kisika (c) (± SE) v vzorcih površinske vode in vode, ki se je pretakala v hiporeiku med vzorčenjem nevretenčarjev. RB1 – plitev hiporeik (30 – 60 cm); RB2 – globlji hiporeik (60 – 90 cm); GB – prodišče (60 – 90 cm). RB1, GB, n=3; RB2, n=2.

**Table 1.** List of invertebrates collected in the hyporheic zone of the River Bača on three sampling occasions in 2005. RB1 – shallow hyporheic zone (30 – 60 cm); RB2 – deeper hyporheic zone (60 – 90 cm); GB – gravel bars (60 – 90 cm). Mean abundances (No. of specimens in 10 $l^{-1}$) are shown for each habitat. RB1 and GB, n=9; RB2, n=4. Taxa in **bold -** stygobionts (i.e. groundwater taxa).

**Tabela 1.** Seznam nevretenčarjev, ugotovljenih v hiporeiku reke Bače januarja, marca in maja 2005. RB1 – plitev hiporeik (30 – 60 cm); RB2 – globlji hiporeik (60 – 90 cm); GB – prodišče (60 – 90 cm). Za posamezne habitate so prikazane povprečne abundance (št. osebkov v 10 l). RB1, GB, n=9; RB2, n=4. **Poudarjeni taksoni -** stigobionti (t.j. podzemni taksoni).

| Taxa | Total number of specimens | RB1 | RB2 | GB |
|---|---|---|---|---|
| Cyclopoida juveniles | 10012 | 185.8 | 1281.3 | 357.2 |
| *Leuctra sp.* | 3194 | 29.0 | 212.8 | 231.3 |
| Chironomidae | 1601 | 150.2 | 14.8 | 21.1 |
| *Acanthocyclops vernalis* (Fischer, 1853) | 1565 | 57.8 | 190.8 | 31.3 |
| *Diacyclops languidus* (G. O. Sars, 1863) | 1389 | 36.1 | 200.3 | 29.2 |
| ***Diacyclops languidoides* (Lilljeborg, 1901)** | **607** | **21.1** | **38.8** | **29.1** |
| Cladocera navpliji | 571 | 8.2 | 77.3 | 20.9 |
| Baetoidea (Baetidae+ Siphlonuridae) | 513 | 11.3 | 33.3 | 30.9 |
| Acarina | 448 | 46.2 | 4.3 | 1.7 |
| Oligochaeta | 310 | 9.4 | 22.8 | 14.9 |
| Nematoda | 246 | 17.1 | 7.3 | 7.0 |
| *Acanthocyclops gmeineri* Pospisil, 1989 | 231 | 8.7 | 31.5 | 3.0 |
| *Siphlonurus* sp. | 201 | 8.4 | | 13.9 |
| Harpacticoida juveniles | 120 | 1.1 | 1.8 | 11.4 |
| Taeniopterygidae | 91 | 10.1 | | |
| Tipulomorpha | 90 | 3.2 | 3.3 | 5.3 |
| *Bryocamptus minutus* (Claus, 1863) | 69 | | 0.3 | 7.6 |
| Hydridae | 65 | | | 7.2 |
| Rotatoria | 42 | | 10.5 | |
| *Bryocamptus zschokkei* (Schmeil, 1893) | 36 | 0.2 | 0.3 | 3.7 |
| ***Bathynella* sp.** | **27** | **3.0** | | |
| Ceratopogonidae | 25 | 1.3 | 0.5 | 1.2 |
| ***Parastenocaris gertrudae* Kiefer, 1968** | **25** | **1.1** | | **1.7** |
| *Habroleptoides* sp. | 20 | 0.7 | | 1.6 |
| *Echinocamptus pilosus* (Van Douwe, 1911) | 12 | 0.3 | 1.3 | 0.4 |
| ***Bryocamptus pygmaeus* (Sars, 1863)** | **11** | **0.3** | **0.8** | **0.6** |
| ***Parastenocaris nolli alpina* Kiefer, 1960** | **11** | **1.2** | | |
| Dryopoidea | 10 | 0.8 | | 0.3 |
| Simulidae | 10 | 0.2 | 0.5 | 0.7 |
| *Bryocamptus dacicus* (Chappuis, 1923) | 9 | | 0.8 | 0.7 |
| Polycentropodidae | 9 | 0.8 | | 0.2 |
| ***Bryocamptus typhlops* (Mrázek, 1893)** | **8** | | **0.8** | **0.6** |
| *Epactophanes richardi* Mrázek, 1893 | 8 | | 0.3 | 0.8 |
| Gastropoda | 8 | 0.6 | 0.3 | 0.2 |
| Candoninae juveniles | 7 | | | 0.8 |
| ***Proasellus* sp.** | **6** | **0.2** | | **0.4** |
| ***Speocyclops* sp.** | **6** | **0.7** | | |
| Athericidae | 4 | | 0.5 | 0.2 |
| *Diacyclops* sp. | 4 | 0.4 | | |
| Beraidae | 3 | | 0.3 | 0.2 |
| Scirtidae | 3 | 0.1 | | 0.2 |
| *Rhitrogena* sp. | 2 | 0.1 | | 0.1 |

| Taxa | Total number of specimens | RB1 | RB2 | GB |
|---|---|---|---|---|
| Sericostomatidae | 2 | 0.1 | | 0.1 |
| *Amphinemoura* sp. | 2 | 0.2 | | |
| Hydropsychidae | 2 | 0.2 | | |
| Philopotamidae | 2 | | 0.5 | |
| *Ephemera* sp. | 2 | | | 0.2 |
| *Ephemerella* sp. | 2 | | | 0.2 |
| *Moraria varica* (Graeter, 1911) | 2 | | | 0.2 |
| *Brachyptera* sp. | 1 | 0.1 | | |
| *Cyclops vicinus* Uljanin, 1875 | 1 | 0.1 | | |
| *Gammarus* sp. | 1 | 0.1 | | |
| Limnephilidae | 1 | 0.1 | | |
| Rhyacophilidae | 1 | 0.1 | | |
| Turbellaria | 1 | 0.1 | | |
| *Alona rectangula* Sars, 1862 | 1 | | 0.3 | |
| *Chydorus sphaericus* (O.F. Müller, 1785) | 1 | | 0.3 | |
| Psychomyidae | 1 | | 0.3 | |
| *Alona costata* Sars, 1862 | 1 | | | 0.1 |
| *Candona candida* (Müller, 1776) | 1 | | | 0.1 |
| ***Fabaeformiscandona breuli* (Paris, 1920)** | **1** | | | **0.1** |
| Heptageniidae | 1 | | | 0.1 |
| *Nemoura* sp. | 1 | | | 0.1 |
| **Total number of specimens** | **21657** | | | |
| **Number of taxa** | **63** | | | |

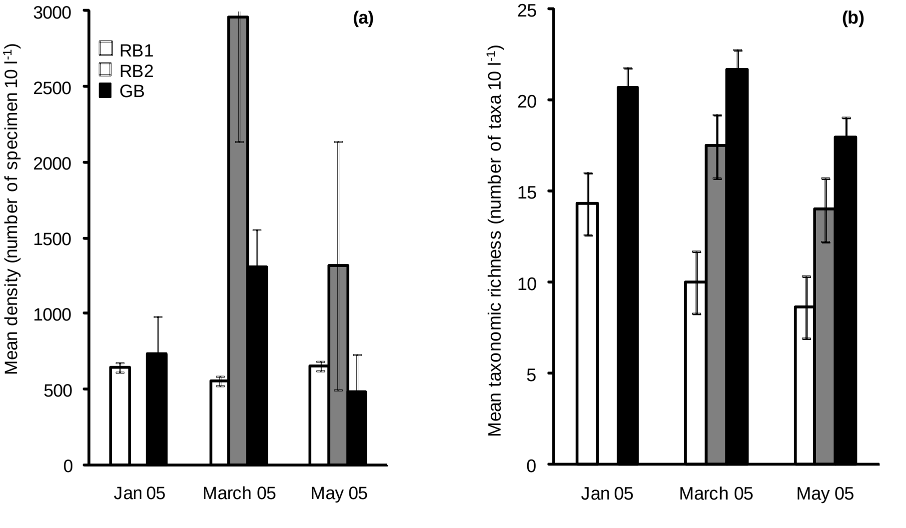


**Figure 3.** Mean densities **(a)** and taxonomic richness **(b)** (± SE) of the samples collected in January, March and May 2005. RB1 – shallow hyporheic zone (30 – 60 cm); RB2 – deep hyporheic zone (60 – 90 cm); GB – gravel bars (60 – 90 cm). RB1, GB, n=3; RB2, n=2.

**Slika 3.** Srednje vrednosti številčnosti osebkov (a) in število taksonov (b) (±SE) v vzorcih, nabranih v januarju, marcu in maju 2005. RB1 – plitev hiporeik (30 – 60 cm); RB2 - globlji hiporeik (60 – 90 cm); GB – prodišče (60 – 90 cm). RB1, GB, n=3; RB2, n=2.

The most abundant taxa (Cyclopoida, *Leuctra* sp.) had different spatio-temporal patterns (Fig. 4a, b). Cyclopoida (Copepoda) were the most abundant in March in all three habitats (RB1 - 476 individuals 10 $l^{-1}$; RB2 – 2,477 individuals 10 $l^{-1}$; GB – 856 individuals 10 $l^{-1}$). In general, their densities were higher in RB2 and GB than in RB1 during all sampling occasions. *Leuctra* sp. (Plecoptera) densities were much lower than densities of Cyclopoida with the highest values in January in GB (403 individuals 10 $l^{-1}$). In March, their densities were lower than in January, but densities in RB2 (206 individuals 10 $l^{-1}$) and GB (255 individuals10 $l^{-1}$) were higher than in RB1 (17 individuals 10 $l^{-1}$). In May, densities in RB2 (217 individuals 10 $l^{-1}$) were the highest, followed by RB1 (53 individuals 10 $l^{-1}$) and GB (35 individuals 10 $l^{-1}$).

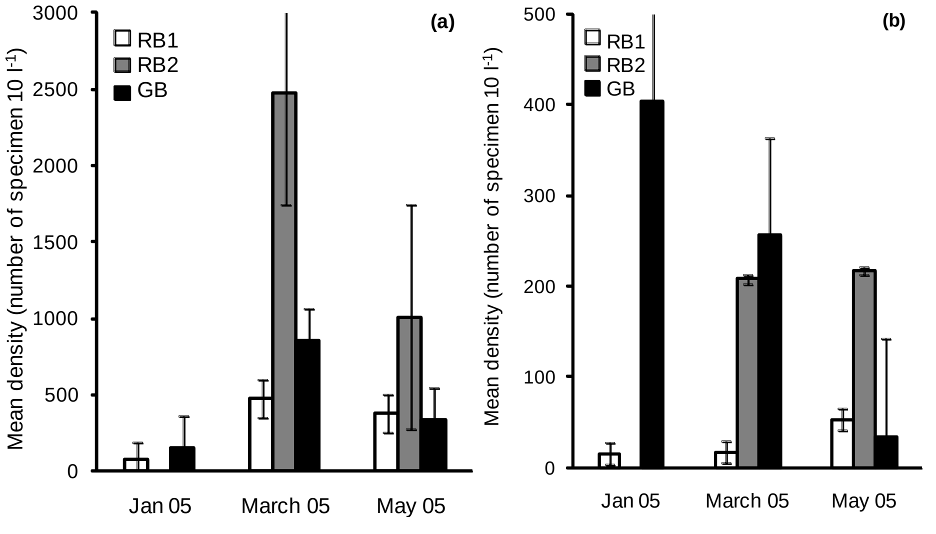


**Figure 4.** Mean densities of Cyclopoida **(a)** and *Leuctra* sp. **(b)** (± SE) of the samples collected in January, March and May 2005 (RB1, GB, n=3; RB2, n=2).
**Slika 4.** Srednje vrednosti številčnosti ceponožnih rakov (Cyclopoida) **(a)** in predstavnikov rodu *Leuctra* sp. (Plecoptera) **(b)** (± SE) v vzorcih, nabranih v januarju, marcu in maju 2005 (RB1, GB, n=3; RB2, n=2).

PCA explained 40.3% of the variance in the data by the first two ordination axes. PCA ordination resulted in the clustering of the RB1 and GB samples into two relatively distinct groups, while the samples from RB2 were grouped between them. A within-habitat variability of the invertebrate community was relatively high, but the lowest in January. The samples from RB1 were associated with higher densities of Chironomidae and *D. languidus*, while the samples from GB were the most distinct from the other two groups due to the presence of Baetoidea and *D. languidoides* (Fig. 5).

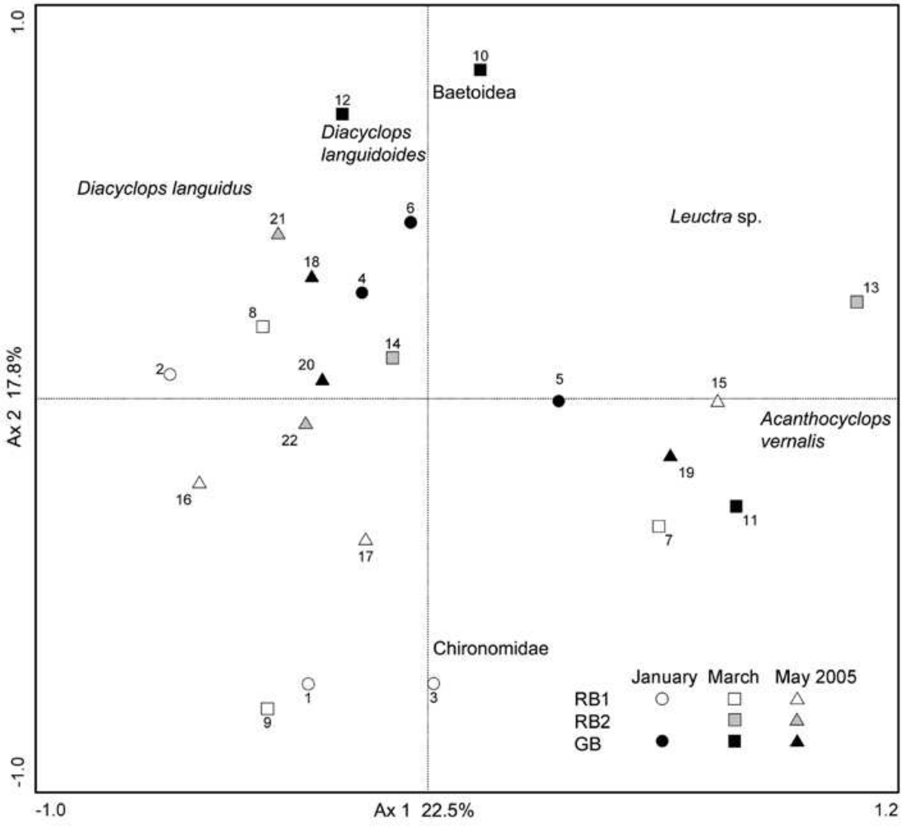


**Figure 5.** PCA ordination diagram of first two axes indicating the grouping of samples collected from three habitat types in the hyporheic zone of the River Bača on three sampling occasions (RB1, RB2, GB; January, March, May 2005).
**Slika 5.** Ordinacijski diagram za prvi dve osi analize glavnih komponent (PCA), ki prikazuje grupiranje vzorcev, nabranih v treh različnih tipih habitatov in v treh sezonah (RB1, RB2, GB; januar, marec, maj 2005) v hiporeiku reke Bače.

## Discussion

Despite low food availability (Simčič & Mori 2007), low mean annual water temperatures and occasional extremely high autumn peaks in discharge (Mori et al. 2011), a diverse array of invertebrate taxa was collected from the hyporheic zone in the River Bača, with Cyclopoida juveniles (Copepoda) (46%) and early instars of *Leuctra* sp. (15%) and Chironomidae (7%) being the most abundant. Cyclopoida have often been reported as a major component of hyporheos (Boulton et al. 1992, Hunt & Stanley 2003), and *Leuctra* sp. spend early larval developmental stages deep in the hyporheic zone (Sivec 2003). Chironomidae and Leuctridae have been found to occur in high relative abundances in the River Bača benthos as well (Environment Agency RS 2007). Juvenile Copepoda stages dominated in the hyporheic zone of the glacial Roseg River, Switzerland (72% of all individuals), where harsh environmental conditions, such as low temperatures (below 4ºC), shape the community composition (Malard et al. 2003). In rivers that are subjected to frequent fluctuations in discharge, frequent modification of river bed and high loads of suspended sediment, the biota is adapted to cope with such conditions and therefore express greater persistence, resistance and rate of recovery than less variable systems (Poff & Ward 1990). In the streams experiencing frequent disturbance, highly mobile species and species that have ability to reproduce quickly and have short generation times (r-selected) prevail (Townsend 1989). The mobility is needed to move into refugia before and during floods and to recolonize vacated areas after a disturbance (Townsend & Hildrew 1994). Resilient lotic communities include substantial proportions of mayflies (Baetidae, Leptophlebiidae, and occasionally Heptageniidae), multi-voltine black flies (Simuliidae), browser and gatherer Chironomidae and Hydropsychine caddisflies (Mackay 1992). The proportion of stygobionts in the hyporheic zone is low in such streams (Fowler & Death 2001). Those statements are in accordance with our results, where insect larvae (*Leuctra* sp., Chironomidae) prevailed in the samples, and stygobionts were present in low numbers.

Data on temperature, conductivity and oxygen concentrations showed little differences between the surface water and the water flowing through river bed and gravel bars sediments. Those parameters can be used to indirectly measure the influence of the surface water in the river bed sediments (White et al. 1987) and for the estimation of the hydraulic conductivity. Small differences in those parameters between the three habitats and surface water indicate good hydraulic connectivity and fast subsurface-surface exchanges of the water in the hyporheic zone of the River Bača. The subsurface-surface exchanges of the water have direct consequences on the physical, chemical and biological patchiness in the hyporheic zone (Dole-Olivier 1998). Those exchanges are controlled mainly by discharge rates and hydrological regime (Datry et al. 2007), and the sediment size and composition (Hunt & Stanley 2003). Oxygen concentrations were relatively high during all measurements. In well sorted and coarse river bed sediments, oxygen concentrations are normally high (Bretschko 1991, Stanford et al. 1994) and hypoxia (< 3 $mgO_2/l$) is not a limiting factor for animals.

Despite the similarity in temperature, conductivity and oxygen concentrations of RB1, RB2 and GB habitats, distinct communities were collected by means of taxonomic richness and community composition. Densities were not significantly different between RB1 and GB, but were higher in GB than in RB1 on two out of three sampling occasions (January, March).

Densities in RB2 were on both sampling occasions (March, May) higher from those in GB and RB1. Taxonomic richness was the highest in gravel bars (GB), followed by that in deeper hyporheic zone (RB2), and in the shallow hyporheic zone (RB1). This is most probably due to the fact that shallow hyporheic zone (up to 60 cm) is more often exposed to the frequent sediment replacements occurring during floods. Disturbances caused by drastic variations in flow have been considered as one of the most important factors regulating the structure of lotic invertebrate communities in whole (Reice 1985), as well as affecting hyporheic communities (Olsen & Townsend 2005). It was proposed by intermediate disturbance hypothesis that biodiversity is the highest when disturbance is neither too rare nor too frequent (Connell 1980). In our case we studied habitats that are often disturbed by smaller floods (RB1 - shallow hyporheic zone) and consequently had lower taxonomic richness than habitats (RB2, GB) that are rarely disturbed by large scale floods, which occur every few years. Additional reasons for lower taxonomic richness in RB1 could be due to higher shear stress than in deeper and adjacent layers. In benthic habitats, invertebrates often aggregate in areas of the streambed characterized by low shear stress (Robertson et al. 1995). Similarly, hyporheic invertebrates could accumulate in areas with lower hydraulic conductivity (slower interstitial flow rates), which are in deeper sediments and gravel bars. The amounts of finer sediments (< 5 mm) extracted by piston pump were higher in gravel bars and deeper sediments than in shallow hyporheic zone in the River Bača (Mori et al. 2011). Consequently, the hydraulic conductivity is lower in deeper layers and GB. This provides a diverse array of more favourable microhabitats than those from shallow hyporheic zone, where water flows faster through coarser grained interstitial spaces. Moreover, the food availability is probably higher in that kind of micro-spaces. When patch quality was manipulated (amount of microbial and fungal biomass and production) in the hyporheic zone, invertebrate abundances increased greatly in high quality areas (Swan & Palmer 2000). The analysis of community composition across three habitats showed that juvenile Cyclopoida and Chironomidae prevailed in RB1, while together with *Leuctra* sp., juvenile Cyclopoida, *D. languidus* and *A. vernalis* dominated in RB2 and juvenile Cyclopoida and *Leuctra* sp. in GB. In deeper, more stable hyporheic zone with lower hydraulic conductivity meiofauna dominate, whereas in more dynamic, coarse grained shallow hyporheic zone representatives of pioneering groups, such as Chironomidae, prevail. The importance of sediment grain size, hydrological exchange patterns and sediment stability for hyporheic invertebrate communities have been shown previously by several other researchers (Creuzé des Chatelliers 1991, Gibert et al. 1994, Olsen and Townsend 2003). The spatio-temporal dynamics of invertebrate community depends not only on environmental conditions, but also on annual life cycles of individual taxa, which result in different temporal patterns. Cyclopoida showed a peak in abundances in March, while *Leuctra* sp. peaked in January. However, no significant differences in total density and taxonomic richness between dates were calculated.

The interpretations of all the above observations need to be taken carefully due to small number of samples (n=22), lack of January samples for RB2 and only three sampling dates. Still, we can conclude that invertebrate community in hyporheic zone of the River Bača exhibits high spatial heterogeneity due to heterogeneous sediment composition and complex hydraulic patterns across the studied habitats, and shows moderate temporal variation over sampling dates mainly due to specific annual life cycles of individual taxa.

## Acknowledgements

The research was supported by the Slovenian Ministry of Higher Education, Science and Technology (Young researcher/RS 105-003). The hydrological data were provided by the Environment Agency of Slovenia. The authors thank C. Fišer, C. Meisch, I. Sivec, B. Sket, G. Urbanič, and D. Zabric for their help in determining Ostracoda, Amphipoda, Isopoda, Plecoptera, Trichoptera and Ephemeroptera, and A. Kapla, S. Lukančič, and M. Osanič for their assistance in the field.

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Prejeto / Received: 30.11.2010
Sprejeto / Accepted: 4.5.2011

# A survey of *Aedes albopictus* (Diptera: Culicidae) distribution in Slovenia in 2007 and 2010

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**Abstract.** Spreading of the invasive mosquito species *Aedes albopictus* in the southwestern part of Slovenia was studied in 2007 and 2010. The study was based on larval and adults search. Mosquito larvae were sampled with a dipper or a net from various artificial containers and the adults caught by human bait catches for 15 minutes. In 2007, the research was carried out in 64 municipalities, where 327 larval habitats were examined. *Ae. albopictus* was observed in 52 municipalities. Mosquito larvae were most often collected in small containers placed in shady areas. All the adults were caught near breeding sites. The species was found in most of the studied areas in south-western Slovenia, especially in its coastal part and near Nova Gorica. In 2010, a research was implemented in 12 municipalities that had proved negative for *Ae. albopictus* in 2007. The incidence of *Ae. albopictus* was surveyed in 100 larval habitats. The presence of *Ae. albopictus* was confirmed in almost all of the municipalities, which is an indicator of its firm establishment in the studied area.

Key words: *Aedes albopictus*, distribution, southwestern Slovenia

**Izvleček. PREGLED RAZŠIRJENOSTI TIGRASTEGA KOMARJA *AEDES ALBOPICTUS* (DIPTERA: CULICIDAE) V SLOVENIJI V LETIH 2007 IN 2010** – Razširjenost tigrastega komarja *Aedes albopictus* v JZ delu Slovenije smo preučevali v letih 2007 in 2010 na podlagi pojavljanja ličink ter odraslih osebkov. Ličinke smo vzorčili po različnih habitatih s posodico ali mrežico, odrasle komarje pa smo lovili z metodo človek – aspirator 15 minut. V letu 2007 smo pregledali 327 različnih habitatov ličink v 64 naseljih. Tigrastega komarja smo zabeležili v 52 naseljih. Komarjeve ličinke smo najpogosteje našli v manjših, osenčenih habitatih, odrasle osebke pa ob leteh. Kot smo pričakovali, je bila gostota komarja v priobalnem pasu velika, a se je v velikem številu pojavljal tudi v preostalem delu JZ Slovenije, predvsem na Goriškem. Leta 2010 smo v raziskavo vključili 12 naselij, v katerih leta 2007 tigrasti komar ni bil potrjen. Skupno smo v letu 2010 pregledali 101 habitat ličink. Tigrastega komarja smo potrdili v skoraj vseh preiskanih naseljih, kar kaže na vzpostavitev stabilne populacije vrste na preiskovanem območju.

Ključne besede: *Aedes albopictus*, razširjenost, jugozahodna Slovenija

# Introduction

The Asian tiger mosquito *Aedes albopictus* (Skuse, 1895) is an invasive mosquito species that originates from tropical and subtropical Asia (Hawley 1988). In just over three decades it has spread to North and South America, the Caribbean, Africa, Southern Europe and some Pacific islands (Knudsen 1995). The spreading is mediated by human activity, as this species has a limited flight range (Hawley 1988). The transport of drought and cold resistant eggs in used tires via air and sea transport played a major role in its spreading. When the tires are shipped and rehydrated again, the eggs can hatch within hours and in a few days adult mosquitoes emerge and disperse (Knudsen 1995). Additionally, transport of its eggs and larvae within the canes of »Lucky bamboo« (*Dracaena* sp.) (Madon et al. 2003, Scholte et al. 2007) and transport of the adults by vehicles is occurring (Flacio et al. 2004, Pluskota et al. 2008).

In its native zone, *Ae. albopictus* is a common species in urban, suburban, rural and forested areas. The tropical environment enables this species to breed all year round (Hawley 1988). In the temperate zone, the distribution of *Ae. albopictus* is limited to urban areas where at least some vegetation is present (Mitchell 1995). The abilities to colonize artificial containers and to produce dormant eggs enable the species to establish under temperate climate.

Adult females of *Ae. albopictus* represent a high nuisance for the human population as they are aggressive biters that feed mainly during daytime, unlike most other mosquito species in urban environment (Hawley 1988). More significantly, *Ae. albopictus* has a high medical importance, since it is an effective vector of dengue and chikungunya viruses (Mitchell 1995). The last epidemic of dengue in Europe was in Greece in 1927 to 1928 (Rosen 1986). In 2010, autochthonous transmission of dengue infection was noticed in two European countries, France (La Ruche et al. 2010) and Croatia (Gjenero-Margan et al. 2011). Apart from the recent outbreaks in the tropics (Gratz 2004, Paquet et al. 2006), there was an outbreak of chikungunya in Italy in 2007 (Angelini et al. 2007). These data indicate that, with the presence of the vector in the area, there is a big chance of new dengue and chikungunya outbreaks in Europe. Additionally the species' role in the transmission of *Dirofilaria* spp. in urban environments of Asia, North America and Europe has been confirmed (Konishi 1989, Nayar & Knight 1999, Cancrini et al. 2003).

The first record of *Ae. albopictus* in Europe was made in Albania in 1979 (Adhami & Murati 1987). The first infestation in Italy was reported from the Port of Genoa in 1990, where it was introduced in a shipment of used tires from the United States (Sabatini et al. 1990) and since then it has reached a homogenous population in almost all of the Italian regions. After the discovery in Italy, several other European countries reported the presence of *Ae. albopictus*, i.e. France, Belgium, Montenegro, Greece, Switzerland, Spain, Croatia, Bosnia and Herzegovina, The Netherlands, Monaco, Germany, San Marino, Vatican City (ECDC 2009). The most recent introduction was in Malta in 2009 (Gatt et al. 2009).

The first record of *Ae. albopictus* in Slovenia was published in 2002, where a few adults were spotted near Nova Gorica (Turel 2002). In the following years, its population and distribution increased, but the data on its geographical distribution and spreading in the region has been scarce, mainly due to the lack of experts of the Culicidae family in Slovenia. Only a few studies of this dipteran family have been carried out so far (Trpiš & Tovornik 1958, Tovornik 1983, Adamović & Paulus 1988, Tovornik 1990), mostly in the central and southeastern parts of Slovenia, mainly involving anopheline mosquitoes.

## Material and methods

In order to obtain more data on *Aedes albopictus* in Slovenia, a study on its distribution was done in 2007. The study was focused on the southwestern part of the country where, according to predicted routes of its spreading in this part of Europe, the species was most likely to occur. Additionally, we tried to determine the eastern and northern border of its distribution. In 2010, the distribution of *Ae. albopictus* was studied again.

In the Northern part of Italy (44°- 46° N), the first eggs of mosquito larvae hatch in April and the adults die off in November (Romi 2001). Its population is highest between 15th August and 15th September (Bellini et al. 2005). We assumed that the seasonal activity of *Ae. albopictus* is similar in Slovenia and therefore all the field work has been carried out when it was most likely for *Ae. albopictus* to be caught. The sampling was done from 9th July to 8th October 2007 and from 21st July to 30th September 2010.

The study in 2007 was performed in several municipalities, which were chosen in a way that all of the area was inspected more or less evenly, whereas the coastal part was studied more accurately. The field work was carried out every month during the three months sampling. If the Asian tiger mosquito was caught already during the first sampling, no additional sampling was made in that municipality. Therefore, minimum one and maximum three samplings were done per municipality. In the repeated samplings in a municipality, the larval habitats from previous inspections were included, as well as new ones added to the study. In 2010, the study was done in the municipalities, where *Ae. albopictus* had not been recorded in 2007. The aim of this year's sampling was to inspect all larval habitats from the previous study, as well as new ones, which weren't present in 2007.

The study of the distribution of Asian tiger mosquito was based on searching for its larvae and adults. Mosquito larvae were sampled with a dipper or a small net of 10 cm in diameter from any artificial container, which contained at least some water. Larval habitats such as barrels, vessels, vases, old bath tubs, small water pools, watering cans, sinks, flower pots and other water-containing objects were included in the study. In the major cities in the area, old tires of local vulcanizing companies were also inspected for mosquito larvae.

All sampled larvae were stored in 50% alcohol immediately after fieldwork. The mounting of fourth instar larvae on glass slides was made by immersing the larvae in a series of alcohol solutions (50%, 70% and 96%), xylene and embedding it in Canada balsam (Furman & Catts

1982). After the preparation, morphological identification was made based on available keys (Gutsevich et al. 1974, Schaffner et al. 2001, Becker et al. 2003).

Adult specimens were collected in a range of maximum 50 meters from the breeding sites by human bait catches for 15 minutes during daytime, between 8 am and 8 pm. By this method, the investigator collects all mosquitoes that land in front of his body during 15 minutes (Service 1993). All adult mosquitoes were killed using temperatures higher than 30°C, placed on the sun during the field work, or with the temperatures below 0°C in a freezer if killed after the field work. After the identification with the keys (Gutsevich et al. 1974, Schaffner et al. 2001, Becker et al. 2003) they were glued to cardboard and then pinned to entomological needles. All mounted mosquitoes are stored in the entomological collection of the Slovenian Museum of Natural History. Additionally, the data on observed adult Asian tiger mosquitoes that weren't caught were included in the study, as the staff who performed field observations was experienced enough to identify with high accuracy the female that landed onto his body.

## Results

A total of 61 municipalities from the southwestern part of Slovenia were included in the study of 2007. After the discovery of this invasive species in Ljubljana, its presence was verified additionally in Postojna, Laze and Vrhnika. Altogether 327 larval habitats were examined, among which 256 were checked for mosquito larvae once, 55 were checked twice and 15 three times. One larval habitat stands for one container with mosquito larvae. In 2010, the study was done in 12 municipalities, where 101 larval habitats were examined. Only 18 larval habitats were the same as in the 2007 study, as almost all of the old habitats were removed or didn't contain water anymore. From 101 larval habitats, 87 were checked once, 12 twice and one three times.

In 2007, a total of 53 larval habitats were positive for *Aedes albopictus*, whereas in 2010 11 were positive for *Ae. albopictus* (Tabs. 1-2). Larvae of *Ae. albopictus* were most often found in barrels, vessels, vases and old tires, placed in shady areas. A typical habitat is shown on Figure 1. Asian tiger mosquito's larvae were also found in an old bathtub, a basin, a watering can, a flower pot, a discarded toy and a collecting duct. The most interesting finding of *Ae. albopictus* was in a discarded mosquito repellent candle, where rainwater had accumulated.

Among five vulcanizing companies in the area (Ajdovščina, Ilirska Bistrica, Portorož, Kozina, Postojna,), only tires in Portorož were positive for *Ae. albopictus* larvae.

From all the collected mosquito larvae, only fourth instar larvae were mounted and identified. Among 242 mosquito larvae, three other mosquito species, apart from *Ae. albopictus,* were registered: *Culiseta longiareolata*, *Culex pipiens* and *Culex hortensis.*

**Table 1.** The number of negative larval habitats for *Ae. albopictus*, positive larval habitats with the number of *Ae. albopictus* larvae in brackets, and the number of caught and observed adults of *Ae. albopictus* per municipality in 2007. Municipalities where no *Ae. albopictus* was detected are written in bold.

**Tabela 1.** Število negativnih habitatov ličink za tigrastega komarja, število pozitivnih habitatov s številom ujetih ličink v oklepaju ter število ujetih in opaženih odraslih osebkov vrste *Ae. albopictus* v letu 2007. Naselja, kjer vrsta *Ae. albopictus* ni bila zabeležena, so napisana s krepko pisavo.

| MUNICIPALITY | LARVAE | | ADULTS |
|---|---|---|---|
| | Negative larval habitats | Positive larval habitats (Number of caught larvae) | Caught specimens (observed specimens) |
| Ajdovščina | 12 | 1 (1) | 1 (0) |
| Ankaran | 3 | 0 (0) | 8 (0) |
| Branik | 1 | 3 (9) | 0 (1) |
| Dekani | 3 | 1 (15) | 2 (0) |
| **Divača** | 10 | 0 (0) | 0 (0) |
| Dobrava | 2 | 2 (26) | 2 (0) |
| Dragonja | 3 | 0 (0) | 0 (3) |
| **Dutovlje** | 7 | 0 (0) | 0 (0) |
| Fiesa | 0 | 1 (1) | 0 (0) |
| Gažon | 3 | 1 (2) | 0 (4) |
| Hrastovlje | 0 | 1 (1) | 1 (0) |
| Hrvatini | 2 | 0 (0) | 1 (0) |
| **Ilirska Bistrica** | 12 | 0 (0) | 0 (0) |
| Izola | 1 | 0 (0) | 3 (0) |
| Jagodje | 3 | 4 (22) | 1 (0) |
| Komen | 7 | 0 (0) | 1 (0) |
| Koper | 3 | 3 (15) | 4 (3) |
| Korte | 2 | 1 (2) | 0 (4) |
| Kostanjevica na Krasu | 8 | 1 (1) | 1 (0) |
| Koštabona | 5 | 2 (4) | 1 (1) |
| Kozana | 1 | 0 (0) | 2 (0) |
| Kozina | 11 | 1 (2) | 1 (0) |
| Kubed | 10 | 0 (0) | 1 (0) |
| Laze | 6 | 1 (1) | 0 (0) |
| Ljubljana | 1 | 0 (0) | 1 (0) |
| **Lokev** | 6 | 0 (0) | 0 (0) |
| Lucija | 2 | 2 (9) | 4 (0) |
| Marezige | 4 | 2 (2) | 1 (0) |
| **Markovščina** | 8 | 0 (0) | 0 (0) |
| Movraž | 4 | 1 (2) | 0 (0) |
| Nova Gorica | 1 | 1 (1) | 0 (2) |
| Ozeljan | 2 | 1 (1) | 1 (0) |
| Parecag | 2 | 1 (2) | 3 (0) |
| Piran | 2 | 3 (3) | 1 (0) |
| **Pivka** | 8 | 0 (0) | 0 (0) |
| Pobegi | 2 | 0 (0) | 2 (0) |
| **Podgorje** | 15 | 0 (0) | 0 (0) |
| **Podgrad** | 9 | 0 (0) | 0 (0) |
| Pomjan | 2 | 1 (4) | 1 (0) |
| Portorož | 2 | 3 (18) | 27 (0) |
| **Postojna** | 8 | 0 (0) | 0 (0) |
| Prade | 3 | 1 (3) | 0 (1) |

| MUNICIPALITY | LARVAE | | ADULTS |
|---|---|---|---|
| | Negative larval habitats | Positive larval habitats (Number of caught larvae) | Caught specimens (observed specimens) |
| **Pregarje** | 5 | 0 (0) | 0 (0) |
| Prvačina | 3 | 0 (0) | 2 (3) |
| Rožna Dolina | 0 | 2 (4) | 2 (2) |
| Seča | 3 | 2 (7) | 0 (1) |
| Sečovlje | 1 | 1 (2) | 0 (1) |
| Selo | 10 | 1 (1) | 1 (0) |
| **Senožeče** | 7 | 0 (0) | 0 (0) |
| Sežana | 13 | 0 (0) | 1 (0) |
| Sp. Škofije | 1 | 1 (2) | 2 (0) |
| Strunjan | 2 | 2 (3) | 1 (0) |
| Sv. Anton | 3 | 0 (0) | 1 (0) |
| Sv. Peter | 1 | 1 (2) | 2 (0) |
| Šalara | 2 | 0 (0) | 2 (0) |
| Šared | 1 | 1 (1) | 3 (0) |
| Šempeter pri Gorici | 1 | 0 (0) | 1 (0) |
| Šmarje | 1 | 0 (0) | 3 (0) |
| Vanganel | 2 | 0 (0) | 1 (0) |
| Vipava | 6 | 1 (1) | 0 (0) |
| Višnjevik | 4 | 0 (0) | 2 (0) |
| **Vrhnika** | 12 | 0 (0) | 0 (0) |
| Vrtojba | 0 | 1 (1) | 3 (0) |
| Žusterna | 1 | 1 (4) | 4 (0) |
| **Total** | **274** | **53 (174)** | **102 (26)** |

**Table 2.** The number of negative larval habitats for *Ae. albopictus*, positive larval habitats with the number of *Ae. albopictus* larvae in brackets, and the number of caught and observed adults of *Ae. albopictus* per municipality in 2010. Municipalities where no *Ae. albopictus* was detected are written in bold.
**Tabela 2.** Število negativnih habitatov ličink za tigrastega komarja, število pozitivnih habitatov s številom ujetih ličink v oklepaju ter število ujetih in opaženih odraslih osebkov vrste *Ae. albopictus* v letu 2010. Naselja, kjer vrsta *Ae. albopictus* ni bila zabeležena, so napisana s krepko pisavo.

| MUNICIPALITY | LARVAE | | ADULTS |
|---|---|---|---|
| | Negative larval habitats | Positive larval habitats (Number of caught larvae) | Caught specimens (observed specimens) |
| Divača | 13 | 2 (16) | 0 (1) |
| Dutovlje | 1 | 1 (6) | 0 (3) |
| Ilirska Bistrica | 8 | 1 (6) | 0 (0) |
| Lokev | 9 | 1 (3) | 0 (0) |
| **Markovščina** | 4 | 0 (0) | 0 (0) |
| **Pivka** | 11 | 0 (0) | 0 (0) |
| Podgorje | 8 | 1 (3) | 0 (0) |
| **Podgrad** | 7 | 0 (0) | 0 (0) |
| Postojna | 11 | 1 (7) | 0 (0) |
| **Pregarje** | 4 | 0 (0) | 0 (0) |
| Senožeče | 7 | 1 (1) | 0 (0) |
| Vrhnika | 7 | 3 (5) | 0 (0) |
| **Total** | **90** | **11 (47)** | **0 (4)** |

**Figure 1.** A typical habitat of *Ae. albopictus* larvae (Foto: Katja Kalan)
**Slika 1.** Habitat, značilen za ličinke *Ae. albopictus* (Foto: Katja Kalan)

All of 102 adults that were caught near the breeding sites in 2007 were *Ae. albopictus*. The highest number of the adults, caught in 15 minutes, was in Portorož (27 individuals) and in Ankaran (8 individuals). The number of the adults at other locations varied from one to three, but most often one mosquito was caught (Tab. 1). No adult mosquitoes were caught in 2010.

In 2007, *Ae. albopictus* was found in 52 of the 64 surveyed municipalities. Maximum three samplings were done per settlement, depending on the occurrence of *Ae. albopictus* during the study. In the first sampling (from 7$^{th}$ July to the first half of the August) *Ae. albopictus* was observed in 37 municipalities, which are mainly located on the coastal area and around Nova Gorica, which is close to Italy. In the second (from the second half of August to the first half of September) and third (from the second half of September to 8$^{th}$ October) samplings, *Ae. albopictus* was caught in 14 municipalities, which are located in the Vipava Valley, in the Karst region and in the surroundings of Koper. Apart from the southwestern part of Slovenia, the Asian tiger mosquito was found in Ljubljana and Laze (Tab. 1, Fig. 2). The northern border of *Ae. albopictus* distribution was determined by the municipalities of Višnjevik, Šempeter pri Gorici, Ajdovščina, Laze and Ljubljana, whereas the eastern border was determined by the municipalities of Kubed, Kozina, Laze and Ljubljana.

The distribution range of *Ae. albopictus* has increased during the last three years, as in 2010 it was found in 8 of 12 municipalities that had been negative in 2007. Only four municipalities were still free of *Ae. albopictus*, i.e. Markovščina, Pregarje, Podgrad and Pivka (Fig. 2).

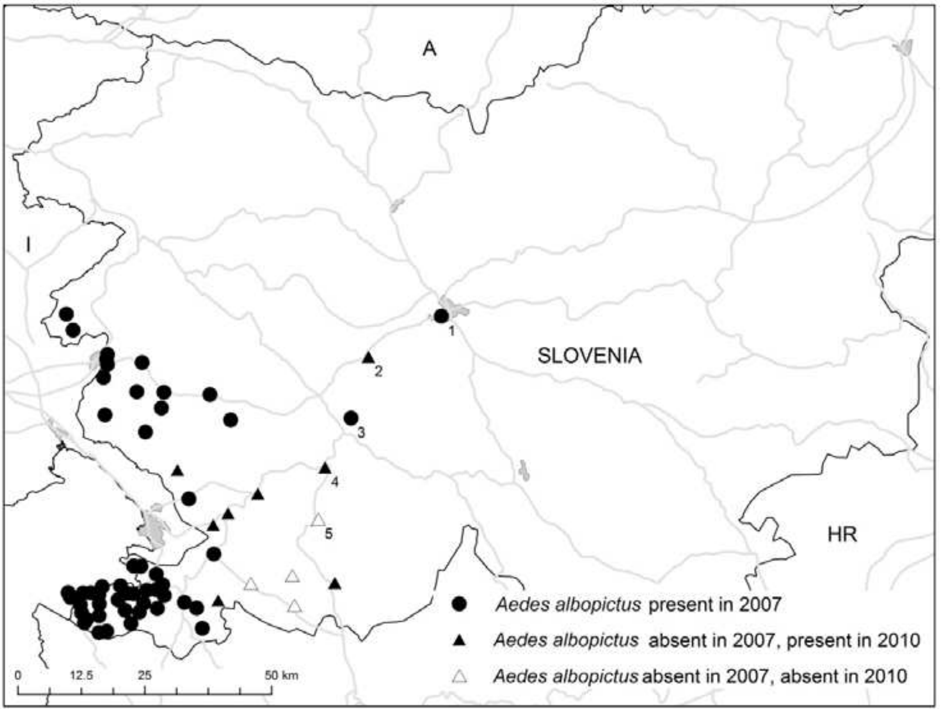


**Figure 2.** The findings of *Ae. albopictus* in the southwestern part of Slovenia in 2007 and 2010. Black spots indicate municipalities that were positive for *Ae. albopictus in 2010,* black triangles show municipalities that were negative for *Ae. albopictus* in 2007 but positive in 2010, while white triangles indicate municipalities that were negative for *Ae. albopictus* in 2007 and 2010. Ljubljana (1), Vrhnika (2), Laze (3), Postojna (4), Pivka (5).

**Slika 2.** Najdbe tigrastega komarja *Ae. albopictus* v jugozahodnem delu Slovenije v letih 2007 in 2010. Črne pike prikazujejo naselja, kjer je bil tigrasti komar zabeležen leta 2007 .Črni trikotniki prikazujejo naselja, kjer tigrastega komarja ni bilo leta 2007, a je bil zabeležen leta 2010. Beli trikotniki ponazarjajo naselja, kjer tigrastega komarja nismo našli ne leta 2007 ne leta 2010. Ljubljana (1), Vrhnika (2), Laze (3), Postojna (4), Pivka (5).

## Discussion

The distribution of Asian tiger mosquito in the southwestern part of Slovenia was studied in 2007 and 2010. Larvae of this invasive mosquito species were most often sampled from small containers, placed in shady areas, which is a known species characteristic (Hawley 1988). All of the adults caught by human bait catches were *Ae. albopictus*, which is probably due to the fact that the sampling of the adults was done during daytime when species is active unlike most of other mosquito species (Hawley 1988). From the number of caught specimens in 15 minutes it was not possible to determine mosquito's daily biting activity in the studied area, as the sampling was done randomly, during all day while searching for mosquito larvae. Nevertheless, there were two locations where the number of caught adults was relatively high in comparison to other sites. The location in Portorož was near a depot of old tires and the location in Ankaran was near barrels with water. At both sites, Asian tiger mosquito's larvae were caught as well. These results are only a confirmation that both container types are ideal habitats for Asian tiger mosquito larvae (Hawley 1988). For the comparison of the mosquito's population size between different sites, sampling at a fixed time of the day and in same climatic conditions at all sites should be done.

Our study in 2007 indicated the presence of an established population of Asian tiger mosquito around Nova Gorica and at the coastal part of Slovenia. According to the known distribution paths of *Ae. albopictus* in Southern Europe we assume that the mosquito was brought to this area from Italy by ground transport (ECDC 2009). The spreading of the species to other regions of Slovenia originated from these areas, which is confirmed by the results of the occurrence of the species during the three month's sampling. The first findings were in the area close to Italy, and the mosquito dispersed to other parts during the season. Only one of the five major vulcanizing companies in the studied area was positive for *Ae. albopictus*. Therefore we assume that spreading of the species by ground transport, via highways and regional roads, had a major role in this species spreading.

One of the goals of the study in 2007 was to determine the northern and eastern border of *Ae. albopictus* distribution in Slovenia. After the discovery of *Ae. albopictus* in Ljubljana we knew that this would be hard to achieve. The species was occurring in a much larger part than predicted because of its spreading paths. Therefore we focused on the southwestern part of Slovenia and included three municipalities, i.e. Postojna, Laze and Vrhnika, along the highway to Ljubljana, which was the most likely path of the mosquito spreading in the area (Pluskota 2008). *Ae. albopictus* was found additionally only in Laze. Further study of the species spreading was needed and these municipalities were inspected more accurately in 2010, when presence of Asian tiger mosquito was confirmed in almost all of them.

From 2007 on, the population of *Ae. albopictus* dispersed and the mosquito was present in 2/3 of the studied area in 2010. The absence of mosquito in Markovščina, Podgrad, Pivka and Pregarje is probably due to the absence of introduction or low number of introduced specimens, and to less favorable climatic conditions. It is possible that *Ae. albopictus* had been introduced in the area before but failed to overwinter. Therefore, special stress on the surveillance of the species in this area should be made in further studies. Future studies should include also municipalities like Ilirska Bistrica, Podgorje and Senožeče, where mosquito larvae were caught only in the third sampling in 2010, as well as the sites with only few specimens sampled in 2007. Additionally, all of the country should be included in the monitoring, since the occurrence of *Ae. albopictus* in other parts of Slovenia is unknown, yet possible. Accordingly to the MCDA model, which also includes climate change, almost all of the country will become highly suitable for the establishment of this species, if climate changes are taken into account (ECDC, 2009).

An effective monitoring program of *Ae. albopictus* population is highly needed in Slovenia in order to survey its occurrence in the area and to establish a successful management program. A pilot study is planned for next year in Koper and Nova Gorica. The monitoring will include mosquito sampling with BG-sentinel traps, which have been proven to be very effective in catching *Ae. albopictus* (Meeraus 2008). These traps for adults will be combined with the ovitraps, which have been and still are widely used for the monitoring of *Ae. albopictus*. The monitoring with traps will be expanded throughout Slovenia in subsequent years. Apart from above mentioned pilot study, all of the country will be inspected for *Ae. albopictus* larvae and adults in the next year.

## Povzetek

Tigrasti komar *Aedes albopictus* (Skuse, 1894) je primarno tropska in subtropska vrsta komarjev, v zadnjih tridesetih letih pa se je razširil po vsem svetu. V Evropi je bil prvič zabeležen leta 1979 v Albaniji, v Sloveniji pa leta 2002. Primarno vlogo pri njegovem širjenju ima prenos jajčec s transportom starih gum, sekundarno pa prenos ličink in odraslih osebkov. Najbolj pogosti omejujoči dejavniki, ki vplivajo na njegovo razširjenost, so temperatura, dolžina dneva, vlažnost zraka in količina padavin. Kolonizacijo v zmerno toplem klimatskem pasu mu je med drugim omogočil tudi razvoj dormantnih jajčec, odpornih proti izsuševanju in nizkim temperaturam.

O pojavljanju tigrastega komarja v Sloveniji zaradi pomanjkanja strokovnjakov s tega področja ni bilo veliko znanega. Obstajali so samo časopisni članki, ki so večinoma navajali pojavljanje tigrastega komarja v obalnih mestih. Z raziskovalnim delom smo v letu 2007 želeli ugotoviti pojavnost tigrastega komarja v jugozahodni Sloveniji. S tem smo poskušali ugotoviti najbolj severno in vzhodno mejo razširjenosti tigrastega komarja v državi. V letu 2010 smo ga ponovno iskali v naseljih, v katerih ga leta 2007 nismo našli.

Razširjenost tigrastega komarja *Aedes albopictus* v JZ delu Slovenije smo preučevali od 9.7.2007 do 8.10.2007 in od 21.7.2010 do 30.10.2010 na podlagi pojavljanja ličink ter odraslih osebkov. Ličinke smo vzorčili po različnih habitatih s posodico ali mrežico, odrasle komarje pa smo lovili z metodo človek – aspirator 15 minut. V letu 2007 smo pregledali 64 naselij, od tega 327 različnih lokacij. Leta 2010 smo ponovili vzorčenje v 12 naseljih, v katerih tigrastega komarja nismo ujeli leta 2007. V tem letu smo pregledali 101 habitat ličink.

Leta 2007 smo tigrastega komarja zabeležili v 52 naseljih. Gostota komarja je bila v priobalnem pasu velika, a se je v velikem številu pojavljal tudi v preostalem delu JZ Slovenije, predvsem na Goriškem. Leta 2010 smo tigrastega komarja potrdili v skoraj vseh naseljih, kar kaže na hitro širjenje vrste. Neobstoj vrste v Markovščini, Podgradu, Pivki in Pregarjah pripisujemo več dejavnikom. Njenemu pojavljanju v naštetih naseljih velja v prihodnjih raziskavah nameniti posebno pozornost. Poleg tega je treba v prihodnje raziskave vključiti celotno Slovenijo, saj je pojavljanje te invazivne vrste drugje kot v jugozahodnem delu države zelo slabo poznano.

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Prejeto / Received: 30.10.2010
Sprejeto / Accepted: 5.11.2010

# New records of four-lined snake (*Elaphe quatuorlineata*) in Natura 2000 site Slovenska Istra (SI3000212)

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**Abstract.** The article presents new records of ten specimens (one juvenile, one subadult and eight snake sheddings) of four-lined snake (*Elaphe quatuorlineata*) recorded in a period between May 2002 and March 2011 on seven locations in Natura 2000 site Slovenska Istra (SI3000212). In some locations, the species was observed several times. Data show successful reproduction within the abovementioned Natura 2000 site.

Key words: reptiles, snakes, colubrid snakes, Colubridae, four-lined snake, *Elaphe quatuorlineata*, distribution, reproduction, Natura 2000, Slovenia

**Izvleček. NOVE NAJDBE PROGASTEGA GOŽA (*ELAPHE QUATUORLINEATA*) V OBMOČJU NATURA 2000 SLOVENSKA ISTRA (SI3000212) –** V članku so opisane nove najdbe desetih osebkov (juvenilni in subadultni osebek ter osem kačjih levov) progastega goža (*Elaphe quatuorlineata*) s sedmih lokacij v območju Natura 2000 Slovenska Istra (SI3000212), zabeležene med majem 2002 in marcem 2011. Na nekaterih lokacijah je bila vrsta večkrat opažena. Podatki potrjujejo uspešno razmnoževanje vrste v omenjenem območju Nature 2000.

Ključne besede: plazilci, kače, goži, Colubridae, progasti gož, *Elaphe quatuorlineata*, razširjenost, razmnoževanje, Natura 2000, Slovenija

In Slovenia, the four-lined snake (*Elaphe quatuorlineata*) reaches the northernmost limit of its distribution (Kreiner 2007). Historical finds are known from Robič, Šempeter near Nova Gorica and from the border area with Italy (Tome 1996, Bressi et al. 2004). Records on occurrence of the four-lined snake in the country published in the last 30 years are rare and confined to the Slovenian part of Istria (Škornik 1985, Škornik 1989, Verovnik 1995, Planinc 1997, Bressi et al. 2004, Cafuta 2005, KPSS 2008, Krofel et al. 2009). The species is protected by Decree on protected wild animal species and is considered an endangered species (Rules on the inclusion of endangered plant and animal species in the Red List, 2002). It is also protected by the Bern Convention (Annex II) and the EC Habitats directive (Annexes II and IV). In Slovenia, the only Natura 2000 site that includes four-lined snake is Slovenska Istra (SI3000212).

During the reptile survey in Natura 2000 site Slovenska Istra in a period between May 2002 and March 2011, new finds of the four-lined snake were recorded. Accurate locations are not given due to conservation reasons. Material was identified with identification keys (Tome 1999, Arnold 2002) and by comparing material from snake shedding collection kept by the author of this article. Measurements of the carcass and live animal are given below. In live specimens, errors are possible due to movements.

New records:

- Brič (UTM square VL03). Material: 1 poorly preserved snake shedding of adult found on 14.08.2008, leg. & det. V. Cafuta.
- Koštabona (UTM square VL03). Material: live subadult found on 31.05.2008 (Fig. 1), leg. & det. G. Planinc. Snout-vent length = 88 cm, tail length = 23 cm.
- Labor (UTM square VL03). Material: altogether 3 poorly preserved snake sheddings of adult animals found on 26.08.2006, 18.08.2007 and 24.05.2008; leg. V. Cafuta & G. Planinc, det. V. Cafuta. Due to poorly preserved material, it is not possible to determine whether sheddings belong to one or more individuals. Comment: first find of a well preserved snake shedding in this location dates from 20.07.2004 (Cafuta 2005).
- Puče (UTM square UL93). Material: 1 poorly preserved snake shedding of adult found on 01.04.2007, leg. & det. V. Cafuta.
- Stena near Dragonja (UTM square UL93). Material: 1 poorly preserved snake shedding of adult animal found on 11.05.2002, leg. & det. G. Planinc; 1 snake shedding of juvenile found on 22.07.2010 (Fig. 2), leg. Anonymous, det. A. Dall'Asta & V. Cafuta. Comment: previous finds of adult animals in this location date from 19.03.1983 (T. Trilar, pers. comm.), June 1983 (Škornik 1985) and April 1994 (Verovnik 1995, R. Verovnik, pers. comm.), snake sheddings (not preserved) found on 30.07.1996 (Planinc 1997) and on 05.07.1997 (G. Planinc & T. Brstilo, pers. comm.).
- Sv. Peter (UTM square UL93). Material: Carcass of road-killed juvenile animal found on 07.04.2007 (Fig. 3), leg. & det. G. Planinc & V. Cafuta. Snout-vent length = 28.6 cm, tail length = 6.8 cm.
- Sv. Štefan (UTM square UL93). Material: 1 poorly preserved snake shedding of subadult or adult animal found on 10.03.2011, leg. M. Silan, E. Ostanek & T. Jagar, det. E. Ostanek. Comment: previous find in this location is mentioned in Škornik (1989).

The carcass and snake sheddings are kept by the author of this article. Finds of juvenile (carcass and shedding) and subadult are the first documented proofs of reproduction of the species in Slovenia.

Locations of finds are distributed on the slopes and in the plain of the Dragonja river valley with tributaries. According to the results of the reptile survey in years 2007, 2008 and 2010, conducted by G. Planinc and V. Cafuta (G. Planinc & V. Cafuta, unpublished data), it can be concluded that the four-lined snake is a rare or very elusive snake species in Natura 2000 site Slovenska Istra. However, older and recent data show that the species successfully reproduces within the region and has been observed several times on some locations.

Additional field work should be carried out in the future to acquire detailed knowledge on distribution of the four-lined snake not just in Natura 2000 site Slovenska Istra, but elsewhere as well. Monitoring should be established soon.

**Figure 1.** Subadult four-lined snake (*Elaphe quatuorlineata*) found on 31st May, 2008, near Koštabona, SW Slovenia (photo: Griša Planinc).
**Slika 1.** Subadultni osebek progastega goža (*Elaphe quatuorlineata*), najden 31.05.2008 v okolici Koštabone, JZ Slovenija (foto: Griša Planinc).

**Figure 2.** Shedding of a juvenile four-lined snake (*Elaphe quatuorlineata*) found on 22nd July, 2010, at Stena near Dragonja, SW Slovenia (photo: Vesna Cafuta).
**Slika 2.** Lev juvenilnega osebka progastega goža (*Elaphe quatuorlineata*), najdenega 22.07.2010 v Steni pri Dragonji, JZ Slovenija (foto: Vesna Cafuta).


**Figure 3.** Carcass of a juvenile four-lined snake (*Elaphe quatuorlineata*) found on 7th April, 2007, near Sv. Peter, SW Slovenia (photo: Vesna Cafuta).
**Slika 3.** Kadaver juvenilnega osebka progastega goža (*Elaphe quatuorlineata*), najdenega 07.04.2007 v okolici Sv. Petra, JZ Slovenija (foto: Vesna Cafuta).


# Povzetek

Podatki o pojavljanju progastega goža (*Elaphe quatuorlineata*) v Sloveniji so redki in v zadnjih 30 letih omejeni izključno na območje slovenskega dela Istre. Med majem 2002 in marcem 2011 je bilo med popisom plazilcev v območju Natura 2000 Slovenska Istra na sedmih lokacijah zabeleženih deset najdb progastega goža (juvenilni in subadultni osebek ter osem kačjih levov). Natančne lokacije niso podane zaradi naravovarstvenih razlogov. Na Briču je bil najden en kačji lev dne 14.08.2008, v Koštaboni en subadultni osebek dne 31.05.2008 (dolžina telesa brez repa je znašala 88 cm, dolžina repa 23 cm), v Laborju trije kačji levi dne 26.08.2006, 18.08.2007 in 24.05.2008, v Pučah en kačji lev dne 01.04.2007, v Steni pri Dragonji kačji lev odraslega osebka dne 11.05.2002 in lev juvenilnega osebka 22.07.2010, v Sv. Petru povožen juvenilni osebek dne 07.04.2007 (dolžina telesa brez repa je znašala 28,6 cm, dolžina repa 6,8 cm) ter pri Sv. Štefanu en kačji lev dne 10.03.2011. Najdbe juvenilnih in subadultnih osebkov so prvi dokumentirani dokaz uspešnega razmnoževanja vrste v Sloveniji. Lokacije najdb so v dolini reke Dragonje s pritoki ter na pobočjih, ki se vzpenjajo nad dolino. Vrsta je v omenjenem območju Nature 2000 redka oziroma zelo težko zaznavna in se uspešno razmnožuje. Z nekaterih lokacij so znana redna opažanja vrste. Najdeni kačji levi ter kadaver so v hrambi pri avtorici tega članka.

## Acknowledgements

I would like to thank Griša Planinc, Mirko Silan, Erika Ostanek, Tomaž Jagar, Tanja Brstilo and Dr Tomi Trilar for permitting me to publish their data. I am also grateful to Tomaž Jagar and Erika Ostanek for donating the shedding of a juvenile from Stena to the snake shedding collection and to Andrea Dall'Asta for his immense help with identifying this particular shedding.

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# Najdba vrste *Bythinella austriaca* (Gastropoda: Hydrobiidae) na Goričkem (severovzhodna Slovenija)

RECORD OF BYTHINELLA AUSTRIACA (GASTROPODA: HYDROBIIDAE) AT GORIČKO (NORTH-EASTERN SLOVENIA)

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Hydrobiidae constitute one of the largest freshwater snail families in Slovenia. Many species are subterranean, many are endemic (Velkovrh 2003). Till now the distribution of Hydrobiid taxa in Slovenia has showed that they are absent only from its north-eastern part (Fig. 1). Vaupotič and Velkovrh (1997) reported only about a remainder of a shell from this part of Slovenia, which could not be precisely determined. They presume that the reason for a lack of Hydrobiidae snails in this region is in relation with the absence of limestone. Representatives of Hydrobiidae are mostly calciphiles.

The second reason seems to be that this area is too poorly malacologically researched. This can be seen in the accidental finding of Hydrobiidae at the time of the terrestrial snail sampling. During the inventarization of *Vertigo angustior* at Goričko (Vaupotič 2006), empty Hydrobiidae shells were found in two of the samples (a meadow near the Črnec stream, Krašči, Zg. Črnci, WM77 and a riverine forest along the Ledava river, Sv. Jurij, WM78). Both localities spread in the river basin of Ledava. In each sample, only one shell belonging to Hydrobiidae was found. According to the conchological signs (Bole 1969, Glöer 2002), it seems that the specimens belong to *Bythinella austriaca* (Frauenfeld 1859). Dr. Rajko Slapnik shares the same opinion. The zoogeographical distribution of this species is East Alpine and Carpathian.

It goes without saying that we must proceed with further intensive investigation of the distribution of Hydrobiidae snails in north-eastern Slovenia. Further research should be focused on finding living animals, given that such findings enable a more precise determination.

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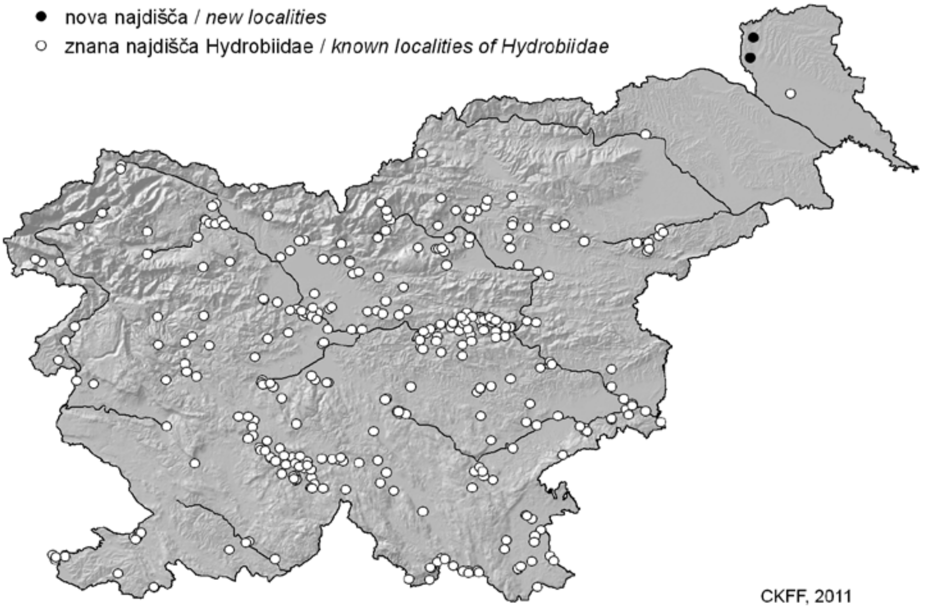


**Slika 1.** Razširjenost hidrobid v Sloveniji.
**Figure 1.** Distribution of Hydrobiidae in Slovenia.

# First record of a melanistic Dalmatian Algyroides (*Algyroides nigropunctatus*) in Slovenia

## PRVA NAJDBA MELANISTIČNE ČRNOPIKČASTE KUŠČARICE (*ALGYROIDES NIGROPUNCTATUS*) V SLOVENIJI

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Dalmatian Algyroides (*Algyroides nigropunctatus* Duméril & Bibron, 1839) is a small lacertid lizard with snout-vent length between 45-70 mm (Arnold et al. 2007). Its distribution is restricted to Southern Europe (Gasc et al. 1996). The commonest colouration of Dalmatian Algyroides is the adult individuals' uniform dark brown or greyish dorsal side with occasionally present small dark markings on the head and back. The body's ventral side is usually yellowish or orange, throat is coloured blue. Juvenile and sub adult specimens have whitish underside, which can occasionally be slightly blue or green (Corti & Lo Cascio 2002, Arnold & Ovenden 2002).

An unusually coloured specimen of Dalmatian Algyroides (*Algyroides nigropunctatus*) (Figs. 1-2) was observed on March 10th 2011 at the stone cliffs near Dragonja village in the coastal part of Slovenia. In this dry, shrubby habitat we also found several normally coloured specimens of the same species and several other sympatric lizard species, like the common wall lizard (*Podarcis muralis*), Italian wall lizard (*Podarcis siculus*) and green lizard (*Lacerta viridis/bilineata*).

The specimen observed had been determined to be a sub adult due to its size. It had a completely black dorsal side without any pattern (Fig. 1). The underside was also dark coloured; throat colour was dark blue with slightly orange sides (Fig. 2). Ventral side of body and tail was greyish blue and slightly yellowish on the sides of the body. This kind of colouration is characteristic for a melanistic mutation with very high levels of melanin (dark skin pigment), which is very rare among lizards, since dark animals are more prone to predation due to the lack of camouflage. This is the first record of a melanistic Dalmatian Algyroides in Slovenia.

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**Figure 1.** Photograph of the dorsal side of a melanistic individual of Dalmatian Algyroides (*Algyroides nigropunctatus*), found near Dragonja, SW Slovenia (photo Erika Ostanek)
**Slika 1.** Fotografija hrbtne strani melanističnega osebka črnopikčaste kuščarice (*Algyroides nigropunctatus*), najdenega v bližini Dragonje, JZ Slovenija (foto Erika Ostanek)

**Figure 2.** Photograph of the ventral side of amelanistic individual of Dalmatian Algyroides (*Algyroides nigropunctatus*), found near Dragonja, SW Slovenia (photo Erika Ostanek)
**Slika 2.** Fotografija trebušne strani melanističnega osebka črnopikčaste kuščarice (*Algyroides nigropunctatus*), najdenega v bližini Dragonje, JZ Slovenija (foto Erika Ostanek)

# First record of a larger hibernaculum of the Soprano pipistrelles *Pipistrellus pygmaeus* (Leach, 1825) in Slovenia

## PRVA NAJDBA VEČJEGA PREZIMOVALIŠČA DROBNIH NETOPIRJEV *PIPISTRELLUS PYGMAEUS* (LEACH, 1825) V SLOVENIJI

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In December 2009, the Slovenian Association for Bat Research and Conservation received a call about bats hiding in an unused ventilation duct of the family house in the village of Crngrob near Škofja Loka in NW Slovenia (exact address: Crngrob 13, coordinates from Atlas okolja ARSO: GKY:446824, GKX:117232). More than 10 bats were flying around the house. On 24th December 2009, we checked which bats were roosting there (the highest daily air temperature: 10.8°C, Košir 2011). We found a dense cluster of numerous hibernating Pipistrelle bats (*Pipistrellus sp.*). We removed one female and identified it as Soprano pipistrelle (*Pipistrellus pygmaeus,* AB=30.2 mm). A week later, on 30th December, we checked the roost once more (the highest daily air temperature: 9.6°C, Košir 2011). On this occasion, we were able to count 62 individuals, but we estimated their number to be higher (probably about 100 animals), due to individuals hiding behind the visible ones. We measured 4 females (female1: AB=30.6 mm D5=39.4 mm; female2: AB=31.8 mm D5=42.1 mm; female3: AB=31.3 mm D5=39.0 mm; female4: AB= 31.4 mm D5=40.4mm) and 2 males (male1: AB=30.2 mm D5=38.2 mm; male2: AB=29.1 mm D5=37.9 mm) and determined (according to Dietz et al. 2007) all of them as Soprano pipistrelles. Despite that it could be possible that the colony contained also individuals of Common pipistrelle (*Pipistrellus pipistrellus*), as Kaňuch et al. (2010) report about hibernation colony of Common pipistrelle mixed with few individuals of Soprano pipistrelles.

The Soprano pipistrelle is a generally distributed species in Slovenia (Presetnik et al. 2001, 2009). Most data were collected with the use of ultrasound detectors, but also with mistneting and through accidental findings. The findings of species roosts are very rare. Our finding of hibernation roost of Soprano pipistrelles at Crngorb confirms that the species has group hibernacula in Slovenia.

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**Slika 1.** Gruča prezimujočih malih netopirjev, verjetno večinoma drobnih netopirjev (*Pipistrellus pygmaeus*), v zračniku hiše v Crngrobu pri Škofji Loki v SZ Sloveniji.

**Figure 1.** The cluster of hibernating pipistrelles, probably mostly Soprano pipistrelles (*Pipistrellus pygmaeus*), in a ventilation duct of the family house at Crngrob near Škofja Loka in NW Slovenia.

# First record of Savi's pipistrelle *Hypsugo savii* (Bonaparte, 1837) in NW Slovenia

PRVA NAJDBA SAVIJEVEGA NETOPIRJA *HYPSUGO SAVII* (BONAPARTE, 1837) V SEVEROZAHODNI SLOVENIJI

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On 3rd November 2010, Mrs Lidija Mohorič, a teacher, informed SDPVN (Slovenian Association for Bat Research and Conservation) that her school children found an exhausted bat. The individual, a male Savi's pipistrelle (*Hypsugo savii*) (Fig. 1), was taken care of in captivity (fed with mealworms), but did not recover and died ten days later. The antebrachium (AB) of the bat, which weighed 4.5 g, measured 33.8 mm. Its carcass is temporarily stored in the author's private collection and will be later handed over to the Slovenian Museum of Natural History. Savi's pipistrelle was found in the centre of Kranj, lying in the street between block of flats (lat. 46°14'6, 34", lon. 14°21'34, 02"). The city has a population of 54.200 inhabitants (Statistical Office of the Republic of Slovenia, 2008). It is located approximately 20 km northwest of the capital Ljubljana and is part of the Ljubljana basin. Kranj is bordered by the Kamniško – Savinjske Alps to the north and the Julian Alps to the west. The region has subalpine climate. The annual precipitations are approximately 1500-1600 mm and the average yearly temperature is 8-10°C (ARSO 2006).

This is the first record of Savi's pipistrelle in northwestern Slovenia. Next closest records are app. 16 km towards southeast from Ljubljana and its surroundings (CKFF 2010). In Slovenia, this species is mostly known from the Submediterranean region (Žibrat 2009), but was recently also found in central and eastern Slovenia (CKFF 2010). This is not surprising, as this originally Mediterranean species has greatly expanded its distributional range towards the north in the last few decades. Breeding colonies are concentrated in lowlands of eastern, northeastern and central Europe. Most mating and hibernation sites are located in western and southern Europe, although some individuals have been found as far as England, Scotland, Jersey and northern Germany (Dietz et al. 2007, Reiter et al. 2010). It is possible that the bat was found during its autumn migration. This finding confirms that this species' range has expanded and that further records can be expected in northern parts of Slovenia.

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**Figure 1.** Savi's pipistrelle (*Hypsugo savii*) found on 3rd November 2010 in Kranj, northwestern Slovenia (photo: Lea Likozar).

**Slika 1.** Savijev netopir (*Hypsugo savii*), najden 3.11. 2010 v Kranju (foto: Lea Likozar).

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**Znanstveni članek** je celovit opis izvirne raziskave in vključuje teoretično ozadje tematike, območje raziskav in metode uporabljene pri delu, podrobno predstavljene rezultate in diskusijo, sklepe ter pregled literature. Dolžina naj ne presega 20 strani.

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## FORMAT IN OBLIKA PRISPEVKA

Prispevki naj bodo napisani v programu Word for Windows, v pisavi "Times New Roman CE 12", z levo poravnavo in 3 cm robovi na A4 formatu. Med vrsticami naj bo dvojni razmak, med odstavki pa prazna vrstica. Naslov prispevka in naslovi posameznih poglavij naj bodo natisnjeni krepko v velikosti pisave 14. Latinska imena rodov in vrst morajo biti pisana ležeče. Uredniku je potrebno prispevek oddati v primerni elektronski obliki (disketa, CD, elektronska pošta) v Rich text (.rtf) ali Word document (.doc) formatu.

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Izvleček v slovenskem jeziku mora na kratko predstaviti namen, metode, rezultate in zaključke. Dolžina izvlečka naj ne presega 200 besed za znanstveni članek oziroma 100 besed za kratko znanstveno vest. Pod izvlečkom naj bodo ključne besede, ki predstavljajo področje raziskave. Njihovo število naj ne bo večje od 10. Sledi abstract in key words v angleškem jeziku, za katere velja enako kot za izvleček in ključne besede.

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Navajanje literature v besedilu mora biti na ustreznem mestu. Kadar citiramo enega avtorja, pišemo Schultz (1987) ali (Schultz 1987), če sta avtorja dva (Parry & Brown 1959) in če je avtorjev več (Lubin et al. 1978). Kadar navajamo citat večih del hkrati, pišemo (Ward 1991, Pace 1992, Amman 1998). V primeru, ko citiramo več del istega avtorja objavljenih v istem letu, posamezno delo označimo s črkami (Lucas 1988a, b). Literatura naj bo urejena po abecednem redu.

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Parry D.A., Brown R.H.J. (1959): The hydraulic mechanysm of the spider leg. J. exp. Biol. 36: 654-657.

Lubin Y.D., Eberhard W.G., Montgomery G.G. (1978): Webs of Miagrammopes (Araneae: Araneaidae) in the neotropics. Psyche 85: 1-13.

Lucas S. (1988a): Spiders in Brasil. Toxicon 26: 759-766.

Lucas S. (1988b): Spiders and their silks. Discovery 25: 1-4.

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Nentwig W., Heimer S. (1987): Ecological aspects of spider webs. In: Nentwig W. (Ed.), Ecophysiology of Spiders. Springer Verlag, Berlin, 211 pp.

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All papers will be subject to peer review by one referee. Authors are invited to suggest the names of referees, although the editor reserves the right to elect an alternative referee to those suggested. The reviewed paper should be corrected by author or authors themselves. In the case of the rejection, the original materials will be sent back to the corresponding author with the editors explanation.

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Lucas S. (1988a): Spiders in Brasil. Toxicon 26: 759-766.
Lucas S. (1988b): Spiders and their silks. Discovery 25: 1-4.

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Foelix R.F. (1996): Biology of spiders, 2. edition. Harvard University Press, London, pp. 155-162.
Nentwig W., Heimer S. (1987): Ecological aspects of spider webs. In: Nentwig W. (Ed.), Ecophysiology of Spiders. Springer Verlag, Berlin, 211 pp.
Edmonds D.T. (1997): The contribution of atmospheric water vapour to the formation of a spider's capture web. In: Heimer S. (Ed.), Proceedings of the 17th European Colloquium of Arachnology. Oxford Press, London, pp. 35-46.