

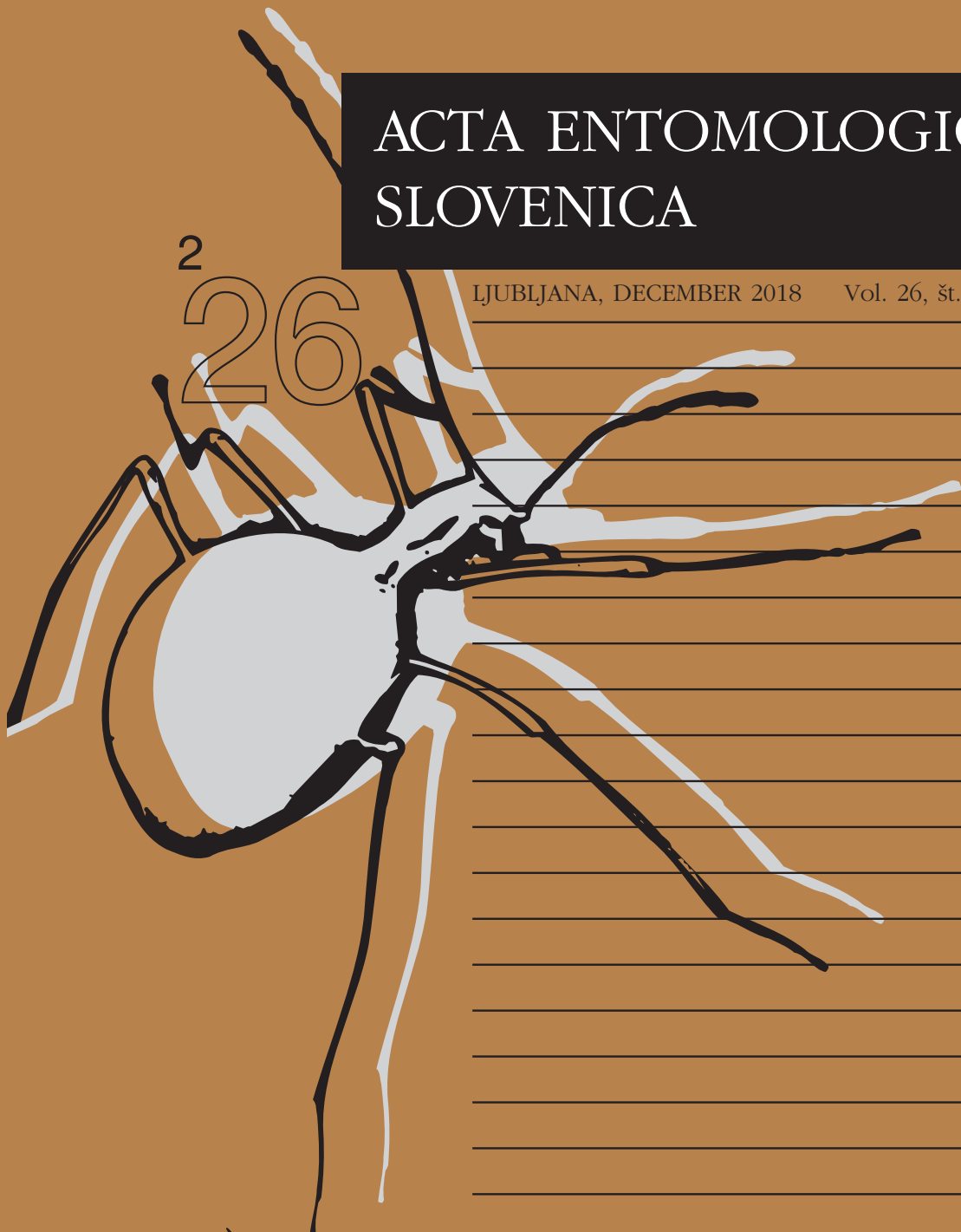
ACTA ENTOMOLOGICA SLOVENICA

2

26

LJUBLJANA, DECEMBER 2018

Vol. 26, št./No. 2



PRIRODOSLOVNI MUZEJ SLOVENIJE
SLOVENSKO ENTOMOLOŠKO DRUŠTVO
ŠTEFANA MICHIELIJA

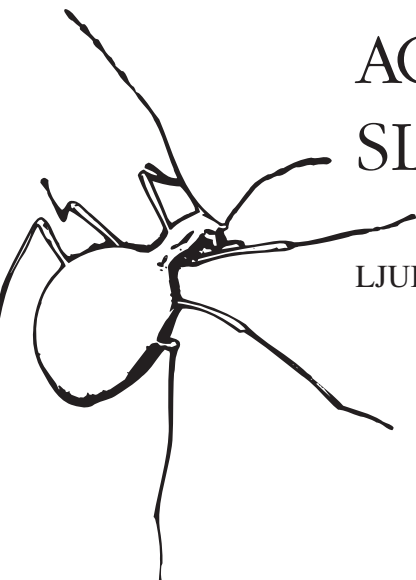
ISSN 1318-1998

CODEN: AESLFM

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ACTA ENTOMOLOGICA SLOVENICA

Revija Slovenskega entomološkega društva Štefana Michielija
in Prirodoslovnega muzeja Slovenije
Izhaja dvakrat letno / Issued twice a year

ISSN 1318-1998
CODEN: AESLFM
UDC (UDK) 595.7(051)

© Acta entomologica slovenica

Izdajatelja / Publishers

Slovensko entomološko društvo
Štefana Michielija
Biološko središče –
Nacionalni inštitut za biologijo
Večna pot 111, SI-1000 Ljubljana

Prirodoslovni muzej Slovenije
Prešernova 20, p.p. 290
SI-1001 Ljubljana

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letnik/Vol. 26, št./No. 2, 2018
Tisk / Printed by: Trajanus, d.o.o., Kranj
Ljubljana, december 2018

<http://www.pms-lj.si/si/o-nas/arhiv-publikacij/acta-entomologica-slovenica>

Povzeto v / To be abstracted in: The Zoological Record, CAB Abstracts

Revijo dobivajo člani Slovenskega entomološkega društva Štefana Michielija
(članarina 20 EUR)

Cena posamezne številke je 8,50 EUR

Zamenjava je zaželjena / Exchanges appreciated

Publikacija je natisnjena s pomočjo Javne agencije za raziskovalno dejavnost R Slovenije.
Uredniško delo podpira Ministrstvo za kulturo R Slovenije.

Številka posvečena 80-letnici akademika prof. dr. Matije Gogala in 50-letnici smrti prof. dr. Štefana Michielija
Issue Dedicated to Academician Prof. Dr. Matija Gogala on the Occasion of His 80th Birthday and 50th Anniversary of the Death of Prof. Dr. Štefan Michieli

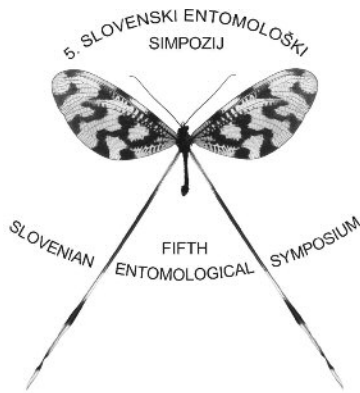
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**5. SLOVENSKI ENTOMOLOŠKI SIMPOZIJ
Z MEDNARODNO UDELEŽBO**
**posvečen 80-letnici akademika prof. dr. Matije Gogala
in 50-letnici smrti prof. dr. Štefana Michielija**
21. in 22. september 2018, Maribor

Na Fakulteti za naravoslovje in matematiko Univerze v Mariboru je 21. in 22. septembra potekal 5. slovenski entomološki simpozij z mednarodno udeležbo. Simpozij so s pomočjo Slovenskega entomološkega društva Štefana Michielija, Fakultete za naravoslovje in matematiko, Oddelka za biologijo FNM ter Inštituta za biologijo, ekologijo in varstvo narave FNM, organizirali zoologi Oddelka za biologijo FNM UM. Tokrat je simpozij imel svečano noto, saj je bil posvečen 80-letnici akademika prof. dr. Matije Gogala in 50-letnici smrti prof. dr. Štefana Michielija. Simpozija se je udeležilo 50 udeležencev, od tega večje število tujih udeležencev iz Avstrije, Bosne in Hercegovine, Hrvaške, Francije, Kosova, Madžarske, Makedonije, Slovenije, Rusije in Združenega kraljestva. Na prvi dan simpozija je udeležence pozdravil dekan Fakultete za naravoslovje in matematiko izr. prof. dr. Mitja Slavinec. Uvodni pozdrav udeležencem sta tudi namenila v imenu organizatorjev prof. dr. Dušan Devetak in Urška Ratajč, mag. ekol. biod., predsednica Slovenskega entomološkega društva Štefana Michielija.

Uvodno predavanje prvega dneva simpozija je pripadalo akademiku prof. dr. Matiji Gogala, ki je govoril o življenju in delu slovenskega entomologa in fiziologa Štefana Michielija, nato je dr. Tomi Trilar predstavil življenjsko delo slavljence, akademika prof. dr. Matije Gogala, velike osebnosti na področju fiziologije živali in entomologije. Sledila so predavanja oz. predstavitve z različnih področij entomologije, od fiziologije, etologije, sistematike, evolucije, favnistike, ekologije, uporabne entomologije, varstva narave do zgodovine entomologije. Udeleženci so prisluhnili kar 33 predavanjem in si ogledali 12 posterjev. Uradna jezika simpozija sta bila slovenski



Sl.1: Udeleženci 5. slovenskega entomološkega simpozija z mednarodno udeležbo, Maribor, 21. in 22. september 2018.

Fig. 1: Participants of the Fifth Slovenian Entomological Symposium with International Attendance

in angleški jezik. V knjigi povzetkov, ki je dostopna na spletni strani simpozija (<http://5ses.fnm.um.si/>), so zbrani vsi prispevki udeležencev.

Ob zaključku simpozija se je za organizacijo še enega uspešnega simpozija zahvalila predsednica Slovenskega entomološkega društva Štefana Michielija, Urška Rataje, ki je tudi naznanila, da bo naslednji simpozij čez tri leta na Univerzi na Primorskem.

**FIFTH SLOVENIAN ENTOMOLOGICAL SYMPOSIUM
WITH INTERNATIONAL ATTENDANCE
Dedicated to Academician Prof. Dr. Matija Gogala
on the Occasion of His 80th Birthday
and 50th Anniversary of the Death of Prof. Dr. Štefan Michieli
Maribor, 21st and 22nd September 2018**

On 21st and 22nd of September 2018, the Fifth Slovenian Entomological Symposium with International Attendance was held at the Faculty of Natural Sciences and Mathematics, University of Maribor. With help of the Slovenian Entomological Society of Štefan Michieli, Faculty of Natural Sciences and Mathematics, University

of Maribor, Department of Biology FNM and the Institute for Biology, Ecology and Nature Conservation FNM, the Symposium was organized by zoologists from the Department of Biology of the hosting faculty.

The Symposium was dedicated to Academician Prof. Dr. Matija Gogala on the occasion of his 80th Birthday and 50th anniversary of the death of Prof. Dr. Štefan Michieli. The Symposium brought together 50 participants from Slovenia and other countries (Austria, Bosnia and Hercegovina, Croatia, France, Kosovo, Hungary, Macedonia, Russia and United Kingdom).



Sl. 2 : Akademik prof. dr. Matija Gogala med predavanjem.

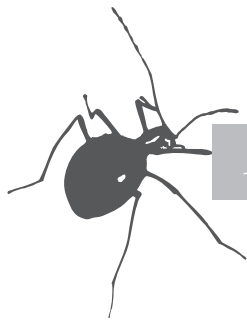
Fig. 2: Academician Prof. Dr. Matija Gogala presenting a lecture.

On the first day the participants were welcomed by Mitja Slavinec, Dean of the hosting faculty, Prof. Dr. Dušan Devetak, a member of organizing committee and Urška Ratajc MSc., the President of Slovenian Entomological Society Štefan Michieli.

First lecture was given by Prof. Dr. Matija Gogala, who dedicated his presentation to the work and life of an important Slovenian entomologist and physiologist, Štefan Michieli. Afterwards, Dr. Tomi Trilar presented Academician Prof. Dr. Matija Gogala, a major figure in the fields of animal physiology and entomology. In two days of the Symposium thirty-three lectures and twelve posters were presented which interfered with the content of the different areas of entomology such as physiology, ethology, systematics, evolution, faunistics, ecology, applied entomology, nature conservation and history of entomology. The official languages of the Symposium were Slovenian and English.

At the end of the Symposium, the President of the Entomological Society Štefan Michieli Urška Ratajc expressed her appreciation for the organization of the successful meeting and she announced that the next symposium will take place in three years at the University of Primorska.

Vesna Klokočovnik in Jan Podlesnik



**SPOMINSKI UTRINKI IZ SKUPNE ENTOMOLOŠKE MLADOSTI
Z AKADEMIKOM PROFESORJEM DR. MATIJEM GOGALO**

Boštjan KIAUTA

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**Abstract – MEMORY SPARKLETS OF THE MUTUAL ENTOMOLOGICAL
YOUTH WITH ACADEMICIAN PROFESSOR DR MATIJA GOGALA**

Styled as a personal letter to M.G., some recollections from 1943 to present are provided. The origins and development of his work in the field of heteropteran and homopteran faunistics, behaviour, bioacoustics and systematics are emphasized. His achievements in photoreception research in Orthoptera and Neuroptera and his novel ideas on computer applications in bioacoustics and biodiversity studies are briefly mentioned. An outline of M.G.'s professional career and bibliographic references are omitted.

KEY WORDS: Matija Gogala, Heteroptera, Homoptera, biology, bioacoustics, systematics

Izvleček – V slogu osebnega pisma, naslovljenega na M.G., je nanizanih nekaj spominov iz obdobja od 1943 do danes. Osvetljeni so prvi začetki in razvoj njegovega dela na področju favnistike, etologije, biologije, bioakustike in sistematike stenic (Heteroptera) in škržadov (Homoptera). Raziskave fotorepcije nekaterih žuželk (Orthoptera, Neuroptera) in njegovi nasveti o uporabi računalniške tehnologije v bioakustiki in v raziskavah biodiverzitete so bežno omenjeni. Oris poklicne poti M.G. in bibliografske reference so izpuščeni.

KLJUČNE BESEDE: Matija Gogala, Heteroptera, Homoptera, biologija, bioakustika, sistematika

Dragi Matjaž,

čeprav sva bila rojena v istem letu (1937), sem domala 11 mesecev starejši od Tebe. Rojenice so Ti položile v zibelko tri velike ljubezni: do žive narave, do fotografiranja in kreativnega razumevanja raziskovalne, predvsem bioakustične aparature in računalnika in do glasbe. Na prvem od teh področij sva si podobna, na ostalih pa me močno nadkriljuješ.

Pred časom si me povabil k "igralskemu" sodelovanju v uvodnem prizoru TV filma o Tvojem življenju in delu. Scena, ki sva jo igrala, je prikazala zgodovinski dogodek iz leta 1952: Tvojo življensko odločitev za delo na področju hemipterologije (in podobno mojo v odonatologiji), ki se je rodila ob prelistavanju Kosovega vodnika po zooloških zbirkah takratnega Narodnega muzeja, v mojem majhnem kabinetu na Gosposvetski cesti 4 v Ljubljani. Tisti čas sva imela za seboj že domala desetletje prijateljavanja in intenzivnega biološkega sodelovanja, vse od šolskega leta 1943/1944, ko sva se srečala kot sošolca v prvem razredu osnovne šole "Vadnica", na Resljevi cesti v Ljubljani in odkrila najino skupno zanimanje za biologijo, predvsem entomologijo. Film pa tako daleč v zgodovino ni posegel.

Med vojno, pod Italijo, smo postali šoloobvezni z dopolnjenim šestim letom starosti. Ob začetku šolskega leta 1943/1944 Ti je manjkalo do predpisane starosti še nekaj mesecev in Tvoja mama je večkrat izrazila moji mami svoje veselje, da so Te kljub temu sprejeli. Sicer pa sva bila oba med najmlajšimi v razredu. Bil si bolj majhne postave in si sedel v prvi klopi, gledano iz katedra: na skrajni desni strani. Mene pa so posadili v predzadnjo klop. Drugače od večine sošolcev, sva bila oba v šoli precej mirna, med odmori sva se dosti pogovarjala in morda prav zato hitro odkrila najino skupno ljubezen do žuželk. Od takrat dalje so tekli najini pogovori skoro izključno o le-teh. Tako tudi po pouku, ko sem Te pogosto spremljal do Tvojega doma na Šentpeterski (sadaj Trubarjevi) ulici, le nakaj minut hoda od šole. Pred hišo sva vedno še dolgo kramljala, nakar si stopil na šolsko torbo, da si dosegel do hišnega zvonca in telefona.

Najini pokojni materi sta bili globoko verni in smo ob nedeljah redno zahajali k šolski maši, ob osmih zjutraj, k frančiškanom. Midva sva jo vedno pobrisala skozi zakristijo in samostan na kor: toliko, da sva slišala pridigo patra Romana Tominca – za primer, da bi bilo doma govora o njeni vsebini. Sicer sva pa tudi na koru, med mašo, intenzivno razpravljala o hroščih, metuljih in o početju pupkov in pezdirkov v Tvojem akvariju. Če se prav spominjam, si imel tudi zeta, ki ga do takrat nisem poznal. Morda bi se komu to ne zdelo preveč "spodobno". Ali pa vendar: saj se je godilo pri frančiškanih, njihov ustanovitelj Frančišek Asiški pa velja za enega največjih ljubiteljev živali in je bil zato proglašen njegov praznik (4. oktober) za svetovni dan živali ...

V tistem obdobju ste imeli nekje v Šiški majhnen zelenjavni vrt, kjer pa nisem bil nikdar in kjer si nabiral hrošče, ki so Te takrat najbolj zanimali. Imel si lepo zbirko, na krojaških iglah, s steklenimi barvastimi glavicami, ker česa drugega takrat v Ljubljani ni bilo dobiti. Še danes imam v spominu primerek hrošča

mlynarja *Polyphylla fullo*, ki ga do takrat nisem nikdar videl. V Tvoji zbirki pa je stal na igli z veliko rumeno glavico, ki me je zelo motila.

Seveda sva se redno obiskovala na domu: si ogledovala zbirko žuželk, življenje v Tvojem akvariju in prelistavala tistih nekaj strokovnih knjig, ki so nama bile na voljo. Takrat je živel še Tvoj oče. Meni se je zdel “velikan”, ki me je večkrat dvignil s tal, me vrgel v zrak, pod strop – in zopet ujel. Vsi ste se smejali, sam pa sem imel bolj mešane občutke.

Moji starši so imeli večji vrt v Rožni dolini, kamor sva seveda pogosto zahajala, predvsem tudi k veliki mlaki na bližnjem travniku, kjer stoji danes Študentsko naselje. Obiskovala sva jo pozimi in poleti in njeno favno dodobra inventarizirala. Po mojih takratnih beležkah sva tam med drugim ugotovila tudi nekaj manj od ducata vrst vodnih stenic iz rodov *Corixa*, *Gerris*, *Hydrometra*, *Nepa*, *Notonecta*, *Plea*, *Ranatra* in *Sigara* ter 20 vrst kačjih pastirjev. Preden sva začela sodelovati, si Ti v glavnem pohajal ob Ljubljani, vse do začetka Barja, moje torišče pa so bili Tivoli, Rožnik, Rožna dolina in Glinščica, nekako do Kosez. Potem sva vsa ta področja združila in razširila – kolikor je bilo pač mogoče v okviru z bodečo žico ograjene Ljubljane, ki jo je zapirala že na Dolenjski cesti, medtem ko je tekla nepropustna meja proti Nemčiji že na Podutiku in na savskem mostu na Ježici.

V prvem razredu nekdanje Klasične gimnazije naju je poučeval prirodopis živalstva Bruno Toič, ki je bil tisto leto suplent na naši šoli, nakar je odšel na gimnazijo v Kočevje in je v Kočevju tudi umrl. Večkrat nas je vodil na izlete po okolici in nas učil konzerviranja nekaterih žuželk in drugih nevretenčarjev v kisu, vendar sva takrat že poznala bolj ortodoksne metode z alkoholom in formalinom.

Od otroštva in nekako do konca nižje gimnazije so Te zanimali predvsem hrošči, mene pa metulji, kačji pastirji in kobilice. Zbirko pa sem začel “resneje” pripravljati šele pod vplivom Tvoje zbirke.

V šolskem letu 1948/1949 sva postala zelo aktivna člana “Prirodoslovnega krožka” na naši gimnaziji, ki ga je idejno vodil naš veleugledni, takratni učitelj zemljepisa, Pavel Kunaver. Po mali maturi (1951) smo krožkarji pripravili javno razstavo o našem delu, na kateri sva sodelovala z deli najinih zbirk žuželk. Razstavo si je prišel ogledat tudi neki osmošolec s Poljanske gimnazije, ki se nam je predstavil s svojim vzdevkom “Gou”. To je bil Štefan Sušec-Michieli, kasnejši sloviti biolog in že takrat velik poznavalec in zbiralec metuljev. Prijateljstvo z njim nama je odprlo pot v krog starejših, uglednih entomologov in v članstvo Entomološke sekcije Društva biologov Slovenije. Slednje je bilo za naju izjemno pomembno. Iz referatov na mesečnih sestankih sva namreč ugotovila, da se je takrat večina slovenskih entomologov ukvarjala s hrošči in metulji, kar naju je stimuliralo, da sva si izbrala za najino proučevanje dva druga, manj raziskana redova žuželk, kot opisano v uvodnem odstavku tega pisma.

Prav kmalu si našel zvezo z Antonom Modrom, župnikom v Dobrovi pri Ljubljani, ki je bil tudi diplomiran biolog in prvi raziskovalec favne stenic Slovenije. Pri njem si si sposodil delo W. Stichel-a (1925-1938): *Illustrierte Bestimmungstabellen der deutschen Wanzen*, ki sva jo potrebovala za določanje vrst. Ko sva

se nekoč s tem ukvarjala v naši dnevni sobi, se mi je zgodila nezgoda, da sem s črnilom popackal naslovnico enega od zvezkov. Ker je šlo za izposojeno publikacijo, mi je bilo strahovito neprijetno in sem se pred Tabo in pred Modrom (ki ga osebno nisem poznal) zelo sramoval. Oče je prinesel iz pisarne neko tekočino, s katero sva skušala madeže odstraniti, kar pa se nama je le deloma posrečilo in tekočina je nekoliko raztopila celo oranžno barvo platnice. Nepopisno sem se oddahnil, ko si mi kasneje povedal, da Moder nezgode ni jemal preveč resno. S tem v zvezi naj še omenim, da so bila nalivna peresa v tistem času skrajno redka in draga, t.im. "kuliji", s kroglično konico in suho tinto pa so bili vsaj še dobro desetletje od takrat v Sloveniji neznani. Za pisanje smo potrebovali tintnik s črnilom po izbiri vrste in barve, peresnik s peresom debeline po izbiri in pivnik.

Proti koncu 1940ih in v začetku 1950ih let sva nekajkrat preživela del poletnih počitnic na posestvu moje babice, na Viru pri Domžalah in sva neumorno raziskovala favno nekaterih skupin žuželk v bližnji in daljni okolici. V začetku 1950ih, me je Tvoja mati povabila na počitnice v Bohinj. V Ukancu ste imeli gozdno parcelo, ob robu katere so podrli nekaj drevja, v zvezi s polaganjem cevi, ki vodi vodo Savice do manjše elektrarne. Ta les ste uporabili za gradnjo počitniške hišice. Gradnja je napredovala le počasi in takrat še ni bilo mogoče tam prenočevati. Zato smo stanovali na Stari Fužini, ne daleč od cerkve Svetega Janeza. Tebi je bila bohinjska favna seveda domača, zame pa se je tam odprl popolnoma nov svet.

Kasneje sva večkrat pohajala po bohinjskih hribih, na resne gorske ture pa skupaj nisva hodila. Edina izjema je bila najina "entomološka odprava": iz Mojs-trane, preko Kriške stene do Kriških jezer, od tam na Škrlatico, potem pa preko Vrat, po Tominškovi poti na Triglav in skozi Voje v Bohinj. Lovila sva z mrežo in kečerjem in ulov je bil vreden truda. Prehranjevala sva se izključno iz nahrbtnika, ker za kaj drugega nisva imela ne časa, ne denarja. Ti si pa slovel kot odličен kuhar čajev, ki si jih pripravljaj iz spotoma nabranih zelišč. Odprava je trajala kak teden. Spričo zadrževanja z lovom, sva zadnji dan hodila kakih 16 ali 18 ur do Bohinskega jezera, kjer sva na Ribčevem laz u padla v travo ob bregu in nemudoma zaspala. Prebudila sva se v ranem jutru, premražena in premočena od rose. V Bohinju sva ostala še kak dan, v Vaši hišici. – Ko je Tvoja mama slišala o dolgotrajni hoji, je bila name prvič in zadnjič v življenju res huda, češ, da sem Te tako gnal, da bi te mogel napor umoriti ...!

Kdaj si si nabavil prvi, preprost fotografski aparat, ne vem več. Mnoge Tvoje fotografije so bile resnično umetniške, v katerih so bili prikazani čarobni efekti igre svetlobe. Sam sem si kupil v starinarnici preprost "meh" nekaj let kasneje. Ko si, vzporedno s študijem, služboval kot violinist v radijskem orkestru, sva imela dostop do njihove temnice na Kolodvorski ulici, kamor sva redno zahajala razvijat filme in povečevat slike. Kmalu pa sva odkrila temnico v Zoološkem inštitutu na Kongresnem trgu in sva pričela delati tam, redoma zvečer. Čez noč sva ostajala v zaklenjenem poslopju, ko pa je zjutraj vratar odklenil vhodna vrata, sva odšla domov. Potrebni papir in kemikalije sva kupovala sama in sva preizkušala različne postopke reprodukcije, toniranja itd. Vse noči sva seveda razpravljala o

entomologiji, dosti pa je bilo tudi romantičnega sanjarjenja, predvsem o najini študijski kolegici Nadi Mervič, ki je postala kasneje Tvoja življenska družica in o "Zajčku", t.j. moji prvi pa neusojeni, osnovnošolski ljubezni do najine sošolke na "Vadnici", Nade Zajec, kasneje poročene Jurjovec. Obe sta že odšli v večnost.

Svoje prve korake v temnici sem opravil pod vodstvom očeta, ki si je uredil temnico doma, v kopalnici. Najina skupna šola v Zoološkem inštitutu pa je postala zame v mnogočem edistvena in odločilna. Prav njej se imam zahvaliti, da mi je uspelo kasneje, na Inštitutu za raziskovanje krasa v Postojni, montirati na mikroskop majhno boks-kamero, s katero sem mogel še dosti uspešno fotografirati kromosomske garniture kačjih pastirjev. Nekatere od teh fotografij sem mnogo let kasneje uporabil pri solicitaciji za mesto doktoranda na Univerzi v Utrechtu (Nizozemska). Da sem takrat uspel, je bila vsaj posredno torej tudi Tvoja za-sluga.

Kot hemipterologa Te od vsega začetka ni zanimala le lokalna favnistika stenic in škržadov, temveč pred vsem tudi razni biološki aspekti, tako npr. skrb za zarod (*Sehirus biguttatus* in druge vrste), sezonsko prebarvanje in predvsem bioakustika, ki si jo prvič odkril pri vrsti *Tritomegas bicolor*. Dosti kasneje si razširil te študije tudi na škržade in si opisal na podlagi njih napevov vrsto novih taksonov, med njimi več kot ducat v kompleksu Scopolijeve *Cicadetta montana*. Pri tem delu in pri za to potrebnih raziskovalnih odpravah Ti je in Ti še pomaga dr. Tomi Trilar.

Prvi začetki Tvojega dela v bioakustiki segajo v konec 1950ih in v začetek 1960ih let. Ko to pišem, mi priplava v spomin Ruža Ačimović, takrat študentka medicine in podnajemnica v Vašem stanovanju na Trubarjevi. Svoje mesto v zgodovini Tvojih bioakustičnih raziskovanj si je zaslužila s tem, da Te je opremila s stetoskopom, instrumentom, ki stoji na začetku vsega. Osebnost jo nisem dosti poznal, v našem takratnem svetu pa je mnogo let predstavljala pomembno stalnico. Ure in ure smo poslušali napeve živali v steklenem kozarcu, katerega pokrov je bil zamenjan s stetoskopom. Problem pa je bila grafična reprodukcija napevov, ker fonografa nismo imeli na voljo. S svojo iznajdljivostjo in tehnično spretnostjo si zadevo rešil in na Biološki inštitutu SAZU so se pričeli vrteti fonogrami raznih vrst, v kvaliteti vseskozi primerni za objavo. To sem še doživel pred svojim odhodom v Holandijo (1962).

Kot "virtuoz" na računalniku si seveda poročal tudi o možnostih uporabe le-tega v bioakustiki in v študiju biodiverzitete. Kolegi se neprestano obračajo nate s prošnjami za nasvet ali tehnično pomoč. Kot sem opazil ob priliki Okrogle mize o Scopoliju, ki jo je organiziral Idrijski muzej leta 2007, si vse odmore uporabil za tehnično pomoč govornikom. Brez le-te bi marsikak referat ne bil primerno ilustriran.

Tvoja dela o fotorecepciji (predvsem *Troglophilus* in *Ascalaphus*) sem mogel spremljati le na razdaljo. Separate (PDF) svojih del mi redno pošiljaš in iz njih sem povzel marsikaj, kar sem mogel uporabiti pri svojih predavanjih zoologije nevretenčarjev na Univerzi v Utrechtu.

Skozi-in-skozi biolog, si po srcu prav tako glasbenik, zato narave ne le raziskuješ, temveč ji tudi intenzivno prisluškuješ. V 1990ih letih si ustvaril dva CDja:

zapisov o petju slovenskih škržadov in o sozvočju glasov v Belumskem pragozdu. V velik užitek slušateljev sem oba po dvakrat predvajal v Utrechtu.

Dragi Matjaž, prisrčna hvala za 75 let prijateljstva in strokovnega sodelovanja, s katerim si bistveno oplemenitil moje delo. Od srca želim nama obema, da bi Ti bilo dano še dosti zdravih, znanstveno plodnih in srečnih let,

Tvoj Boštjan



MOJI SPOMINI NA PROF. ŠTEFANA SUŠCA-MICHIELIJA

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Abstract – MY MEMORIES OF PROF. ŠTEFAN SUŠEC-MICHIELI

On the occasion of the 50th anniversary since the sudden death of Prof. Štefan Michieli (with the full name Štefan Sušec-Michieli) in his 35th year of age I am trying to present his life and work to younger generations of biologists and especially entomologists. The Slovenian entomological society is named after him. Prof. Michieli was a lepidopterologist, working also on some other groups of insects (Neuroptera, Embioptera), ethologist and zoophysiologicalist with the main interest in sensory physiology and visual orientation of animals.

KEY WORDS: biography, bibliography, Štefan Sušec-Michieli

Izvleček – Ob petdeseti obletnici nenadne smrti prof. Štefana Michielija (s polnim imenom Štefan Sušec-Michieli) v njegovem 35. letu skušam predstaviti njegovo življenje in delo mlajšim generacijam biologov in še posebno entomologov. Slovensko entomološko društvo se imenuje po njem. Prof. Michieli je bil lepidopterolog, preučeval je tudi nekatere druge skupine žuželk (Neuroptera, Embioptera), etolog in zoofiziolog, zanimala sta ga predvsem fiziologija čutil in orientacija živali z vidom.

KLJUČNE BESEDE: biografija, bibliografija, Štefan Sušec-Michieli

Letošnje srečanje slovenskih entomologov, združenih v Slovenskem entomološkem društvu Štefana Michielija (s polnim imenom Štefan Sušec-Michieli) je potekalo v letu, ko mineva petdeset let od njegove prezgodnje smrti. Čeprav društvo že vrsto let nosi njegovo ime, se je na tem srečanju pokazalo, da se preminulega entomologa in zoofiziologa spominja le malo ljudi, saj so bili premladi ali pa se sploh še niso rodili.



Sl. 1: Portret Štefana Sušca-Michielija, delo akademskega slikarja Florisa Oblaka (po spominu in fotografiji, 1969).

Zato je prav, da o njemu napišem sestavek, v katerem bom mlajšim poskusil približati njegov lik in njegovo delo.

Ta prikaz bo seveda oseben, kar kaže tudi naslov, saj je bil moj mentor in prijatelj. Spoznala sva se, ko sem bil še dijak in me je že takrat zanimala biologija in še posebej žuželke. Moj bratranec Borut Bohte, ki je živel v "Rdeči hiši" ob Poljanskem nasipu in je hodil v tamkajšnjo Poljansko gimnazijo, mi je povedal, da se njegov sošolec Štefan ali Gou, kot so ga imenovali prijatelji, ukvarja z metulji. Gou je stanoval na drugi strani Ljubljane na Usnjarski ulici poleg tovarne Rog, jaz pa tudi zelo blizu na Trubarjevi cesti 27. Menda je tudi moja mama poznala družino in tako sva vzpostavila prve stike. Spominjam se, da sva kmalu skupaj odšla na entomološki izlet v okolico Ljubljane, kjer sem jaz nabiral stenice on pa metulje. Povabil me je tudi na svoj dom in mi razkazal svojo čudovito zbirko metuljev. Kmalu pa smo se začeli družiti tudi z drugimi entomologi na sestankih nekakšne entomološke sekcije, za katero nisem niti dobro vedel, sekcija česa je bila. Morda je bila del združenja študentov ali Društva biologov ali česa drugega. Bistveno je bilo, da smo spoznali druge zbiratelje žuželk in slišali za njihove izkušnje, poslušali njihove nasvete, predavanja, in včasih smo odšli tudi skupaj na kakšen entomološki izlet ali pa na ogled kakšne zbirke. Med temi so bili tako ljubitelji kot tudi poklicni biologi in študenti biologije.

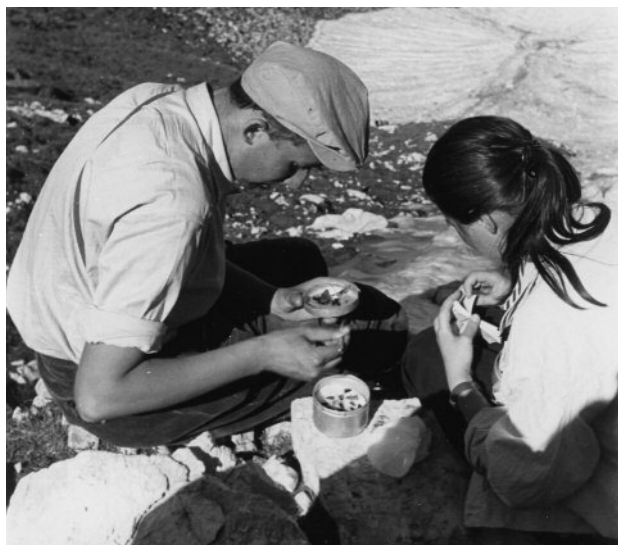


Sl. 2: Z ženo Majdo na lovu metuljev na Durmitorju, junij 1958.

To so bili začetki današnjega Slovenskega entomološkega društva Štefana Michielija. Tam sem spoznal tudi njegovega tesnega sodelavca Jana Cerneluttija, pa malakologa Jožeta Boleta, ki se je veliko družil z entomologi, Rajka Rakovca in številne druge biologe in ljubiteljske žužkoslovce. Pogosto se je teh sestankov udeleževal tudi moj sošolec, prijatelj in entomološki navdušenec Boštjan Kiauta.

Poleg metuljev so Štefana zanimale tudi druge žuželke, posebno nogoprelci (Embioptera), ki jih je odkril tudi v Piranu v Sloveniji in na številnih krajih vzdolž Jadranske obale. S sodelavcem Jožetom Boletom sta jih tudi gojila in preučevala v laboratoriju in tam sem jih tudi jaz prvič videl in jih kasneje našel tudi v naravi v Vipavski dolini. Michieli in Bole sta posebej ali skupaj objavila več člankov o tej nenavadni skupini žuželk (Michieli 1956a, 1958a, 1958b, Michieli & Bole 1956, Bole 1978). Druga skupina, ki jo je Michieli tudi zbiral in preučeval, so bili mrežekrilci (Neuroptera) in kljunavci (Mecoptera). Njegovo zbirko mrežekrilcev iz Slovenije, Hrvaške in Črne gore je nedavno restavriral in preveril določitve prof. Dušan Devetak in o tem poročal na 5. Slovenskem entomološkem srečanju v Mariboru 21. in 22. septembra 2018. Zbirka vsebuje 31 vrst in večino primerkov je že Michieli pravilno določil. Vrsta, ki je v tej zbirki ni, pa jo je poznal in pogosto nabiral, je metuljčnica, ki smo jo takrat imenovali s starejšim imenom *Ascalaphus macaronius*, po novem *Libelloides macaronius* (glej spodaj). Vse smo namreč uporabili za poskuse.

Štefan Michieli se je že pred diplomo leta 1956 zaposlil na Biološkem inštitutu SAZU, nato je v študijskem letu 1959-60 delal kot honorarni asistent na Biološkem inštitutu Medicinske fakultete pri prof. Hubertu Pehaniju. Marca leta 1959 je doktoriral



Sl. 3: Prebiranje in spravljanje ulova na isti ekskurziji.

in od julija istega leta spet nastopil službo kot znanstveni sodelavec na Inštitutu za biologijo SAZU, ki ga je takrat vodil akademik Jovan Hadži. S štipendijo UNESCO je leta 1959 odšel na izpopolnjevanje v Zahodno Nemčijo, v München, Würzburg in Tübingen, kjer je spoznaval sodobne smeri in tehnike pri študiju fiziologije živali s poudarkom na področjih fiziologije čutil, zlasti vida in orientacije pri žuželkah. Leta 1960, po vrnitvi iz tujine, je bil izvoljen za docenta na Biotehniški fakulteti Univerze v Ljubljani, jaz pa pri njemu za asistenta. Leta 1965 je napredoval v izrednega profesorja, medtem pa sem tudi jaz po doktoratu dobil Humboldtovo štipendijo za izpopolnjevanje v Nemčiji (1964/65). Tam sem se v razgovorih z nemškimi kolegi lahko prepričal, kako globok vtis je Michieli zapustil s svojim znanjem, delom in publikacijami.

Štefan je bil manj kot štiri leta starejši in postal je moj učitelj ali mentor in moj dober prijatelj. Svetoval mi je tudi pri študiju in ko sem diplomiral leta 1959, je bil on že v službi na takratnem Biološkem inštitutu Slovenske akademije znanosti in umetnosti. Na njegovo pobudo sem postal volonter, torej neplačani sodelavec na tem inštitutu, kjer sem se takrat nekaj mesecev pred odhodom k vojakom ukvarjal z zanimivimi glasovi stenic. Oprema za tako delo je bila skrajno skromna, toda dobrodošla: stetoskop in izjemoma izposojeni magnetofon z mikrofonom. Toda tudi s stetoskopom smo lahko prisluhnili nenavadnim zvokom žuželk iz družine talnih stenic (Cydniidae). Prve posnetke steničnih glasov pa smo naredili v studijih takratnega Radia Ljubljane.

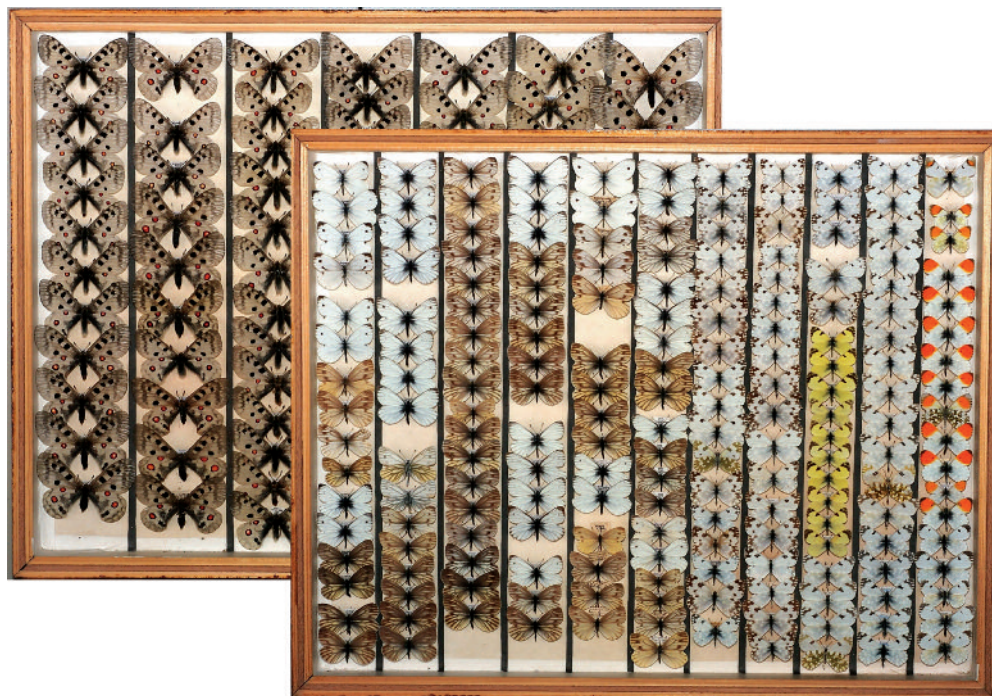
Omenil sem že, da sva v mojih dijaških letih z Gouom nekajkrat šla skupaj na entomološke izlete. Tudi kasneje, ko sem bil študent in kasneje asistent, sva nekajkrat šla skupaj na teren in na nekaj takih ekskurzij imam še danes žive in prijetne spomine. Tak izlet je bil na primer leta 1958 v dolino sedmerih Triglavskih jezer, kjer sva večino časa preživela v koči, saj je neprestano deževalo, čas sva pa preganjala s pogovori in preprostimi vedenjskimi poskusi z različnimi členonožci. Pričakovala sva še Jana Carneluttija, ki je obljubil, da se nama bo pridružil, pa sva ga čakala zaman. Ko

sva se odločila, da greva domov v dolino, se je pa zjasnilo in je bil čudovit dan. Isto leto (1958) smo se odpravili še v Črno goro, najprej na Durmitor, na goro Meded, k Črnemu jezeru, pod Šljeme in kasneje še v dolino Komarnice pri Šavniku. Poleg Štefana in njegove žene Majde je bil z nami še znani speleobiolog Egon Pretner in jaz - takrat še študent. Vsak od nas je iskal svoje živali, Štefan in Majda metulje, Egon hrošče in jaz stenice. Ker sem bil takrat zelo suh, me je Egon uporabil, da sem mu pomagal v raznih jamah pobirati vabe in nabirati hrošče. Tako sem se splazil v neko jamo nad Komarnico, da sem mu prinesel vabe, nastavljene nekoč prej, saj je bila špranja za druge preozka. Ko sta se Majda in Štefan poslavljala, smo na avtobusni postaji srečali Jana Carneluttija, ki je odhod spet za en teden zamudil. Tudi kasneje smo po Sloveniji skupaj naredili še marsikatero entomološko ekskurzijo, tako imam žive spomine na izlet na Nanos, v Vipavsko dolino in še kam - toda vedno je bil namen entomološka dejavnost in pogosto nabiranje poskusnih živali za vedenjske ali fiziološke poskuse.

Ko sem postal pri docentu Michieliju asistent, smo seveda morali najprej zagotoviti študijski proces - on je predaval primerjalno fiziologijo živali in splošno fiziologijo z osnovami fiziologije človeka, jaz pa sem moral pripravljati in voditi vaje. Kakšne sodobnejše opreme takrat nismo imeli in treba je bilo imeti veliko smisla za improvizacijo. Prof. Michieli je že s svojo disertacijo dal odličen zgled, da se da s skromnimi sredstvi doseči veliko, saj je za poskuse optične orientacije pri nevretenčarjih potreboval predvsem papir, karton ter vodene barvice za arenške ter optomotorične poskuse.



Sl. 4: Štefan Michieli razlaga skupini naravoslovcev posebnosti ulovljenega primerka (1961).



Sl. 5: Dve izbrani škatli Michielijeve zbirke metuljev, ki jo hrani Prirodoslovni muzej Slovenije.

Iz rezultatov pa je pravilno sklepal na občutljivost poskusnih živali za barve ali da nanje niso občutljive, ali pa reagirajo foto ali skototaktično, z drugo besedo ali jih privlači svetloba ali tema, kakšna je njihova fuzijska frekvenca in podobno. Ena izmed ugotovitev je bila, da se mnoge živali usmerjajo v poskusnih arenah na mejo med svetlimi in temnimi ali barvno kontrastnimi objekti. Ta pojav je dr. Michieli imenoval **perigramotaksis** ali robni efekt, pojem, ki ga še danes uporabljajo in citirajo (npr. Lehrer 1997, Gora et al. 2016). Prav s svojimi domiselnimi toda preprostimi poskusi si je doma in v tujini pridobil velik ugled.

Seveda je Michieli kot vodja Zoofiziološkega laboratorija stremel k modernizaciji laboratorijske opreme, kakršno je med svojimi obiski v tujini videl v tujih laboratorijih. Za raziskave čutil so v petdesetih in šestdesetih letih postale najpomembnejše elektrofiziološke metode. Ker takrat vsaj na Biološkem oddelku Biotehniške fakultete in na Inštitutu za biologijo ni bilo mogoče dobiti deviz za nabavo ustreznih aparatov iz zahodnih držav, predvsem iz ZDA, se je s prof. Alešem Strojnikom z Elektrotehniške fakultete dogovoril, da bodo posebej za nas naredili osciloskop, osnovno napravo za beleženje električnih odgovorov očesa oziroma njihovih čutilnih celic na svetlobne dražljaje. Delo je poveril takratnemu asistentu dr. Lojzetu Vodovniku in tako smo leta 1962 dobili prvo aparaturo, prototip dvožarkovnega osciloskopa za elektrofiziološke raziskave.

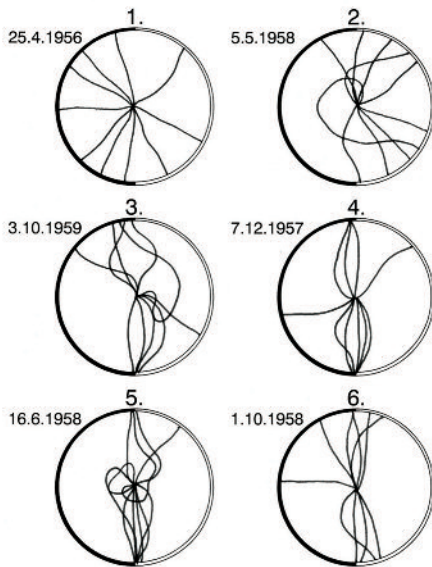
Po kratkem uvajanju v to novo tehniko smo v zoofiziološkem laboratoriju kmalu prišli do prvih rezultatov naših meritev. Ugotavljali smo obliko sumaričnih osvetlitvenih potencialov izbranih žuželk (Gogala & Michieli 1964), stopitveno frekvenco žuželčjih oči (Michieli 1965), spektralno občutljivost žuželk (Michieli 1966). Največje zanimanje med strokovnimi kolegi je vzbudil kratek članek o ultravijolični občutljivosti dvojnih oči metuljčnice *Ascalaphus macaronius* (Gogala & Michieli 1965). Te živo-barvne mrežekrilce smo namreč izbrali za elektrofiziološke poskuse občutljivosti oči in ugotovili njihovo nenavadno spektralno občutljivost z vrhom v ultravijoličnem delu spektra. Samo stransko fasetno oko ima drugi vrh občutljivosti tudi v nam vidnem delu spektra. Sicer sem to izjemno občutljivost za ultravijolično svetlobo res jaz prvi odkril, toda primerke za te poskuse mi je prinesel moj mentor Štefan Michieli. Zato sva prvi članek o tem tudi skupaj objavila (Gogala & Michieli 1965). Kasneje, že po Štefanovi smrti, smo v sodelovanju z nemškimi kolegi pod vodstvom prof. Kurta Hamdorfa podrobneje raziskovali vid teh žuželk in izolirali tudi svetločutni pigment, ki ima na posebno beljakovino (opsin) vezano enako molekulo retinala, kakršno ima tudi človek v vidnem škrlatu (rodopsinu) (Gogala et al. 1970, Hamdorf et al. 1971).

Z drugo metodo, Warburgovim aparatom, sta merila porabo kisika med sezonskim prebarvanjem pri stenicah *Nezara viridula* Michieli in Borut Žener (1968a in 1968b). S problematiko spreminjanja barv pri žuželkah smo se v našem laboratoriju začeli ukvarjati že v prvih letih po ustanovitvi (Gogala & Michieli 1962a, 1962b, 1966, 1967).

Omeniti moram še Michielijevo uredniško delo. V znanstveno revijo *Biološki vestnik* je pisal že od drugega letnika naprej, od leta 1961 ali osmega letnika do svoje



Sl. 6: Pisec ob daljnogledu s Štefanom Michielijem na Nanosu julija 1961.



Gibt es eine echte skototaktische Orientierung?

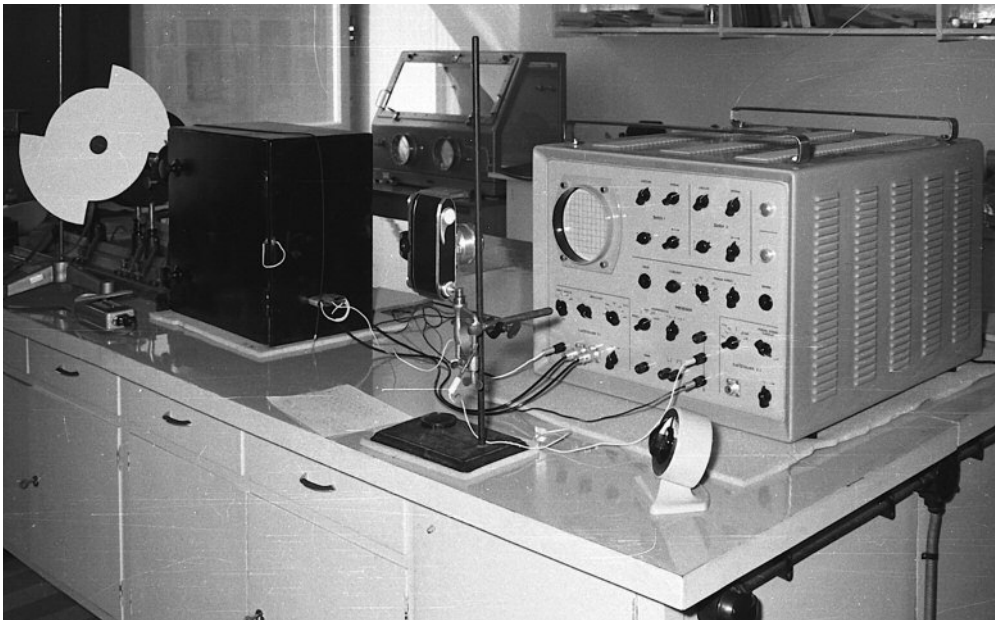
(Zusammenfassung)

VON ŠTEFAN SUŠEC-MICHELJI

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Mit dem Wort „*Skototaxis*“ bezeichnet man nach ALVERDES (1930) und DIETRICH (1931) eine telotaktische Orientierung gegen die scharf umgrenzten dunklen Flächen, die sich innerhalb eines beleuchteten Feldes befinden. In einer diffus beleuchteten weißen Arena mit schwarzen Schirmen an den Wänden kriechen viele Tiere den Schirmen zu. Das betrachteten die erwähnten Autoren als Beweis für das Bestehen einer besonderen Dunkelheitsreaktion. Dieses Reagieren wurde ursprünglich nur einigen photonegativen Crustaceen — Isopoda (DIETRICH, 1931), Decapoda (ALVERDES, 1930) —, Myriapoden (GÖRNER, 1959; KLEIN, 1934) und Insekten (KLEIN, 1934; MEYER, 1932) zugeschrieben, scheint aber im Tierreich sehr weit verbreitet zu sein. *Skototaxis* hätte zwar mit

Sl. 7: A) Slika iz doktorske disertacije dr. Michielija s primeri perigramotaktične orientacije raznih členonožcev (1959); B) Glava nemškega članka dr. Sušca-Michelija z isto tematiko v publikaciji *Ergebnisse der Biologie* 1963.

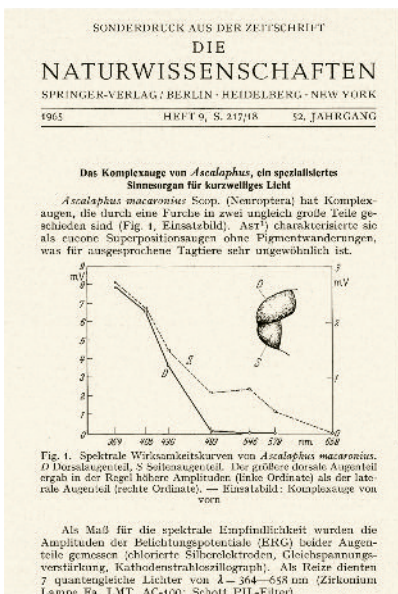


Sl. 8: Prvi osciloskop zoofiziološkega laboratorija s pomožnimi napravami za rizične fotorepcije.

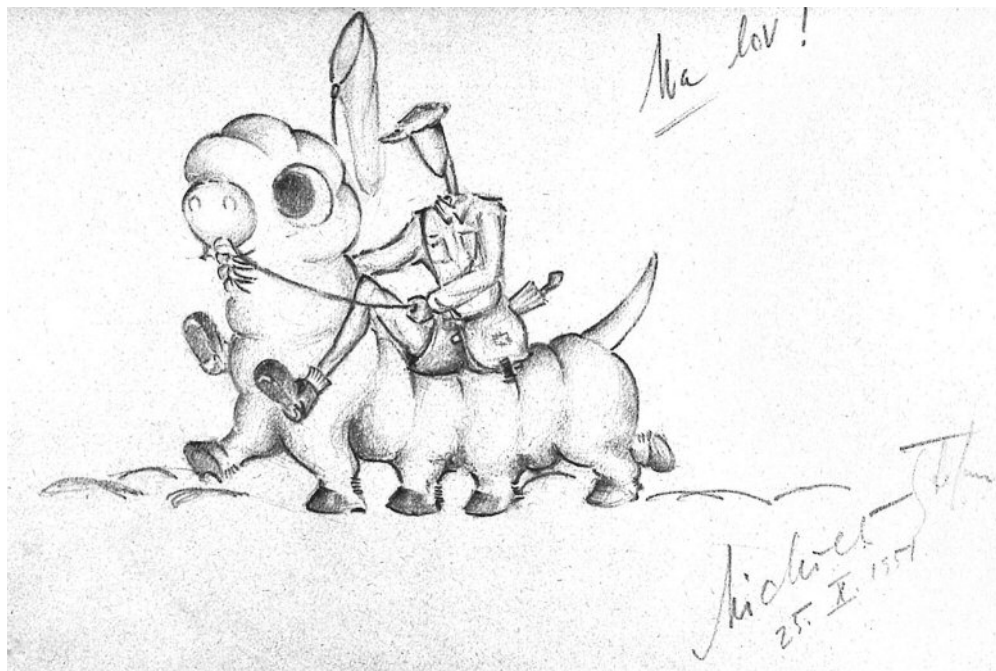
smrti pa je bil njen glavni in odgovorni urednik, kjer je poročal tudi o pomembnih tujih publikacijah in dogodkih (Michieli 1967b, Michieli 1967c).

Kljub veliki zavzetosti za napredek zoofiziološkega laboratorija je Štefan Michieli našel čas in voljo za lepidopterološko delo, ki je bilo njegova prva ljubezen in ga je veselilo od mladih nog. Njegova prva znanstvena objava je bila o nastopanju južnih vrst metuljev (Michieli 1953), s prijateljem in sodelavcem Janom Carneluttijem sta objavljala prispevke k favni metuljev Slovenije (Carnelutti & Michieli 1955, 1960a, 1960b). Prav tako sta oba avtorja objavila tri članke o makrolepidopterih Triglavskega narodnega parka (Carnelutti & Michieli 1966, 1969, 1973 - posthumno). Tretji prispevek k favni metuljev Slovenije sta pripravila skupaj s pisateljem in navdušenim ljubiteljskim metuljarjem dr. Vladimirjem Bartolom (Bartol et al., 1965). Z njim in njegovim sinom Borutom je Michieli objavil tudi favno metuljev otoka Krka (Bartol et al. 1964). Poleg tega je Štefan Michieli sam objavil vrsto drugih metuljarskih prispevkov (Michieli 1960, 1962, 1963, 1966a, 1966b, 1967, 1970). Posebno mesto predstavlja zadnje pomembno lepidopterološko delo, ki je izšlo šele po njegovi prezgodnji smrti in vsebuje pregled favne metuljev Slovenije in njenih posebnosti (Michieli 1970). Ta publikacija je bila v slovenskem prevodu in z barvnimi ilustracijami ponatisnjena še dvakrat, leta 1983 in 1984.

Štefan Michieli je bil astmatik in težave s to boleznijo je reševal s kombinacijo zdravil in močne kave. V soparnem dnevu dne 29. junija 1968 pa njegovo srce tega ni več zdržalo.



Sl. 9: A) Prva stran članka z rezultati elektrofizioloških meritev spektralne občutljivosti oči metuljčnice *Ascalaphus macaronius* (po novem *Libelloides macaronius*), 1965; B) metuljčnica (*Libelloides macaronius*).



Sl. 10: Karikatura iz Štefanove skicirke, ki simbolizira njegovo navdušenje nad metulji od mladih dni do konca življenja (1951).

Zbirka metuljev Štefana Michielija je ohranjena v Prirodoslovnem muzeju Slovenije, zbirka mrežekrilcev je restavrirana in hranjena na Univerzi v Mariboru. Seznam publikacij prof. Michielija, tako znanstvenih kot tudi poljudnoznanstvenih in strokovnih, sem poskusil čim bolj popolno zbrati in urediti v tem prispevku in so navedena v posebnem seznamu literature. Večina publikacij Štefana Michielija je pisana v slovenščini ali nemščini s povzetki v drugem jeziku. Takrat večina slovenskih biologov še ni pisala svojih prispevkov v angleščini in je od tujih jezikov nemščina prevladovala. Veliko člankov prof. Michielija je bilo kratkih, a nikakor ne nepomembnih. Poleg navedenih del je Michieli objavil tudi razne krajše prikaze slovstva, komentarje k dogodkom, prevedel je tudi knjigo Buddenbrocka: Živali v ljubezni (1964). Navedel nisem tistih del, kjer je bil prof. Michieli mentor. Kljub temu je seznam publikacij za 35 let življenja zavidanja vreden. Čeprav je bilo njegovo polno ime Štefan Sušec-Michieli, je v svojih publikacijah uporabljal razen ene izjeme (Sušec-Michieli 1963) le priimek Michieli. Upam, da sem s tem zapisom lik entomologa, zoofiziologa in široko razgledanega biologa približal mlajšim entomologom, ki ga niso mogli poznati in spoznati.

Naj na koncu omenim še to, da je bil zelo prijazen in mil človek. Pri vrstnem redu sodelavcev pri objavah je pogosto dajal prednost mlajšim in ljubiteljskim entomologom. Če se je za kaj odločil, je tudi vztrajal pri svojem stališču. Zato je bil zelo uspešen organizator, toda tega v svojem kratkem življenju ni mogel polno razviti in dokazati.

Literatura Dela Štefana Michieliija

- Bartol, B., Bartol, V., Michieli, Š., 1964. Beitrag zur Kenntnis der Makrolepidopterenfauna der adriatischen Insel Krk (Veglia). *Nachrichtenblatt der Bayerischen Entomologen* **13**(4-6): 33-59.
- Bartol, V., Carnelutti, J., Michieli, Š., 1965. III. Prispevek k favni lepidopterov Slovenije. *Biološki vestnik: glasilo slovenskih biologov*, **13**: 69-76.
- Buddenbrock, W. von, 1964. *Živali v ljubezni*. (Prevod Š. Michieli) Ljubljana: Državna založba Slovenije, 190 str
- Carnelutti, J., Michieli, Š., 1955. Prispevek k favni lepidopterov Slovenije. *Biološki vestnik: glasilo slovenskih biologov*, **4**(1): 43-55.
- Carnelutti, J., Michieli, Š., 1958. I. Beitrag zur Kenntnis der Lepidopterenfauna von Crna gora. *Fragmenta balcanica*, **2**: 67-81.
- Carnelutti, J., Michieli, Š., 1960a. Nove podvrste metuljev iz Slovenije. *Biološki vestnik: glasilo slovenskih biologov*, **7**: 101-111.
- Carnelutti, J., Michieli, Š., 1960b. 2. prispevek k favni lepidopterov Slovenije. *Biološki vestnik: glasilo slovenskih biologov*, **7**: 113-124.
- Carnelutti, J., Michieli, Š., 1966. Makrolepidopteri Triglavskega narodnega parka in okolice (Lepidoptera: Rhopalocera, Hesperioidea). *Varstvo narave* **5**: 107-127.
- Carnelutti, J., Michieli, Š., 1969. Makrolepidopteri Triglavskega narodnega parka in okolice II. (Lepidoptera: Bombyces, Sphinges). *Varstvo narave* **6**: 105-119.
- Carnelutti, J., Michieli, Š., 1973. Makrolepidopteri Triglavskega narodnega parka in okolice III (Lepidoptera: Noctuidae). *Varstvo narave* **7**: 65-95.
- Gogala, M., Michieli, Š., 1962a. Beitrag zur Kenntnis der Farbstoffe bei Heteropteren. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **7**(3): 61-62.
- Gogala, M., Michieli, Š., 1962b. Sezonsko prebarvanje pri nekaterih vrstah stenic (Heteroptera). *Biološki vestnik: glasilo slovenskih biologov*, **10**: 33-44.
- Gogala, M., Michieli, Š., 1964. Monofazični in difazični retinogrami pri insektih. *Biološki vestnik: glasilo slovenskih biologov*, **12**: 13-20.
- Gogala, M., Michieli, Š., 1965. Das Komplexauge von Ascalaphus, ein spezialisiertes Sinnesorgan für kurzweiliges Licht. *Naturwissenschaften*, **52**(9): 217-218.
- Gogala, M., Michieli, Š., 1966. Vpliv svetlobe in temperature na sezonsko prebarvanje pri Nezara viridula (L.)(Heteroptera). *Biološki vestnik: glasilo slovenskih biologov*, **14**: 83-90.
- Gogala, M., Michieli, Š., 1967. Berichtigung zu unseren Veröffentlichungen über Farbstoffe bei Heteropteren. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **12**(1-2): 6.
- Michieli, Š., 1953. Nastopanje južnih vrst metuljev v Ljubljani in okolici. *Biološki vestnik: glasilo slovenskih biologov*, **2**(1): 84-88
- Michieli, Š., 1955a. Insekti - tulčarji. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **17**(10): 283-287.
- Michieli, Š., 1955b. Markiranje kitov. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **18**(3): 92.

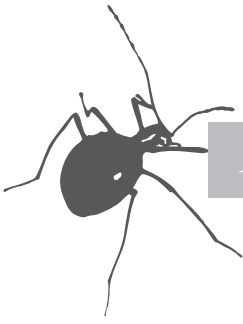
- Michieli, Š., 1955c. Nekaj o hormonih pri nevretenčarjih. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **18**(4-5): 113-117.
- Michieli, Š., 1956a. Vorkommen der Embiopteren in Jugoslawien. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **3**(1): 9.
- Michieli, Š., 1956b. Nastopanje južnih vrst metuljev v Sloveniji: nadaljevanje. *Biološki vestnik: glasilo slovenskih biologov*, **5**, št. 1, str. 115-120.
- Michieli, Š., 1956c. Metulji, ultrazvok in netopirji. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **18**(9): 255.
- Michieli, Š., 1956č. Metulji in mravlje. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **19**(3): 88-89.
- Michieli, Š., 1956d. Vtisi biologa s potovanja na Skadarsko jezero. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **19**(4-5): 97-104.
- Michieli, Š., 1957a. Beobachtungen bei skototaktischen Versuchen mit Landarthropoden. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **3**(3): 70.
- Michieli, Š., 1957b. Wirkung kurzweiligen Lichtes auf Schmetterlinge. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **3**(3): 70.
- Michieli, Š., 1957c. Ali izrabljajo gosenice tudi vsebine nepregriznenih rastlinskih celic. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **19**(6): 165.
- Michieli, Š., 1957č. Sladkovodni polži izločajo strupene snovi. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **19**(7): 191.
- Michieli, Š., 1957d. Kako prebavlja voščeni molj vosek. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **20**(1): 26.
- Michieli, Š., 1957e. O spreminjanju barve pri živalih. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **20**(4-5): 114-118.
- Michieli, Š., 1957f. Elektrofiziološka raziskovanja možganov pri žuželkah. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **20**(4-5): 130-131.
- Michieli, Š., 1958a. Ökologie und Zoogeographie der Embiopteren des Illyrischen Karstgebietes. *Zoologischer Anzeiger (Verhandlungen der Deutschen Zoologischen Gesellschaft, Graz)* Supplement **21**: 525-529.
- Michieli, Š., 1958b. Über einige interessante Insektenfunde in der Crna Gora (Montenegro). *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **4**(2): 51.
- Michieli, Š., 1958c. Nekaj pripomb k postavljanju infraspecifičnih kategorij. *Biološki vestnik: glasilo slovenskih biologov*, **6**(1): 124-134
- Michieli, Š., 1958č. Nov način borbe proti pebrini. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **20**(6): 161-162.
- Michieli, Š., 1958d. Nevidna risba metuljih kril. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **20**(7): 195-196.
- Michieli, Š., 1959a. Analiza skototaktičnih (perigramotaktičnih) reakcij pri artropodih. *Razprave*, **5**: 235-286,
- Michieli, Š., 1959b. *Analiza skototaktičnih reakcij pri artropodih: [disertacija]*. 78 f.
- Michieli, Š., 1959c. Doprinos našega znanstvenika k razvoju nauka o evoluciji. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **21**(9-10): 263-265.
- Michieli, Š., 1959č. O stanovanjskem problemu. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **22**(3): 92-93.

- Michieli, Š., 1959d. Nova dognanja o biološkem pomenu električnih organov pri ribah. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **22**(4-5): 110-112.
- Michieli, Š., 1960. Beitrag zur Kenntnis der Konturwahrnehmung der Insekten. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **5**(3): 72-73.
- Michieli, Š., 1961a. Prispevek k poznavanju evolucijskega mehanizma troglobiontov. II. *Jugoslavenski speleološki kongres, Zagreb*, 199-203.
- Michieli, Š., 1961b. O pomenu sodobne entomologije. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **24**(1): 7-10.
- Michieli, Š., 1962a. Über die neuzeitlichen Änderungen in der Schmetterlingsfauna des südöstlichen Alpenraumes. *Zeitschrift der Wiener Entomologischen Gesellschaft*, **47**: 153-157.
- Michieli, Š., 1962b. Tehnika se uči od živali: (kako se orientirajo živali). *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **24**(9/10): 230-234.
- Michieli, Š., 1962c. Nekaj novosti o spolnih vonjavah pri metuljih in še kaj. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **24**(9/10): 252-253.
- Michieli, Š., 1962č. Tudi žuželkam se poviša telesna temperatura, kadar obolijo. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **24**(9-10): 253.
- Michieli, Š., 1962d. Kako vidijo barve sesavci? *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **25**(1): 16-18.
- Michieli, Š., 1962e. II. Kongres biologov Jugoslavije. *Biološki vestnik: glasilo slovenskih biologov*, **10**: 141-142.
- Michieli, Š., 1963. Beitrag zur Kenntnis der Makrolepidopterenfauna Mazedoniens (S.R. Makedonija). *Acta Musei Macedonici Scientiarum Naturalium* **9**(2): 15-33.
- Michieli, Š., 1965. Zur Kenntnis der zeitlichen Auflösungsvermögen der Insektenaugen. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **10**(6): 150.
- Michieli, Š., 1966a. Perigrapha I - cinctum Schiff. slovenica ssp. nova (Lepid.). *Biološki vestnik: glasilo slovenskih biologov*, **14**: 97-98.
- Michieli, Š., 1966b. Spektralna občutljivost insektov = Spektrale Empfindlichkeit der Insekten, elektrophysiologische Untersuchungen an ausgewählten Arten. *Razprave*, **9**: 205-251
- Michieli, Š., 1966c. Zur Ausbreitung der melanistischen Lepidopterenformen im südöstlichen Voralpenraum (Slowenien). *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **11**(10-12): 6.
- Michieli, Š., 1966č. G. A. Mazohin Poršnjakov: Zrenie nasekomyh, Moskva 1965. *Biološki vestnik: glasilo slovenskih biologov*, **14**: 134-135.
- Michieli, Š., 1966d. E. Kálmán, L. Sztanyik, E. Unger, V. Várterész: Strahlenbiologie, Akadémiai kiadó Budapest, 1966. *Biološki vestnik: glasilo slovenskih biologov*, **14**: 135.
- Michieli, Š., 1967a. Sto let širjenja jamamaja (*Antheraea yamamai* Guer., Lepid.) v Sloveniji. *Biološki vestnik: glasilo slovenskih biologov*, **15**: 73-77.
- Michieli, Š., 1967b. Zasluženno priznanje slovenskemu biologu. *Biološki vestnik: glasilo slovenskih biologov*, **15**: 127.
- Michieli, Š., 1967c. J. Thurner: Die Lepidopterenfauna jugoslawisch Mazedoniens. *Biološki vestnik: glasilo slovenskih biologov*, **15**: 140.

- Michieli, Š., 1970. Zur lepidopterologischen Erforschung des südöstlichen Alpen- und Voralpenraumes. *Jahrbuch des Vereins zum Schutze der Alpenpflanzen und -Tiere*, **35**: 194-201.
- Michieli, Š., 1978. Raziskave metuljev jugovzhodnega alpskega in predalpskega prostora. *Proteus: ilustriran časopis za poljudno prirodoznanstvo*, **40**(9/10): 324-336.
- Michieli, Š., 1983. *Raziskave metuljev jugovzhodnega alpskega in predalpskega prostora*. Ljubljana: Prirodoslovni muzej Slovenije, 15 str.
- Michieli, Š., Bole, J., 1956. Morfološka, anatomsko-histološka in ekološka opazovanja na vrstah *Haploembia solieri* Ramb et Grassi in *Embia mauritanica* Luc. *Biološki vestnik: glasilo slovenskih biologov*, **5**(1): 90-106.
- Michieli, Š., Carnelutti, J., 1958. *Biston betularia* L. f. *carbonaria* Jord. (Lepid.) in Slowenien gefunden. *Bulletin Scientifique - Conseil des Academies de la RSF de Yougoslavie*, **4**(2): 53-54.
- Michieli, Š., Gogala, M., 1962. Neki rezultati upotrebe živinih lampi pri proučavanju entomofaune Slovenije. *Agronomski glasnik: glasilo Hrvatskog agronomskog društva*, **5-6-7**: 504-511.
- Michieli, Š., Žener, B., 1968. Der Sauerstoffverbrauch verschiedener Farbstadien bei der Wanze *Nezara viridula* (L.). *Zeitschrift für vergleichende Physiologie* **58**: 223-224.
- Michieli, Š., Žener, B., 1968. Poraba kisika med imaginalnim spreminjanjem barve pri stenici *Nezara viridula* (L.) (Heteroptera, Pentatomidae). *Razprave*, **11**: 229-243.
- Sušec-Michieli, Š., 1963. Gibt es eine echte skototaktische Orientierung? *Ergebnisse der Biologie*, Springer Verlag, Berlin, Göttingen, Heidelberg, **26**: 83-89.

Druge publikacije omenjene v članku

- Bole, J., 1978. Prispevek k poznavanju embiopterov (Embioptera, Insecta) Jugoslavije. *Biološki vestnik: glasilo slovenskih biologov*, **26**(2): 169-174.
- Devetak, D., 2018. Lacewings (Insecta: Neuropterida) in the Štefan Michieli's entomological collection. 5. SES MNH 21.-22. 9. 2018 - Poster
- Gogala, M., Hamdorf, K., Schwemer, J., 1970. UV-Sehfarbstoff bei Insekten. *Z. vergl. Physiol.*, **70**: 410-414.
- Gora, E. M., Gripshover, N., Yanoviak S. P., 2016. Orientation at the water surface by the carpenter ant *Camponotus pennsylvanicus* (De Geer, 1773) (Hymenoptera: Formicidae). *Myrmecological News* **23**: 33-39.
- Hamdorf, K., Schwemer, J., Gogala, M., 1971. Insect visual pigment sensitive to ultraviolet light. *Nature*, **231**: 458-459.
- Lehrer, M., 1997. Orientation and communication in Arthropods. Birkhäuser Basel AG, 144 str.



PREDATOR-PREY INTERACTIONS IN ANTLIONS: TRANSMISSION OF VIBRATIONAL SIGNALS DEEP INTO THE SAND*

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Abstract - Trap-building antlion larvae dig conical pitfall traps in sand for catching small arthropods. The larvae detect them according to substrate vibrations produced by the movement of the prey on sand surface. While most studies have been devoted to surface waves, here we elucidate the role of vibrations travelling in deeper sand layers. We demonstrate that an antlion larva, even when buried deep in the sand, is capable to detect its prey and it consequently reacts attacking it. Both, pit builder and non-pit-builder antlions respond to signals travelling deep into sand. This kind of the signals have not yet been measured so far. We conducted measurements of artificial signals and signals produced by walking insects (prey) with an accelerometer buried in the substrate. We addressed the following question: Do sand properties have any impact on the signal transmission? Particle size highly affects signal transmission. Sand is a filter for higher frequencies. Smaller are the sand particles, more intense is the filtering, which means that fine sand is a more efficient filter. However, low frequency signals are still propagated to a certain distance and they are biologically relevant for prey detection.

KEY WORDS: antlion, Neuroptera, substrate vibration, predatory behaviour, pit builders, non-pit-builders

Izvleček – INTERAKCIJE MED PLENILCEM IN PLENOM PRI VOLKCIH: PREVAJANJE VIBRACIJSKIH SIGNALOV GLOBOKO V PESEK

Ličinke volkcev lijakarjev gradijo v pesku stožčasto oblikovane lijakaste pasti za lov drobnih členonožcev. Ličinke jih zaznavajo na osnovi vibracij podlage, ki jih plen proizvaja med hojo po peščeni površini. Medtem ko je bila večina raziskav posvečena površinskim valovom, pa mi osvetljujemo vlogo vibracij, ki potujejo v globlje plasti

peska. Ugotavljamo, da celo globoko v podlago zakopana ličinka lahko zazna plen in se odzove nanj z napadom. Oboji – lijakarji in nelijakarji – se odzivajo na signale, ki potujejo globoko v pesek. Te vrste signalov doslej še niso merili. Z akcelerometrom, zakopanim globoko v substrat, smo merili umetne signale in signale, ki nastajajo zaradi hoje žuželke. Zastavili smo si naslednje vprašanje: Ali imajo lastnosti podlage vpliv na prevajanje signalov? Velikost delcev podlage zelo vpliva na njihovo prevajanje. Pesek filtrira signale visokih frekvenc. Manjši so peščeni delci, močnejše je filtriranje, kar pomeni, da je fini pesek učinkovitejši filter. Kljub temu se signali nizkih frekvenc prevajajo na določenih razdaljah in so biološko pomembni pri zaznavanju plena.

KLJUČNE BESEDE: volkec, Neuroptera, vibracije podlage, plenilsko vedenje, lijakarji, nelijakarji

*Dedicated to Matija Gogala on the occasion of his 80th birthday / Posvečeno 80-letnici Matije Gogala

Introduction

Antlions (Myrmeleontidae) are a family of the order Neuroptera with a remarkable diversity in larval ecology. Most antlion larvae live in dry, loose soil and sand, and this sand-dwelling or psammophilous habit, which required fossorial adaptations, was probably a key factor in the radiation of Myrmeleontidae into the largest family of Neuroptera (Mansell 1996, 1999, Badano et al. 2017, 2018). Only in a small number of antlion species, the larvae construct pitfall traps, thus they are considered strict sit-and-wait predators, while the majority of sand-dwelling antlion species ambushes prey just beneath the sand surface, without a pit (Mansell 1996, 1999, Klokočovnik and Devetak 2014). Psammophilous antlion larvae prefer special microhabitat, fine sand or loose soil, and many species even require a particular combination of fine sand and shelter from rain and sun (Scharf et al. 2011).

The antlion larvae detect prey according to substrate vibrations produced by the movement of the prey on sand surface (Devetak et al. 2007, Devetak 2014). While most studies on sand dwelling arthropods using substrate vibration signals have been devoted to the study of surface (Rayleigh) waves, i.e. a type of surface acoustic or vibrational waves that travel along the surface of solids (e.g. Brownell 1977, Brownell & Farley 1979, Gogala 1985, Aicher & Tautz 1990, Devetak et al. 2007), here we elucidate the role of vibrations travelling in deeper sand layers. Until now, deep sand vibrations relevant for sand dwelling arthropods have not yet been evaluated.

We addressed the following questions:

- (i) Are the non-pit-builders sensitive to substrate vibrations produced by prey, similarly to the pit-builders?
- (ii) Does the antlion buried into the deep layers of sand detect its prey moving on the surface?
- (iii) How are vibrational signals propagated deep into the sand?

Material and Methods

Animals

The antlions used in the study were third-instar larvae of *Euroleon nostras* (Geoffroy in Fourcroy, 1785) (Fig. 1a) collected in Boč mountain and the surroundings of Maribor, Slovenia. Larval stages were determined by measuring head capsule width and body length (Devetak 2005, Devetak et al. 2005). The antlions used in behavioural observations belonged to the pit-building *Myrmeleon hyalinus* Olivier, 1811 which were collected in Salamis, Cyprus, and to the non-pit-builder *Synclisis baetica* (Rambur, 1842), which were instead collected in the Divjakë-Karavasta National Park, Albania (Fig. 1b). Prior to experiments, the larvae were kept in the laboratory, at room temperature, in natural sand within plastic cups (7 cm diameter, 9 cm height). Reactions of antlions were observed in presence of prey – such as: firebugs, *Pyrrhocoris apterus* (Linnaeus, 1758) and ants, *Lasius fuliginosus* (Latreille, 1798), both collected in Maribor, and mealworm beetles, *Tenebrio molitor* (Linnaeus, 1758), originating from our laboratory stock. Ants, *Lasius* sp., were used as food source. Feeding took place every day and one ant was delivered to each antlion.

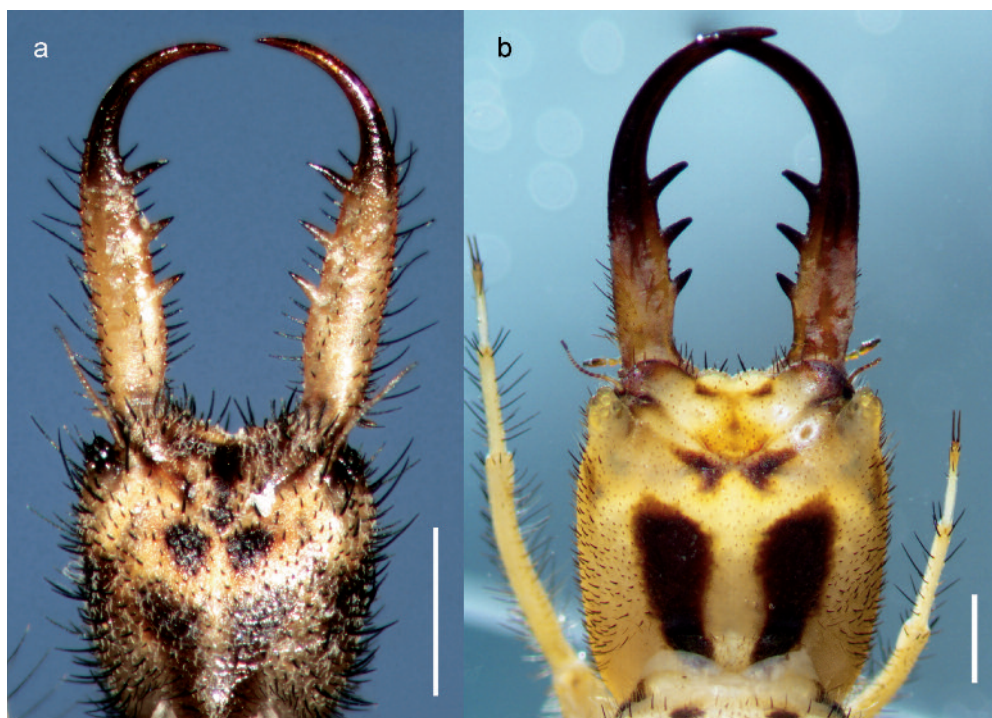


Fig. 1: The head of two antlion species, a pit-builder *Euroleon nostras* (a) and a non-pit-builder *Synclisis baetica* (b). Scale bar 1 mm.

Behavioural experiments

The response of the larvae, elicited by the sand vibrations of the prey, was recorded with a Sony HDR-CX 240E video camera, using a 16 GB SD card and a Sony HDR-CX 130 video camera, using a 32 GB SD card. To minimize disturbance, the camera was left unattended during recording.

Sand

Prior to treatment, antlions were kept in sand, originating from their natural habitat. In experiments, we used four sands differing in particle size (Table 1). The sands were obtained by sieving. The sand fractions were weighted and then, taking into account weight percentage of certain sand fraction, mean sand particle size was calculated (for details, see Devetak & Arnett 2015).

Table 1: Particle size of sands used in experiments.

	Particle sizes range	Mean particle size
Finest sand	60–230 μm	105 μm
Fine sand	230–540 μm	360 μm
Medium sand	540–1000 μm	770 μm
Coarse sand	1000–2200 μm	1650 μm

Production, recording, and analysis of the vibrational signals

The subject of the analyses were artificial and natural vibrational signals. Artificial signals were pure sine-wave pulses, with a 100-ms duration and a 25-ms amplitude ramp at the start and end of the pulse, to remove the transient onset/offset unwanted frequencies. Signals with the repetition rate of 1 s^{-1} and frequencies of 50, 100, 200, 300, and 500 Hz were applied to the sand surface using a sine wave oscillator Bistim 01 (Elestro, Slovenia) and B&K 2706 attenuator (Brüel & Kjaer, Denmark), connected to a B&K 4810 mini-vibrator. The sand surface was stimulated by direct contact with the tip of a cone (15 mm diameter, 45 mm length) mounted on the mini-vibrator (Fig. 2). The tip of the cone was sunk for 5 mm deep into sand. The source of natural vibrational signals was instead an insect walking or crawling on the sand surface.

To reduce noise from the surroundings, a plastic container filled with sand was placed on a sand layer, which in turn rested on cork, mineral-wool layer, and on a concrete plate supported by a mineral-wool layer. The experimental setup was placed on a vibration-free table, in an anechoic chamber. A plastic box (38 x 38 x 20 cm) was filled with sand. Artificial and natural vibrational signals were recorded within sand with a Brüel & Kjaer 4381 accelerometer buried inside the sand in the box at a certain depth of the substrate. The sensitive surface of the accelerometer was positioned

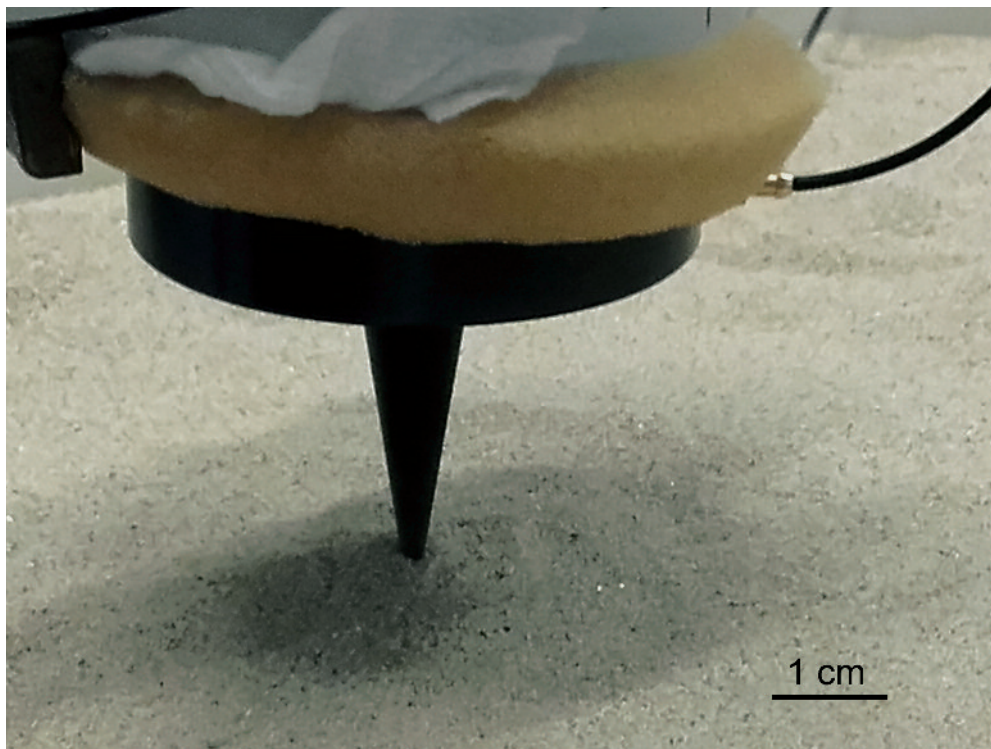


Fig. 2: Mini-vibrator Brüel & Kjaer 4810 in close contact with the sand surface at a tip of the cone.

parallel to the sand surface, so the sensitive axis of the accelerometer was orientated towards the source of vibrations. The accelerometer was connected to a B&K 2525 measuring amplifier and a personal computer.

Recordings were analysed using Avisoft SASLab Pro software (Avisoft Bioacoustics, Germany). All frequency analyses (Fast Fourier Transform) were performed using acceleration values of vibratory signals as the input parameter.

Results

Predatory behaviour

While the predatory behaviour of pit-building antlions has been thoroughly described by a number of authors (for reviews see Scharf & Ovadia 2006; Devetak 2014), there is a remarkable lack of information on the behaviour of non-pit-builders. Here, we describe the responses to the presence of prey in a non-pit-builder, i.e. *Synclisis baetica*. In this species, two prey-catching behaviours were observed, namely (i) immediate grasping the prey without previous pursuit, and (ii) active pursuit followed by grasping (Figs. 3-4).

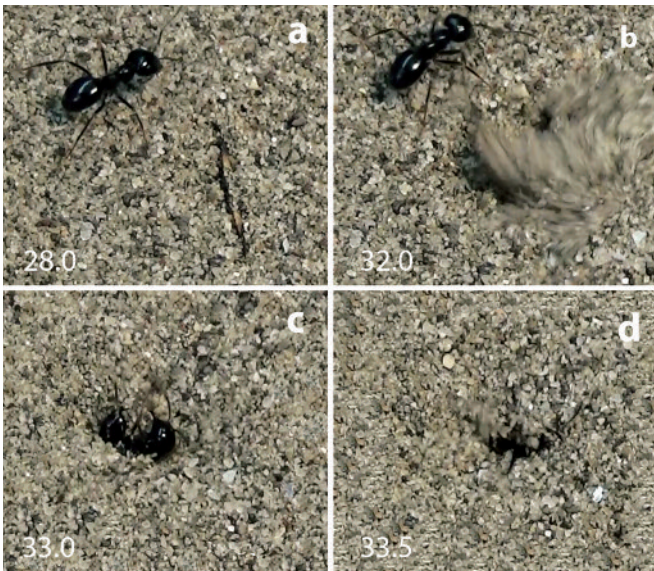


Fig. 3: Predatory behaviour in a non-pit-builder, *Synclisis baetica*: immediate grasping the prey without previous pursuit: *a* an ant approaching the agape jaws of the antlion, *b* attack, *c* grasping, *d* submersion. Numbers represent time frames in seconds. In *a*, the antlion's jaws are clearly visible.

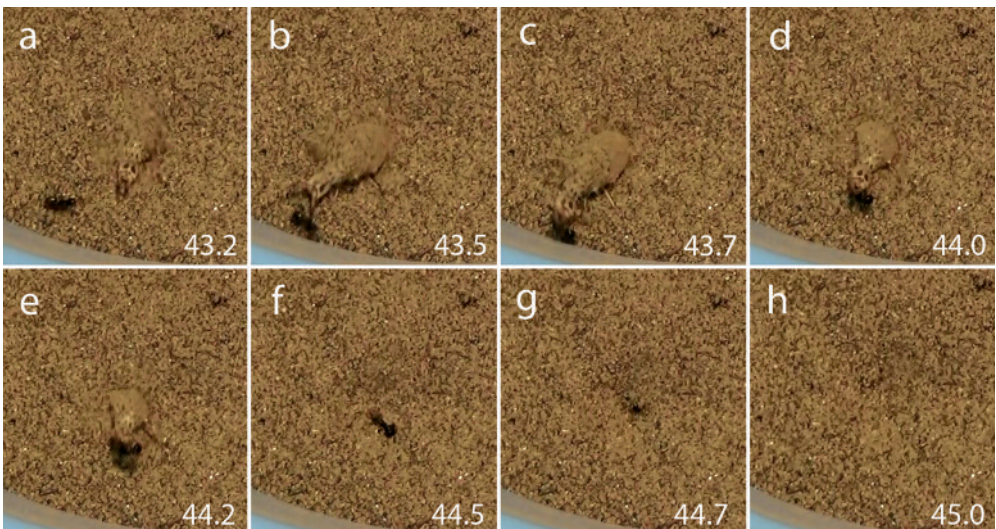


Fig. 4: Predatory behaviour in a non-pit-builder, *Synclisis baetica*: active pursuit followed by grasping: *a-b* pursuing prey, *c* grasping, *d-e* retreat, *f-h* submersion. Numbers represent time frames in seconds.

(i) Immediate grasping the prey without previous pursuit.

When an ant was gently dropped on the sand surface, the antlion larva detected the locomotory activity of the prey and moved closer to the surface. Therefore, the larva reacted to the presence of the prey without previous visual detection. The predator waited motionless just below the surface with jaws agape. When the prey

was close enough, the larva stretched out the head and prothorax in the direction of the prey and grasped it (Fig. 3).

(ii) Active pursuit followed by grasping.

When the prey was crawling at a greater distance from the predator, the antlion emerged from sand, walking forwards on the sand surface, and then it pursued the prey and grasped it (Fig. 4). In contrast to other non-pit-builders, *Synclisis* larvae moved on sand surface forwards. Video recordings clearly demonstrated that, initially, the antlion larvae were buried deeper in the substrate, consequently, vision can be safely excluded.

In another species, the pit-building antlion *Myrmeleon hyalinus*, the larvae responded to artificial vibrations with a few behavioural patterns: sand tossing, climbing up the slope of the pit, and approaching the vibrating tip of the mini-vibrator. Common European pit-building antlion species *Euroleon nostras* responded to vibrational stimuli with sand tossing and approaching the vibrating tip of the mini-vibrator.

Transmission of vibrational signals deep into sand

To get insight into the signal transmission, artificial signals were first tested. When pure sine wave signals were applied, their amplitude was reduced during transmission deep into sand (Fig. 5). Damping depended on the frequency, sand particle size and depth of substrate and the results will be discussed in a separate paper.

Substrate borne vibrations produced by small arthropods, travelled in all directions, both on sand surface and deep into substrate (Fig. 6). Power spectrum revealed that the prey signals close to sand surface, at a depth of 1 cm were relatively broadband, with a frequency range up to 4 kHz. Deeper in the substrate, at the depth of 3 cm, the upper part of the frequency range was cut off at 3.5 kHz, while at 6 cm depth at 3 kHz respectively (Fig. 7). Similar results were obtained by all three prey species tested in the experiment. Attenuation depended on sand structure; finer sands highly attenuated vibrational signals. In finer sands, higher attenuation was noted than in coarser sands, amplitudes of the signal in finer sands are up to one order of magnitude less than in

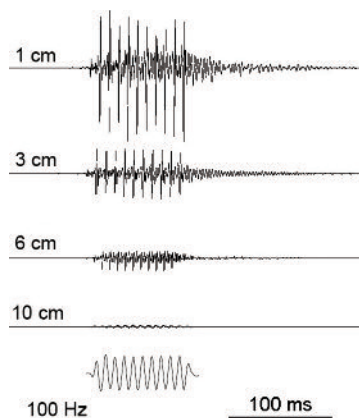


Fig. 5: Attenuation of the artificial vibrational signal (100 Hz) in coarse sand with mean particle size of 1650 μm , measured with an accelerometer at four different depths



Fig. 6: Oscillogram of the vibrational signal produced by a walking mealworm beetle (*Tenebrio molitor*), when the accelerometer was buried 1 cm deep into substrate. In this experiment, coarse sand with particle sizes 1000–2200 μm was used.

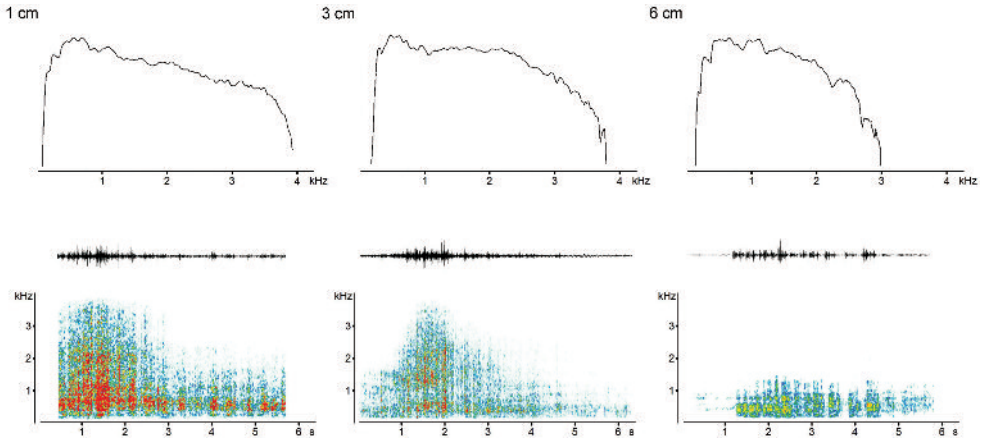


Fig. 7: Sonograms (*lower row*), oscillograms (*middle*) and power spectra (*top row*) of the vibrational signal produced by a walking *Tenebrio molitor*, when the accelerometer was buried 1 cm, 3 cm and 6 cm deep into substrate respectively. Medium sand, with particle sizes 540–1000 μm , was used.

coarser one. While fine sands filter higher frequencies, signals of low frequency are still conducted in distances of biological importance for the predatory behaviour.

Discussion

Non-pit-building antlion species are insufficiently known regarding their predatory behaviour and only a few papers describing it exist (for review, see Klokočovnik and Devetak 2014). Nevertheless, the larval behaviour in *Synclisis baetica* (included in the tribe Acanthaclisini) is described in a number of papers (e.g. Principi 1947, Krivokhatsky 2011, Badano and Pantaleoni 2014, Klokočovnik et al. 2016) and this species is surely one of the better known European non-pit-builder, being extensively studied (for review – see Badano and Pantaleoni 2014). Non-pit-builders are buried in sand but only occasionally move on sand surface. Most larvae (e.g. members of the tribes Palparini, Dendroleontini, Nemoleontini, Myrmecaelurini, Nesoleontini and Acanthaclisini) are able to move both forward and backward (Badano and Pantaleoni 2014), but only Myrmecoleontini move exclusively backward and this character supports the monophyly of the tribe (Badano et al. 2017). In our study, we found that at least two predatory strategies exist in *Synclisis baetica*. Indeed, in contrast to pit-builders and to most non-

pit-builders, the larva of *Synclisis* is able to move on sand surface both forward and backward. Moreover, it is also a quick runner able to pursue the prey.

It has been known for a long time that pit-building antlions rely on vibrational clues to detect prey (for review see Devetak 2014). In the present study, we demonstrated that even non-pit-builders detect substrate vibrations in sand. Propagation of vibrational signals is important in predator-prey interactions on sand surface, thus it is a well explored topic (e.g. Brownell 1977, Devetak et al. 2007, Fertin and Casas 2007, Devetak 2014, Martinez et al. 2018). Here, we present measurements of the vibrational signals in deep sand for the first time.

Signals produced by insect prey crawling on sand, travel on sand surface and penetrate deep into the medium. The vibrations propagating deep into the substrate behave in similar manner to surface waves (Devetak et al. 2007). However, both types of signals travelling through medium are attenuated, as a result of geometric spreading and frictional losses. Vibrations in fine sand are attenuated more strongly than in coarse sand, thus the predator detects its prey at a relatively short distance. Although the most efficient signal propagation seems to be in coarse sand, it contains too large particles thus it is inconvenient for antlions. Predators make a compromise between fine and coarse sand, choosing medium sand.

Acknowledgements

We would like to thank the Ministry of Environment, Forests and Water of the Republic of Albania for permission to collect insects in the Divjakë-Karavasta National Park. This research was supported partly by the research project Biodiversity of the Neuropterida in the Balkans (RP BioDiv Neuropterida Balkan – ALBH 2013) and partly by the Slovenian Research Agency within the Infrastructure Research Programme (Grants IP-0552 and CORE@UM).

References

- Aicher B., Tautz J.,** 1990: Vibrational communication in the fiddler crab, *Uca pugilator*. I. Signal transmission through the substratum. *Journal of Comparative Physiology A* 166: 345-353.
- Badano D., Aspöck U., Aspöck H., Cerretti P.,** 2017: Phylogeny of Myrmeleontiformia based on larval morphology (Neuropterida: Neuroptera). *Systematic Entomology* 42: 94-117.
- Badano D., Engel M.S., Basso A., Wang B., Cerretti P.,** 2018: Diverse Cretaceous larvae reveal the evolutionary and behavioural history of antlions and lacewings. *Nature Communications* 9: 3257. DOI: 10.1038/s41467-018-05484-y
- Badano D., Pantaleoni R.A.,** 2014: The larvae of European Myrmeleontidae (Neuroptera). *Zootaxa* 3762: 1-71.
- Brownell P.H.,** 1977: Compressional and surface waves in sand: used by desert scorpions to locate prey. *Science* 197: 479-482.
- Brownell P.H., Farley R.D.,** 1979: Prey-localizing behaviour of the nocturnal desert scorpion, *Paruroctonus mesaensis*: orientation to substrate vibrations. *Animal Behaviour* 27: 185-193.

- Devetak D.**, 2005: Effects of larval antlions *Euroleon nostras* (Neuroptera, Myrmeleontidae) and their pits on the escape-time of ants. *Physiological Entomology* 30: 82-86.
- Devetak D.**, 2014: Sand-borne vibrations in prey detection and orientation of antlions. In: Cocroft R.B., Gogala M., Hill P.S.M., Wessel A. (eds.), *Studying vibrational communication*. Springer, Heidelberg, pp. 319-330.
- Devetak D., Arnett A.E.**, 2015: Preference of antlion and wormlion larvae (Neuroptera: Myrmeleontidae; Diptera: Vermilionidae) for substrates according to substrate particle sizes. *European Journal of Entomology* 112: 500-509.
- Devetak D., Mencinger-Vračko B., Devetak M., Marhl M., Špernjak A.**, 2007: Sand as a medium for transmission of vibratory signals of prey in antlions *Euroleon nostras* (Neuroptera: Myrmeleontidae). *Physiological Entomology* 32: 268-274.
- Devetak D., Špernjak A., Janžekovič F.**, 2005: Substrate particle size affects pit building decision and pit size in the antlion larvae *Euroleon nostras* (Neuroptera: Myrmeleontidae). *Physiological Entomology* 30: 158-163.
- Fertin A., Casas J.**, 2007: Orientation towards prey in antlions: efficient use of wave propagation in sand. *Journal of Experimental Biology* 210: 3337-3343.
- Gogala M.**, 1985: Vibrational communication in insects (Biophysical and behavioural aspects). In: Kalmring K., Elsner N. (eds) *Acoustic and Vibrational Communication in Insects*, Paul Parey, Germany, pp. 143-150.
- Klokočovnik V., Devetak D.**, 2014: Pit-builder vs non-pit-builder: advantage of trap building strategy in antlion larvae does not mean greater behaviour diversity. *Behaviour* 151: 653-668.
- Klokočovnik V., Podlesnik J., Devetak D.**, 2016: Occurrence of the antlion tribe Acanthaclisini in the Balkan Peninsula. *Spixiana* 39: 99-104.
- Krivokhatsky V.A.**, 2011: Murav'inye l'vy (Neuroptera: Myrmeleontidae) Rossii [=Antlions (Neuroptera: Myrmeleontidae) of Russia]. *Tovarišestvo Naučnyh Izdanij KMK* [=KMK Scientific Press], Sankt-Peterburg, 334 pp. (in Russian)
- Mansell M.W.**, 1996: Predation strategies and evolution in antlions (Insecta: Neuroptera: Myrmeleontidae). In: Canard M., Aspöck H., Mansell M.W. (eds) *Pure and Applied Research in Neuropterology*, Sacco, Toulouse, pp. 161-169.
- Mansell M.W.**, 1999: Evolution and success of antlions (Neuropterida: Neuroptera: Myrmeleontidae). *Stapfia*, 60, *Neue Folge* 138: 49-58.
- Martinez V., Nowbahari E., Sillam-Dussès D., Lorent V.**, 2018: Antlions are sensitive to subnanometer amplitude vibrations carried by sand substrates. *bioRxiv* 429209, online Sept 27, 2018; doi: <http://dx.doi.org/10.1101/429209>
- Principi M. M.**, 1947: Contributi allo studio dei Neurotteri Italiani. VI. *Synclisis baetica* Ramb. (Myrmeleontidae – Acanthaclisini). *Bollettino dell'Istituto di Entomologia dell'Università degli Studi di Bologna* 16: 234-253.
- Scharf I., Lubin Y., Ovadia O.**, 2011: Foraging decisions and behavioural flexibility in trap-building predators: a review. *Biological Reviews* 86: 626-639.
- Scharf I., Ovadia O.**, 2006: Factors influencing site abandonment and site selection in a sit-and-wait predator: A review of pit-building antlion larvae. *Journal of Insect Behavior* 19: 197-218.

Received / Prejeto: 2. 10. 2018



**CAVE CRICKET GENUS *TROGLOPHILUS* AS A MODEL FOR
STUDYING FUNCTION AND EVOLUTION OF SENSORY SYSTEMS
AND BEHAVIOUR**

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Abstract - The European cave crickets *Troglophilus neglectus* and *T. cavicola* (Orthoptera: Ensifera; Rhaphidophoridae) represent an important insect model for studies of sensory systems and behaviour related to detection of exteroceptive stimuli. The reason lies both in their specific life style and the absence of hearing organs and sound communication, which are intensively investigated in other Ensifera, in particular in crickets and bushcrickets. In the first and the most extensive part of the review, I describe studies of mechanosensory systems, communication and behaviour in *Troglophilus* related to detection of mechanical signals such as substrate-borne vibration, air currents and gravity. Following are studies of the specific scent organs and olfactory communication developed in these species. These systems show a mixture of ancestral and derived characters, not only in comparison to Ensifera and other orthopteroids, but also between the two investigated species, thus offering important functional and evolutionary insights.

KEY WORDS: sensory physiology, neuroanatomy, sensory evolution, biotremology, mechanoreception, vibration, olfaction, aggression

Izvešček - JAMSKÉ KOBILICE RODU *TROGLOPHILUS* KOT MODEL ZA ŠTUDIJE DELOVANJA IN EVOLUCIJE SENZORIČNIH SISTEMOV IN VEDENJA

Evropski vrsti jamskih kobilic *Troglophilus neglectus* in *T. cavicola* (Orthoptera: Ensifera; Rhaphidophoridae) predstavljata pomemben model za raziskave senzoričnih sistemov in vedenja žuželk, povezanega z zaznavo zunanjih dražljajev. Razlog za to je tako v njihovem specifičnem načinu življenja kot tudi v odsotnosti slušnih organov in zvočne komunikacije, ki so intenzivno raziskovani pri ostalih dolgotopalnicah, predvsem murnih in kobilicah. V prvem in najboljšežnejšem delu pregleda bom opisala

raziskave senzoričnih sistemov, komunikacije in vedenja povezanega z zaznavo mehanskih dražljajev kot so vibracije podlage, zračni tok in gravitacija. Sledile bodo raziskave specifičnih organov za oddajanje vonja in s tem povezane komunikacije pri vrstah iz rodu *Troglophilus*. Ti sistemi jamskih kobilic kažejo mešanico predniških in izpeljanih lastnosti, a ne le v primerjavi z dolgotipalčnicami in ostalimi ravnokrilci, pač pa tudi med obravnavanimi vrstama. S tem nam omogočajo pomemben vpogled v razumevanje tako njihovega delovanja kot evolucijskega razvoja.

KLJUČNE BESEDE: senzorična fiziologija, neuroanatomija, senzorična evolucija, biotremologija, mehanorepcija, vibracije, voh, agresija

Introduction

Rhaphidophoridae, commonly called cave crickets or camel crickets, comprise a wingless and ecologically specialized group of Orthoptera (so. Ensifera) with most of the species adapted to a certain degree of cave life (DiRusso and Sbordoni, 1998). They have been often considered a relic ensiferan lineage for their morphology (e.g. Ander, 1939; Desutter-Grandcolas, 2003) and the wide disjunct distribution across temperate areas of both hemispheres (Hubbel and Norton, 1978). In the still unresolved phylogeny of the Ensifera, however, different approaches placed cave crickets at various branch points of the group (e.g. Legendre et al., 2010; Song et al., 2015). Yet, regardless of phylogenetic position, their sensory systems and behaviour are very interesting to study comparatively with respect to other Ensifera. The reason is not only in their specific life habits but also in the absence of auditory communication and hearing, which is present and extensively studied in crickets and bushcrickets.

The genus *Troglophilus*, in the monotypic subfamily Troglophilinae, is distributed in the Eastern Mediterranean with at least 14 species showing one centre of species richness in the Balkans and the second one in the southern part of Asia Minor, including a part of the Aegean islands (Karaman et al., 2011). *T. neglectus* and *T. cavicola* are the most widely distributed European species that reach over Slovenia to Austria and Italy at the most north-western border of their area (Karaman et al., 2011). They represent the most abundant arthropods in the Slovenian karstic undergrounds, where both species often appear syntopically (Novak and Kuštor, 1983). As suggested already by the genus name, *Troglophilus* is not strictly bound to the underground habitats. The animals overwinter in deep cave parts, while in summer they are nightly active in the forests and use superficial parts of the caves and other endogenous forest places only as daily shelters (Novak and Kuštor, 1983; Karaman et al., 2011; Fig. 1). The life cycle investigated for *T. neglectus* and *T. cavicola* shows strict seasonality, a new generation each year, and is completed in two to two and a half years (Pehani et al., 1997). There is a temporal shift between the species, with *T. cavicola* mating in the early spring and *T. neglectus* in the late summer (Pehani et al., 1997; Stritih and Čokl, 2012). Consequently, the adults of one or another species may be encountered in caves literally throughout the year, which makes them continuously accessible for investigations. In the present review I describe studies of their

Fig. 1: *T. neglectus* male during a summer day, residing on a wall of an artificial tunnel (in Brje pri Komnu, SW Slovenia) close to its entrance. Scale bar = 10 mm.



sensory systems and the related behaviours, which were initiated already at the beginning of the previous century (Seliškar, 1923).

In the first part of the review, I describe studies of mechanosensory systems, communication and behaviours in *Troglophilus* related to detection of various mechanical signals, such as substrate-borne vibrations, air currents and gravity. Following are studies of the specific scent organs and olfactory communication developed in these species. The majority of research in both fields was conducted at the National Institute of Biology in Ljubljana (former Institute of Biology). Also the scientific career of Acad. Prof. Dr. Matija Gogala, to whom this special issue of AES is dedicated, started at this institute, with the research of vision particularly in *Troglophilus* cave crickets. In his doctoral dissertation, prof. Gogala demonstrated that compound eyes of these insects are normally developed and functional (Gogala, 1964; 1966). And although visual signals cannot be of much use for communication or orientation of a nightly active species such as is *Troglophilus*, they may be considered important for maintaining their activity rhythm related to daily migrations between the hypogean and the epigean habitats.

Mechanosensory systems

Detection, production and responses to substrate vibration

Due to the lack of stridulatory structures and supported by the existing data on mating behaviour, Rhabdophoridae appear unable to produce audible sound (see Stritih and Čokl, 2012; Stritih and Strauß, 2015). They do, however, produce sub-

strate-borne vibratory signals during sexual communication, which was demonstrated for the first time in *Troglophilus* cave crickets (Stritih and Čokl, 2012). In this respect, the mechanosensory complex scolopidial organ for sound and/or vibration detection in the legs of ensiferan insects (Lakes-Harland and Strauß, 2014) was investigated in *Troglophilus* for the presence and inter-specific homology of individual groups of sensilla (i.e. sensory organs; Jeram et al., 1995; Strauß et al., 2014; Strauß and Stritih, 2016), sensitivity to sound and vibration (Jeram et al., 1995; Čokl et al., 1995), morphology and central projections of sensory neurons (Stritih and Čokl, 2014; Stritih and Stumpner, 2009; Buh, 2011; Stritih Peljhan et al., submitted), anatomy and function of postsynaptic neurons in the ventral nerve cord and their homology to auditory network elements (Stritih, 2009; Stritih and Stumpner, 2009), as well as the mechanical response of the legs and the body that filter the received signals prior sensory transduction (Stritih Peljhan and Strauß, 2018; Stritih Peljhan et al., submitted).

The subgenual organ complex

While the majority of insects possess only the subgenual organ in the proximal tibiae as the major vibrosensitive organ (albeit with highly varying complexity), orthopteroids developed an especially complex tibial mechanoreceptor system with up to 4 different sound and/or vibration sensitive scolopidial organs in close proximity (Lakes-Harlan and Strauß, 2014). In this “tibial organ” in the legs of cave crickets (Jeram et al., 1995), more recently called also the “subgenual organ complex” (SGOC; Strauß et al., 2014), the existence of two major groups of scolopidial sensilla was demonstrated by the initial histological study: the subgenual organ (SGO) with ca. 30 scolopidial sensilla and the intermediate organ (IO) with 13–15 sensilla, showing a similar structure to that in bushcrickets (Jeram et al., 1995). No accessory auditory structures like external tympana or internal tracheal modifications for sound reception and transmission were found, and no sensilla at the distal location in the organ to suggest homology to auditory sensilla of Ensifera. Summed responses to auditory stimuli recorded from the leg nerve had very high thresholds compared to species with tympana and were restricted to low-frequencies (Jeram et al., 1995). In an accompanying study, the individual SGO and IO sensilla showed a high sensitivity to substrate vibration (and weak or no responses to airborne sound; Čokl et al., 1995; see also below). However, given that a relic (or reduced) auditory organ (called the “*crista acustica* homologue”, CAH), the third major structure in the complex, was subsequently found in all other major groups of Ensifera lacking tympana (Strauß and Lakes-Harlan, 2008a; 2008b; 2010), its putative presence in *Troglophilus* was reinvestigated, giving further anatomical details on neuronal innervation of sensilla (Strauß et al., 2014). The study confirmed the presence of only two major organs in the anterior SGOC, consistent with an ancestral organisation such as seen in outgroup Orthopteroidea (Strauß et al., 2014; Fig. 2A). Furthermore, the axonal tracing method revealed an additional small scolopidial organ posteriorly in the tibia. This is the accessory organ (AO), comprising a distinct cluster of 6–8 sensilla just next to the posterior hypodermis and the SGO (Strauß and Stritih, 2016; Fig. 2B). This organ is found to occur irregularly across orthopteroids (Strauß 2017).

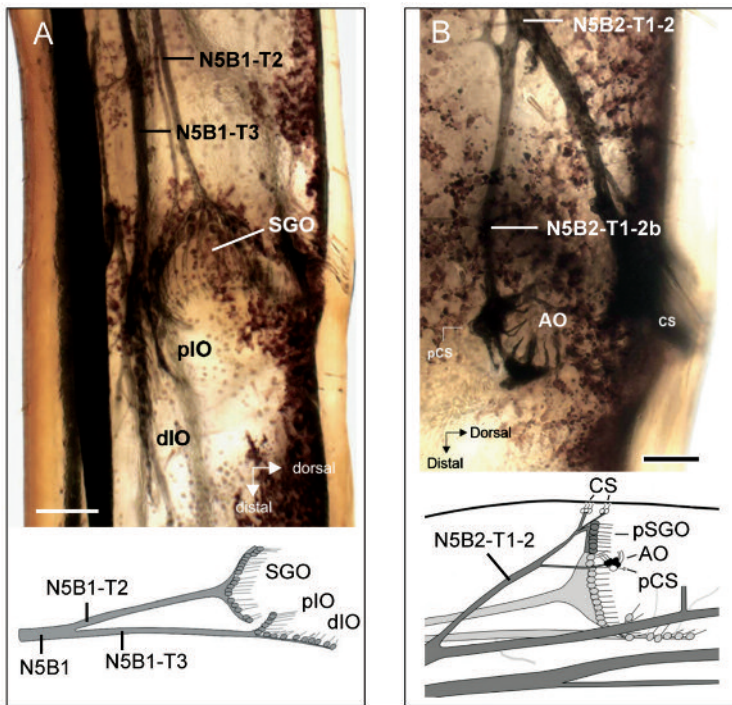


Fig. 2: Neuroanatomy of the SGOC in *T. neglectus* in wholemount preparations (above) and drawing reconstructions of innervation (below). **A)** Sensory elements innervated by nerve 5B1 (branches N5B1-T2 and -T3), anteriorly in the tibia. Above: midleg preparation, scale bar 100 μm. Below: the consensus branching pattern of N5B1, consistent with the presence of only two organs in the anterior SGOC; the SGO and the IO. **B)** Sensory elements innervated by nerve 5B2 (branch N5B2-T1-2), posteriorly in the tibia. Above: foreleg preparation, scale bar 50 μm. In the scheme below, elements innervated by N5B1 are shown at the back, and the upper line represents leg cuticle. The innervation schemes are not to scale, and are shown in 90° counter-clockwise orientation. Abbreviations: AO – accessory organ, CS – campaniform sensilla, pCS –posterior campaniform sensillum, pIO – proximal intermediate organ, dIO – distal intermediate organ, SGO – subgenual organ. Adapted from: A) Strauß et al. (2014) and B) Strauß and Stritih (2016), the latter with permission from John Wiley & Sons.

The physiological responses of individual receptor neurons from the SGO and the IO in *T. neglectus* were extensively investigated by extracellular recordings (Čokl et al., 1995). Described were eleven functional receptor types, four with best sensitivity to vibration between 700 and 2000 Hz and the rest with a tuning to lower frequencies (200–700 Hz), supposedly originating in the IO and the SGO, respectively (Čokl et al., 1995). This presumption was based on the comparison to bushcrickets that show

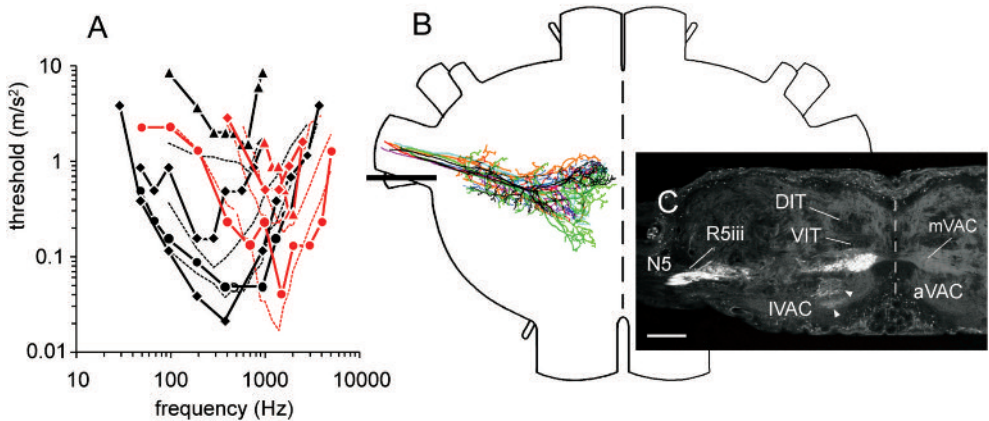


Fig. 3: Physiology, morphology and anatomy of central axonal projections of vibratory receptor neurons from the anterior SGOC of *T. neglectus*. **A)** Threshold tuning curves for seven types of intracellularly recorded receptors from forelegs (full lines with symbols), with corresponding tuning curves of the extracellularly recorded response types (dashed lines). Black: SGO receptors, red: IO receptors. **B)** Terminal arborisations of the intracellularly stained receptor neurons in the prothoracic ganglion (wholemout dorso-ventral view). Individual neurons from different preparations are shown in different colour and superimposed. The assembly shows a typical bifurcation pattern, revealed also by the anterograde tracing of N5B1 axons. **C)** Anatomical location of axonal projections from N5B1, filled anterogradely with Lucifer Yellow, in the transverse section of the ganglion at the level indicated in B). Abbreviations: DIT, dorsal intermediate tract; VIT, ventral intermediate tract; aVAC, antero-ventral association centre; mVAC, medio-ventral association centre; N5, nerve 5 (= main leg nerve); R5iii, third root of the leg nerve. New data analysis is shown in B), while A) and C) are adapted from Stritih and Čokl (2014), with permission from Springer, and Strauß et al. (2014, respectively).

similar vibratory receptor classes, of which the IO receptors show the response also to low-frequency sound due to their functional coupling to the auditory apparatus (Kalmring et al., 1994). The constraint of these studies, however, was that neither paid attention to responses tuned to frequencies below 200 Hz, a priori considering them as a response of proprioceptors and thus less important for complex sensory processing. In following investigations, vibratory receptor neurons were studied in *Troglophilus* using combined intracellular recording and staining, which allows for a morphological characterisation of the terminal branching pattern and anatomical position or the recorded axons in the neuropile (Stritih and Stumpner, 2009; Buh, 2011; Stritih and Čokl, 2014; Stritih Peljhan et al., submitted). These studies showed that the high-frequency tuned receptors conforming to physiological classes of Čokl et al. (1995; Fig. 3A), which were identified most frequently, project ventrally into the medio-ventral association centre (mVAC) of the segmental ganglion – the region

specialised for processing of auditory and vibratory inputs (e.g. Strauß et al., 2014; Fig. 3B, C). An additional low-frequency receptor neuron type with a tuning to 50–300 Hz and projections into the dorsal part of the mVAC was described for the first time as a part of the SGO complex, and originates either in the AO or the posterior SGO, based on anatomical and physiological characteristics (Stritih Peljhan et al., submitted). This provides the first intracellular data on the sensory input into the region of the ventral nerve cord devoted to processing of low-frequency vibratory stimuli, such as are used in communication of *Troglophilus* and many other orthopteroids (Stritih and Čokl, 2014; see also below).

Mechanical leg response

Detection of substrate vibration is related to exceptionally strong physical constraints of the transmission medium that filters and distorts the propagating signals. Using laser vibrometry, we have investigated the influence of mechanical properties of the legs in *Troglophilus*, the finite element in signal transmission, on the sensory adaptations of the individual organs in the SGOC (Stritih Peljhan and Strauß, 2018; Stritih Peljhan et al., submitted). The tibia was found to be the most appropriate place for vibrosensory organs, since it vibrated stronger than any other leg segments in the response to substrate vibration due to mechanical resonance (Fig. 4A). Position of the response peak depended largely on various parameters of the stance, such as the level of leg flexion (Fig. 4B), the presence of body-substrate contact and apparently also the muscle tension, which gives the animals a potential to strongly influence vibration detection by postural adjustments. The response intensity increased with the increasing stimulus frequency (Fig. 4C), and the shape of the response function peaking at high frequencies matched the threshold curves of two IO receptor types from *Troglophilus* (Čokl et al., 1995) closely (Fig. 4D). These data suggest an adaptive value of the IO in detecting high frequency vibration transmitted over the leg surface (Stritih Peljhan and Strauß, 2018). Such a function would further distinguish the IO from the SGO, which is excited by haemolymph movements within the tibia caused by substrate vibration (Kilpinen and Storm, 1997). In the following set of measurements we compared the mechanical response between the lateral sides of the proximal tibia, showing that in the narrow low-frequency range between 100 and 200 Hz the surface of the posterior tibia oscillates slightly, but significantly, more intensely than the anterior tibia. This difference indicates that the specific position of the AO, linked to the posterior cuticle, may be adaptive (Stritih Peljhan et al., submitted).

Anatomy, function and homology of vibratory interneurons

When a sensory organ changes functionally during evolution, what happens to the central neuronal network receiving inputs from this organ? This question directed our research of vibration-sensitive interneurons in the prothoracic ventral nerve chord ganglion of *T. neglectus* (Stritih and Stumpner, 2009; Stritih, 2009). Having in mind the conservative nature of the central neural system, we expected to find homologues to the auditory neurons of Ensifera, which are in the hearing species connected to the functionally elaborated sound- and vibration-sensitive organ in the forelegs. Among the 26

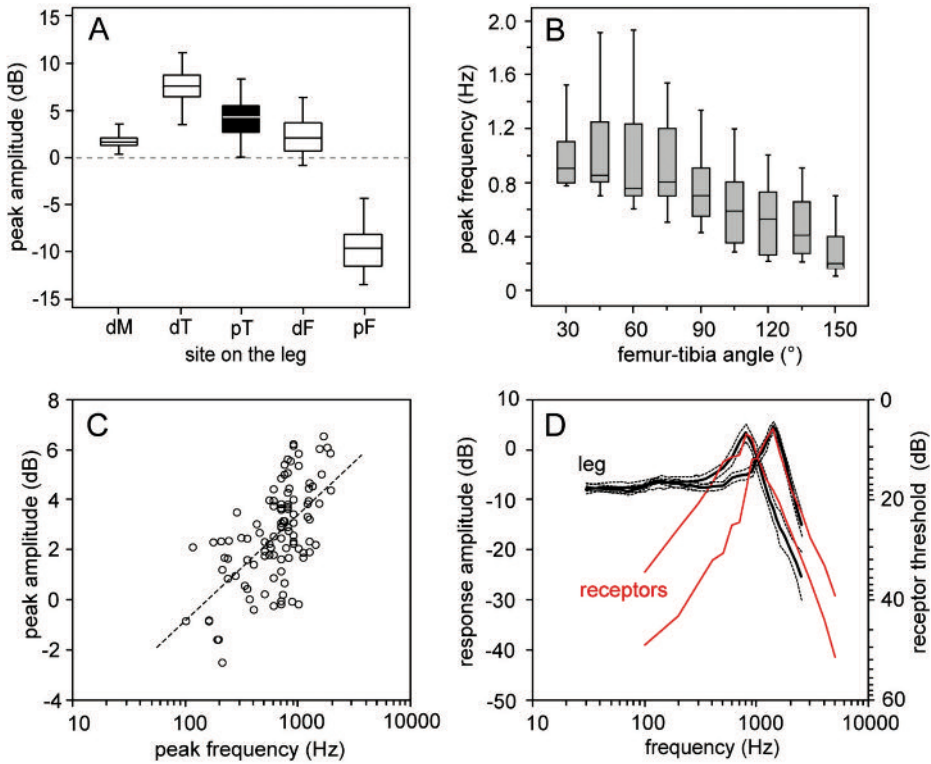


Fig. 4: The mechanical leg response to vibratory stimuli in *T. neglectus*. **A)** Response gain at different measurement sites of the leg (dM – distal metatarsus, dT – distal tibia, pT – proximal tibia (SGOC location; in black), dF – distal femur, pF – proximal femur), with the femur and tibia standing at right angles. Dashed line at 0 dB indicates the intensity of stimuli applied at the tarsus. **B)** Peak response frequency at different femur-tibia angles and **C)** peak response amplitude as a function of frequency from the same data set. **D)** Leg frequency-response functions (black lines, mean with S.E. range; left scale) for the legs/positions showing the peak at 800 Hz and 1400 Hz, superimposed to the mean (inverted) threshold curves of two IO receptor types tuned to these frequencies (red lines; right scale, shown in relative values – the intensity of threshold curves is set to the best match with the leg response). Adapted from Stritih Peljhan and Strauß (2018), with permission from Springer.

neuron types identified by their morphology and/or physiology, we recognised homologues to some of the specialised first-order auditory interneurons of crickets and bushcrickets (Stritih and Stumpner, 2009; Fig. 5). While retaining the same morphology of primary branches and soma location, similar intrinsic properties, and apparently also their basic implementation in the network, the auditory neurons showed drastic changes in dendritic morphology compared to their vibratory counterparts (Fig. 5A). Clearly, these changes reflect the modified receptor input from the vibratory to the auditory

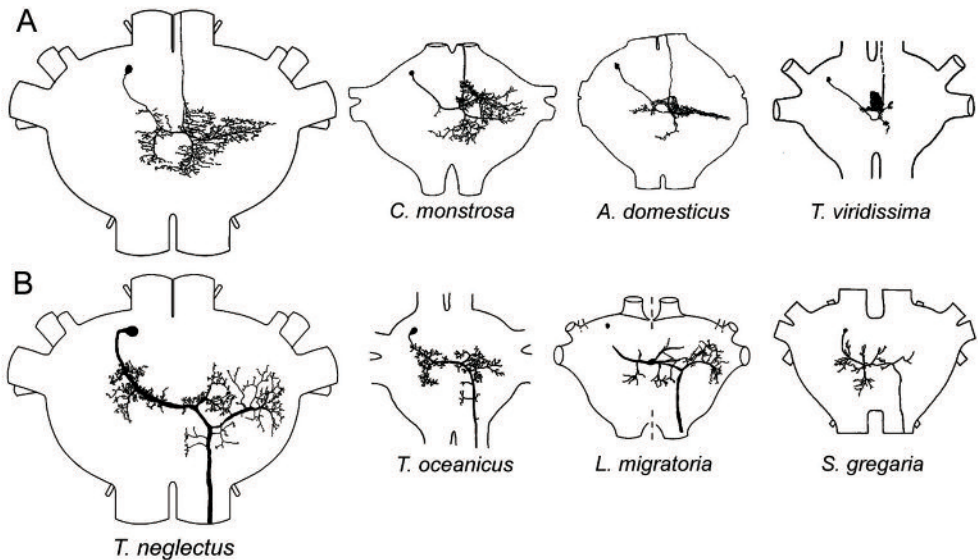


Fig. 5: Morphology of vibration-sensitive interneurons in the prothoracic ganglion of *T. neglectus*, with putative homologues from different Orthoptera (the hump backed cricket *Cyphoderris monstrosa*, crickets *Acheta domesticus* and *Teleogryllus oceanicus*, and the bushcricket *Tettigonia viridissima* of Ensifera, and the grasshoppers *Locusta migratoria* and *Schistocerca gregaria* of Caelifera). The homologues in **A**) indicate the presumed evolutionary changes in morphology (from left to right) following auditory specialization from a vibrosensitive precursor neuron. The homologues in **B**) represent morphologically and apparently also functionally preserved neurons in the different lineages. Adapted from Stritih and Stumpner (2009), with permission from Elsevier. The neuron of *S. gregaria* is included additionally from Stritih (2006). The wholemount morphology of *T. neglectus* neuron in A) was reconstructed *de novo* from the original material (photos of histological sections).

portion of the sensory organ and the modified requirements for directional processing between the systems (Stritih and Stumpner, 2009). Again, in *Troglophilus* these neurons conform more to a primeval rather than reduced sensory organisation. Several further cave cricket neurons were homologised to neurons from various orthopteroids, where they often receive multimodal inputs and show comparatively little or no change in morphology and function (Fig. 5B). They were suggested as elements of the evolutionary conserved multimodal escape or warning system (Stritih and Stumpner, 2009).

From the functional viewpoint, an unexpected bias to processing of low frequency vibration inputs was found in *Troglophilus*, with the majority of interneurons responding most sensitively to vibration below 400 Hz (Stritih, 2009; Fig. 6A). While responses and neuropile location in a portion of these neurons suggested inputs from proprioceptive organs, a group of highly-sensitive neurons had dendritic (i.e. postsynaptic) segments in the mVAC neuropile specialised for processing of auditory and

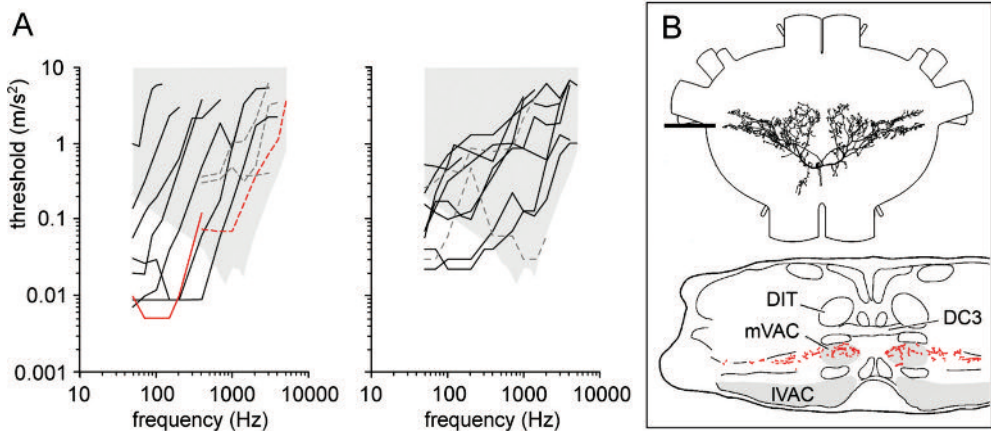


Fig. 6: Processing of low-frequency stimuli in the vibratory system of *T. neglectus*. **A)** Threshold tuning of 15 interneuron types with the best sensitivity to vibration below 400 Hz (full lines—excitation, dashed lines—inhibition). Neurons are shown in two classes according to the shapes of tuning curves. The gray area shows the response range of SGOC receptors (after Čokl et al., 1995). Note the the miss-match to interneurons, apparently with vibratory inputs from other receptor elements. **B)** Morphology of a highly-sensitive first-order interneuron (above; wholemount dorsoventral view) and its location in the neuropile in the transverse section of the ganglion (below; neuronal branches are shown in red) at the level indicated above. In A), thresholds of this neuron type are marked red. Adapted from: A) Stritih (2009), with permission from John Wiley & Sons, and B) Stritih and Stumpner (2009), with permission from Elsevier.

vibratory stimuli. Dorsal location of some neurons in this neuropile (Fig. 6B) is consistent with inputs from a part of the femoral chordotonal organ, the posterior-most portion of the SGO and/or the AO sensilla (Stritih, 2009; see also Nishino, 2003; Nishino and Field, 2003). Such information processing was later shown to conform to processing of low-frequency vibratory tremulation signals in *Troglophilus* (Stritih and Čokl, 2012), signals that are often a part of multimodal courtship displays in other orthopteroids as well (Stritih and Čokl, 2014).

Mating behaviour and vibratory signalling

The high ecological similarity of *T. neglectus* and *T. cavicola*, together with their complete temporal isolation (Novak and Kuštor, 1983; Pehani et al., 1997), generally suggests a weak selection pressure for their divergent behavioural evolution. It was thus surprising to find differences in their mating behaviour, not only in the patterns or timing of principally similar behaviours, but extending to the level of employed stimulus modalities (Stritih and Čokl, 2012). During the close range courtship, *T. neglectus* males emit low-frequency vibratory signals by abdominal tremulation (i.e. oscillation without contacting the substrate; Fig. 7A, B), while such signalling is absent

prior to pair formation in *T. cavicola* (Fig. 7C). In this species, the phase of mutual antennal fencing of the partners is much longer than in *T. neglectus*, suggesting a primary importance of tactile stimuli in courtship. And while the complete mating process only lasts a few minutes in *T. neglectus*, about 10-20 minutes is typical for *T. cavicola* (Fig. 7C). We suggested these differences to reflect the divergent mating habitats in and outside caves for *T. cavicola* and *T. neglectus*, respectively, which comply with timing of their respective sexual maturation immediately after and long after completed diapause (Stritih and Čokl, 2012). In spring one can frequently encounter female *T.*

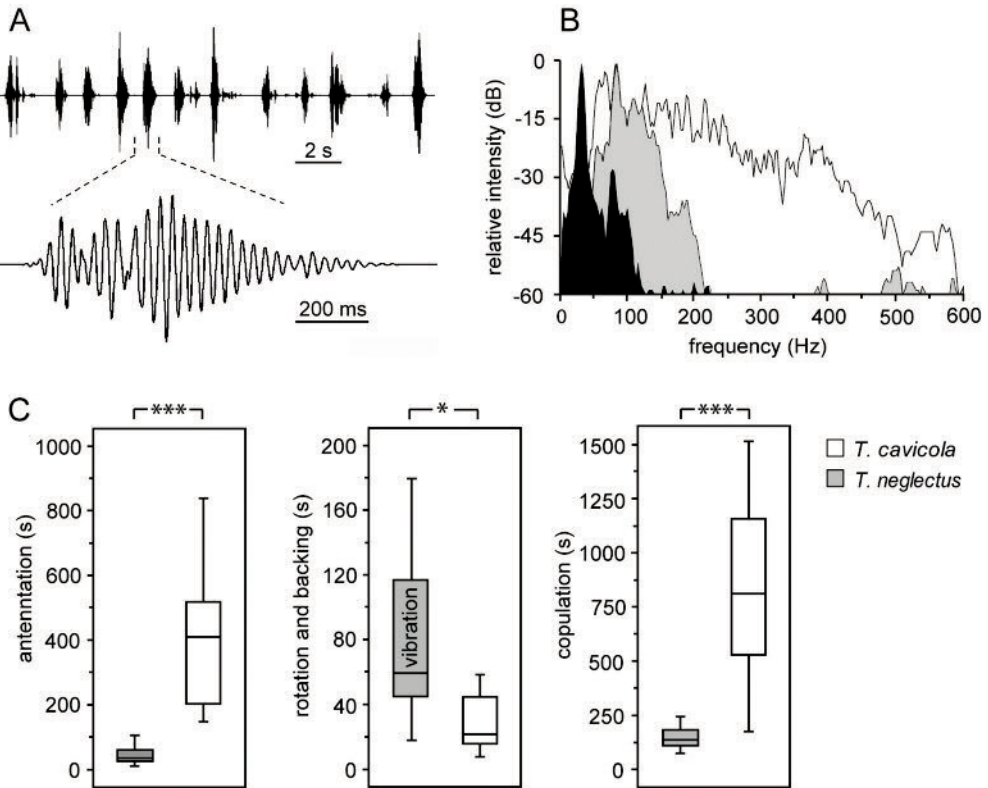


Fig. 7: Mating behaviour and vibratory signalling. **A)** Sample oscillograms of male vibratory courtship signals emitted by abdominal tremulation in *T. neglectus*. **B)** Sample spectrograms of these signals recorded from different substrates (black – elm bark, grey – spruce bark, white – moss). **C)** Duration of main phases of the mating process (appearing in succession from left to right) compared between *T. neglectus* and *T. cavicola*. Asterisks indicate different degrees of statistical significance (for more details see Stritih and Čokl, 2012). Vibrational signalling in courtship is expressed in *T. neglectus* only (see the middle diagram). After copulation, males of both species express vigorous whole-body tremulation with an unknown function (not shown). Adapted from Stritih and Čokl (2012).

cavicola with spermatophores still in deep cave parts, and its prolonged copulation possibly reflects the relaxed predation pressure in a cave environment. Since rock was proved extremely inefficient for vibration transmission (Stritih and Čokl, 2012; see also Stritih and Strauß, 2015; Strauß and Stritih 2017), we suggested vibratory signalling to be reduced in *T. cavicola* following its adaptations to mating underground. The sexual behaviour of *T. neglectus*, on the other hand, was suggested to represent a primitive condition of the sylvicolous cave cricket ancestors (Stritih and Čokl, 2012; see also Hubbel and Norton, 1978). In line with this hypothesis, recent data indicate that the genus *Troglophilus* diverged from the common ancestor very early in the evolution of Rhabdiphoridae (Song et al., 2015; Zhou et al., 2017) and may have thus retained many primitive characters. Its vibratory signalling may also represent the primitive mode of mechanosensory communication for the Ensifera, in which the different ways of vibratory signalling seen in the extant taxa could have been easily derived from abdominal tremulation (Stritih and Čokl, 2012; Stritih and Strauß, 2015).

A further divergence in the sexual behaviour of the two species relates to olfactory signalling and agonistic behaviour. An extensive reliance on odour has been demonstrated for *T. neglectus* males in agonistic contests (Stritih, 2014; Stritih and Žunič-Kosi, 2017; see also below). In *T. cavicola*, not only are their scent glands much less developed and were never observed exposed to the body surface as in *T. neglectus*, the species shows also no sign of inter-male aggression in the mating period (Stritih and Čokl, 2012). For cavernicolous animals aggression may be completely reduced to optimise energy expenditure (Ellipot et al., 2013), which is in line with a higher level of cavernicolous adaptations proposed for *T. cavicola*.

Behavioural responses to vibration

Despite the courtship vibratory signalling of *T. neglectus* males not being a subject of systematic experimental manipulation, its function in increasing female sexual receptivity and inducing her mounting for copulation may generally be assumed. This is also supported by far the longest vibratory courtship phase recorded in the pair that mated on the stony substrate in our study, on which the intensity of vibratory signals was below the vibrosensory detection threshold of the species (Stritih and Čokl, 2012; Stritih and Strauß, 2015). A clear behavioural response to vibration can be induced, on the other hand, by low frequency vibratory stimuli delivered to cave crickets at very high intensities. A stationary startle response, expressed as a jerky contraction of the legs and the body, occurs with a sharp tuning to 30–50 Hz vibrations that follow the line of equal stimulus displacement with the increasing stimulus frequency (Stritih and Čokl, 2014). The reaction, supposed to function as preparatory behaviour for the escape jump, is induced by almost the same frequency-intensity range of vibratory stimuli in locusts (Friedel, 1999). This behavioural agreement provides a further argument for the evolutionary conserved escape neuron networks of orthopteroids.

Detection and responses to air currents and gravity

As in other insects, the cave cricket's escape behaviour is multimodally triggered, but specifically for their life style it is strongly influenced by inclination of the

ground. Anyone working with cave crickets would immediately notice how easy it is to collect them from cave walls, while on horizontal surfaces they typically show a high level of arousal. The inclination-sensitive gating of their locomotor activity and ventilatory movements was studied extensively by Kastberger (1982; 1984; 1985). He showed that the jump rate in *T. cavicola* stimulated by air puffs or touch decreases with the increasing steepness of the floor up to 60° and is almost completely inhibited on steeper surfaces (Fig. 8A). Along with jumping, cave crickets show thigmotactic behaviour (i.e. seeking shelters) that is positive on horizontal and negative on vertical

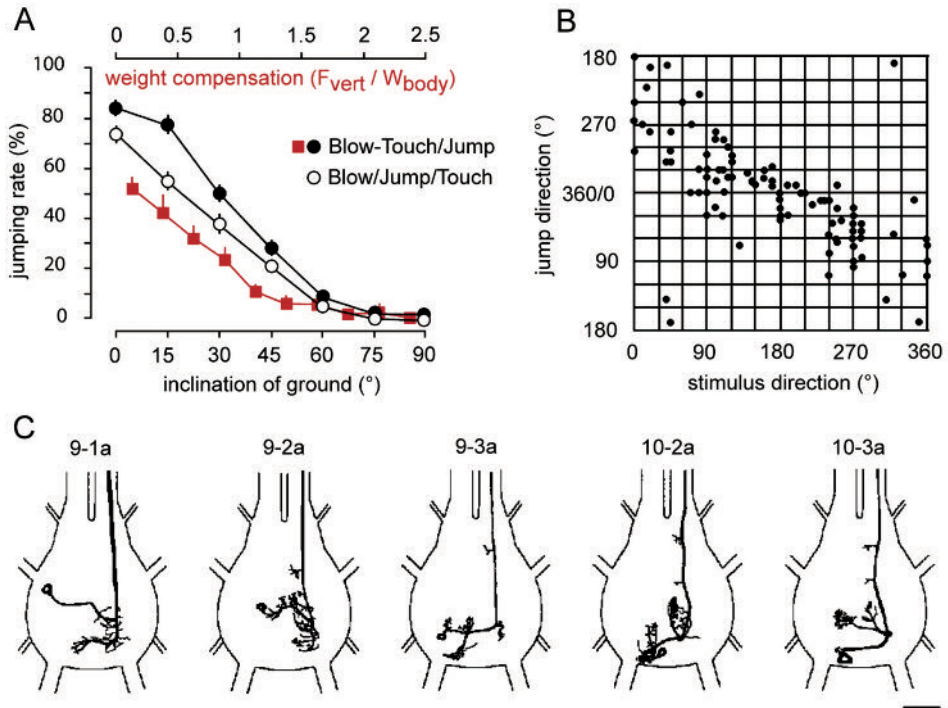


Fig. 8: Evasive behaviour, its proprioceptive gating, and giant interneurons of the cercal system. **A)** Dependence of the rate of evasive jumping in *T. cavicola* on the ground inclination (with two stimulus modes; black and white symbols, lower scale) and on compensation for body weight (red symbols, upper scale; F_{vert} –vertical force that compensates for body weight– W_{body}). Redrawn and combined from Kastberger (1982) and Kastberger (1984), with permission from John Wiley & Sons. **B)** Direction of the evasive jump in *T. neglectus* to wind puffs (0/360° - front of the animal, 180° - rear of the animal). Redrawn from Schrader (2000), with permission from Springer. **C)** Morphology of five types of GIs in the terminal abdominal ganglion of *T. neglectus* (wholmount dorso-ventral view) receiving mechanosensory inputs from the cerci. Their labels conform to the scheme in crickets; the neurons from 9-2a to 10-3a resemble the cricket counterparts most closely. From Schrader et al. (2002), with permission from John Wiley & Sons.

surfaces. Also, at inclinations above 45° the majority of cave crickets face upwards, while below 45° there is no bias in their orienting direction (Kastberger, 1982). Using innovative experimental approaches in free-standing and tethered animals exposed to various stimulation regimes and stimuli combinations, Kastberger (1984) demonstrated that gating of these behaviours is mediated via leg proprioceptors (Fig. 8A) and modulated by at least two further channels of gain control: the extero-mechanoreceptive and visual inputs. In the following study, these stimuli were shown to influence also the rhythm of abdominal respiratory movements (ARM), which specifically in cave crickets is modulated strongly by posture (Kastberger, 1985). Under most experimental conditions, the cycling of the ARM pacemaker was found retarded in vertical stance and advanced in horizontal stance, suggesting coupling of the ventilatory rhythm to either general state of arousal or locomotor activity. A model for resetting and sensory modulation of ARM was proposed (Kastberger, 1985).

The cercal system of cave crickets for detection of air currents and triggering escape responses differs from other orthopteroids in that the abdominal cerci covered with sensory hairs are oriented perpendicularly and not parallel to the ground. The effect of this difference was studied in *T. neglectus* behaviourally and at the level of cercal giant interneurons (GIs; Schrader, 2000; Schrader et al., 2002). Cave crickets well detect the direction of wind stimuli and jump away from a wind puff (Fig. 8B), but in contrast to crickets they jump directly away from the stimulus without turning their body first; e.g. if stimulated from the front, the animal jumps backwards (Schrader 2000). Five types of wind-sensitive GIs (Schrader et al., 2002; Fig. 8C) and an additional two types of local interneurons (Schrader, 2000) were identified in the terminal abdominal ganglion of the ventral nerve cord. Four dorsal GIs closely resemble their putative cricket homologues morphologically and in directional sensitivity, while the ventral GI differs somewhat from its cricket counterpart in the location of dendritic branches and the responsiveness to horizontal stimuli. The local neurons were suggested to modulate directional sensitivity of the GIs with inhibitory inputs. As no change in directional sensitivity was found in cave crickets at the level of central processing, the study presumed compensatory changes in directional preferences of sensory hairs due to the changed orientation of the cerci (Schrader et al., 2002).

Chemosensory systems and communication

In the absence of long-distance acoustic signals and also useful visual signals for nocturnal and cavernicolous Rhaphidophoridae, these species have been traditionally regarded to strongly rely on chemical communication. Converгентly developed hypodermal glands were long known from males of different genera, and in the most elaborated form from *Troglophilus* (Seliškar, 1923). Here, two pairs of large gland sacks are present dorsally in the male abdomen, being filled with a red secretion that is strongly aromatic. Each pair of gland sacks protrudes to the body surface within a dermal bulb between the subsequent abdominal tergites (Fig. 9A₁). Almost a century ago, the Slovenian physiologist and speleobiologist Albin Seliškar investigated histology and development of these glands in *T. neglectus* and *T. cavicola* and tried to elucidate

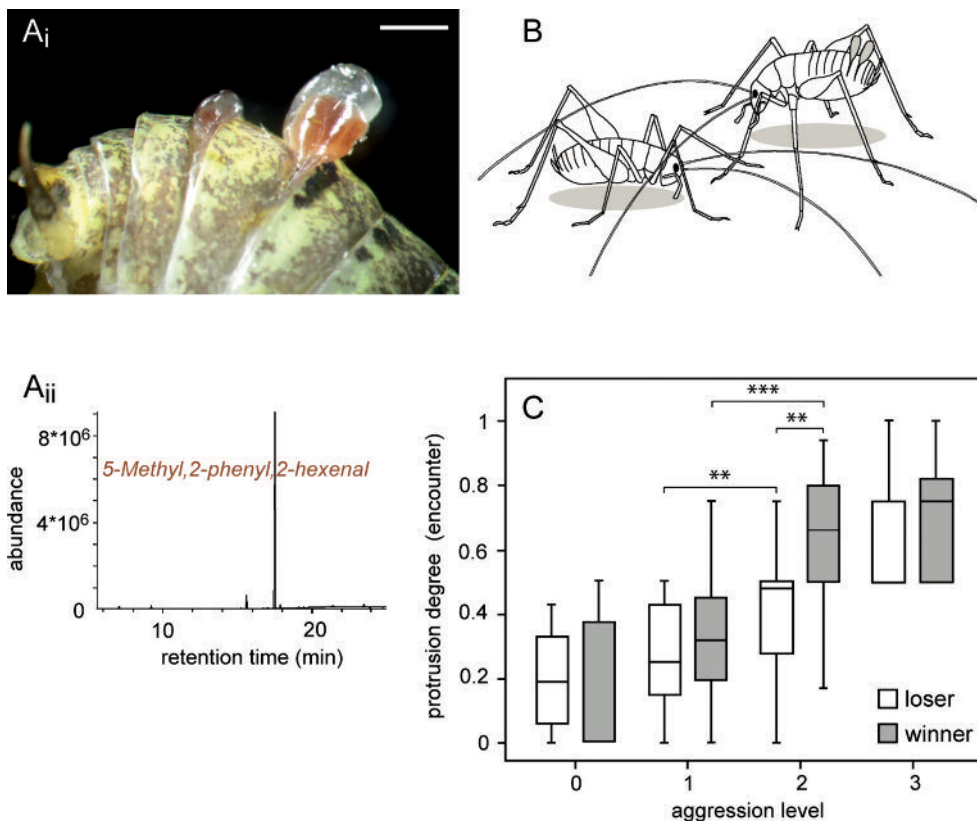


Fig. 9: Scent glands in *T. neglectus*, the released odour and its role in inter-male aggression. **A_i**) Protrusion of dermal bulbs, containing gland sacks with red secretion, induced in the intersegmental regions between 5th–7th abdominal segments by slight compression of the male's abdomen. **A_{ii}**) Gas chromatogram of the released volatile. Large amounts of 5-Methyl, 2-phenyl, 2-hexenal release was demonstrated from only briefly protruded glands, typical for *T. neglectus* contests. **B**) Drawing reconstruction of a male pair in a contest. The dominant male (right), with an elevated (i.e. aggressive) body posture, protrudes both gland bulbs in the phase just prior to attack. The subordinate male has glands retracted and shows a lowered (submissive) posture just prior to retreat. **C**) Gland protrusion degree (a combined, normalized measure on the frequency-intensity of protrusion) in winners and losers of individual encounters (contests) at different levels of aggressive escalation. The diagram shows the increase of gland protrusion in the aggressive context, its significant increase in both contestants with the occurrence of the elevated body posture (aggression level 2), and its decisive influence for winning/losing a contest at this level of aggressive escalation, just prior to an attack (aggression level 3). The asterisks relate to different degrees of statistical significance (for more details see Stritih and Žunič Kosi, 2017). Adapted from Stritih and Žunič Kosi (2017).

their function by behavioural observations (Seliškar, 1923). He showed that the gland epithelium becomes functional after the final molt, is much more extensive in *T. neglectus* than in *T. cavicola* and protrudes spontaneously to the body surface only in the former species. Making interspecific behavioural comparisons to orthopteroids, like tree crickets and cockroaches, he generally presumed the function of the released odour in attraction and/or sexual stimulation of females (Seliškar, 1923). Much later on, 5-Methyl-2-phenyl-2-hexenal was identified as the major volatile compound from gland secretion in *Troglophilus* (Raspočnik et al., 1998; see also Fig. 9A_{ii}). The compound was offered to larvae and adults of both sexes in a simple experiment that elicited no behavioural response. Our later studies demonstrated the male odour to function in the complex behavioural context of inter-male aggression (Stritih, 2014; Stritih and Žunič Kosi, 2017). By analysing pre-mating behaviour within small male-female groups of *T. neglectus*, we showed that gland protrusion does not necessarily accompany male courtship or pre-mating time, in general, and causes neither female attraction nor influences courtship success (Stritih, 2014). Gland protrusion occurred most frequently during male-male encounters and particularly their aggressive behaviour, thus implying the function of the released odour as an inter-male agonistic signal (Stritih, 2014). In the following study we investigated the details of male contest behaviour and correlated them with the frequency and extent of gland tissue protrusion in each individual as an indication of the amount of released odour (Stritih and Žunič Kosi, 2017; Fig. 9B, C). These correlations suggested the odour to function as an aggressive threat signal that significantly influences contest resolution (Fig. 9C), as well as signals dominance, thereafter. We further manipulated the signal exchange by preventing gland tissue protrusion in the contestants, and analysed the behavioural consequences of different treatments (Stritih and Žunič Kosi, 2017). This approach directly demonstrated that the odour functions as a highly effective threat that prevents maximal contest escalation and decreases the contest-related costs. The study provided the first evidence of olfactory signalling of aggressive intent (motivation) in a terrestrial animal, using a system of eversible scent glands for the instantaneous modulation of odour release along with the changing behavioural context.

Conclusions and outlook

The mechanosensory and chemosensory systems described in *Troglophilus* show a mixture of ancestral and derived characters, not only in comparison to other Ensifera and orthopteroids but also between the two investigated species. While *T. neglectus* and *T. cavicola* appear highly similar in morphology and their general ecological preferences, their sexual behaviour and communication strongly differ. Apparently, these differences reflect a higher level of cavernicolous adaptations in *T. cavicola* related to the reproductive period in comparison to its sympatric species. Studying different aspects of their sensory physiology, sensory anatomy, biophysics and behaviour in a comparative framework markedly increased our understanding of the function and evolution of these systems. The current level of knowledge provides us with a line of further questions to be answered, thus keeping *Troglophilus* as a promising area of future research.

Acknowledgements

I thank the past head of our department at NIB and my mentor, Andrej Čokl, and the present head Meta Virant-Doberlet, for their constant support of the work. I am grateful to Andreas Stumpner (Göttingen) and Johannes Strauß (Giessen) for their friendship and scientific cooperation, from which I've learned a lot. I would like to acknowledge Matija Gogala for paving the way of research of our group in biotremology and sensory physiology. I thank Johannes Strauß, Peggy Hill (Tulsa) and Matija Gogala for revising the manuscript.

Funding

The author's work presented in this review was funded by the Slovenian Research Agency (Masters and PhD grants, research project J-0823-0105, and research core funding P1-0255) and the EU grant of the 5th RTD Framework Programme (Marie Curie Training Site, QLGA-1999-51322).

References

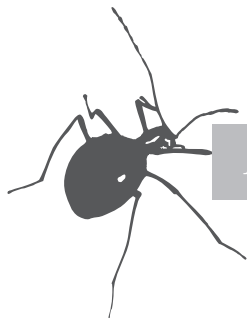
- Ander, K.**, 1939. Vergleichend-Anatomische und phylogenetische Studien über die Ensifera (Saltatoria), *Opuscula Ent.* Suppl. II., Lund.
- Buh, B.**, 2011. Morphological and functional characterization of vibratory receptor neurons in cave crickets of the genus *Troglophilus* (Orthoptera, Rhaphidophoridae). Graduation thesis, University of Ljubljana.
- Čokl, A., Kalmring, K., Rossler, W.**, 1995. Physiology of atympanate tibial organs in forelegs and midlegs of the cave-living Ensifera, *Troglophilus neglectus* (Rhaphidophoridae, Gryllacridoidea). *J. Exp. Zool.* 273: 376-388.
- Desutter-Grandcolas, L.**, 2003. Phylogeny and the evolution of acoustic communication in extant Ensifera (Insecta, Orthoptera). *Zool. Scr.* 32: 525-561.
- DiRusso, C., Sbordoni, V.**, 1998. Gryllacridoidea. In Juberthie, C., and Decu, V. (eds.), *Encyclopaedia Biospeologica, Moulis*, Bucharest, pp. 979-988.
- Elipot, Y., Hinaux, H., Callebert, J., Rétaux, S.**, 2013. Evolutionary shift from fighting to foraging in blind cavefish through changes in the serotonin network. *Curr. Biol.* 23: 1-10.
- Friedel, T.**, 1999. The vibrational startle response of the desert locust *Schistocerca gregaria*. *J Exp Biol* 202:2151 -2159.
- Gogala, M.**, 1964. Fotorepcija pri naših jamskih kobilicah fam. Rhaphidophoridae. Dissertation, University of Ljubljana (in Slovene).
- Gogala, M.**, 1966. Die Photorezeption bei *Troglophilus neglectus* Kr. *Biološki vestnik* 14: 91- 96.
- Hubbel, T.H., Norton, R.M.**, 1978. The systematics and biology of the cave-crickets of the North American tribe Hadenocini (Orthoptera Saltatoria: Ensifera: Rhaphidophoridae: Dolichopodinae). *Miscellaneous publications*, No. 156, University of Michigan.

- Jeram, S., Čokl, A., Kalmring, K.,** 1995. Structure of atympanate tibial organs in legs of the cave-living Ensifera *Troglophilus neglectus* (Gryllacridoidea, Rhaphidophoridae). *J. Morphol.* 223: 109-118.
- Kalmring, K., Rössler, W., Unrast, C.,** 1994. Complex tibial organs in the fore-, mid- and hindlegs of the bushcricket *Gampsocleis gratiosa* (Tettigoniidae): comparison of physiology of the organs. *J. Exp. Zool.* 270:155-161.
- Karaman, I., Hammouti, N., Patićević, D., Kiefer, A., Horvatović, M., Seitz, A.,** 2011. The genus *Troglophilus* Krauss, 1879 (Orthoptera: Rhaphidophoridae) in the west Balkans. *Zool. J. Linnean. Soc.* 163: 1035-1063.
- Kastberger, G.,** 1982. Evasive behaviour in the cave-cricket, *Troglophilus cavicola*. *Physiol. Entomol.* 7: 175-181.
- Kastberger, G.,** 1984. Gating of locomotor activity in the cave-cricket, *Troglophilus cavicola*. *Physiol. Entomol.* 9: 297-314.
- Kastberger, G.,** 1985. Gating of ventilatory activity in the cave-cricket, *Troglophilus cavicola*. *Physiol. Entomol.* 10: 461-473.
- Kilpinen, O., Storm, J.,** 1997. Biophysics of the subgenual organ of the honeybee, *Apis mellifera*. *J. Comp. Physiol. A* 181: 309-318.
- Lakes-Harlan, R., Strauß, J.,** 2014. Functional morphology and evolutionary diversity of vibration receptors in insects. In: Cocroft, R.B., Gogala, M., Hill P.S.M., Wessel, A. (eds): *Studying Vibrational Communication*. Springer, Berlin, Heidelberg, pp 277-302.
- Legendre, F., Robillard, T., Song, H., Whiting, M. F., Desutter-Grandcolas, L.,** 2010. One hundred years of instability in ensiferan relationships. *Syst. Entomol.* 35:475-488.
- Nishino, H.,** 2003. Somatotopic mapping of chordotonal organ neurons in a primitive ensiferan, the New Zealand tree weta *Hemideina femorata*: I. Femoral chordotonal organ. *J. Comp. Neurol.* 464: 312-326.
- Nishino, H., Field, L. H.,** 2003. Somatotopic mapping of chordotonal organ neurons in a primitive ensiferan, the New Zealand tree weta *Hemideina femorata*: II. Complex tibial organ. *J. Comp. Neurol.* 464: 327-342.
- Novak, T., Kuštor, V.,** 1983. On *Troglophilus* (Rhaphidophoridae, Saltatoria) from north Slovenia (YU). *Mém. Biospéol.* 10: 183-189.
- Pehani, Š., Virant-Doberlet, M., Jeram, S.,** 1997. The life cycle of the cave cricket *Troglophilus neglectus* Krauss with a note on *T. cavicola* Kollar (Orthoptera: Rhaphidophoridae). *Entomologist* 116: 224-238
- Raspotnig, G., Freitag, B., Kastberger, G., Windischhofer, W., Leis, H.-J.,** 1998. 5-Methyl-2-phenyl-2-hexenal in the scent gland secretion of male cave crickets, *Troglophilus cavicola* and *T. neglectus* (Ensifera, Rhaphidophoridae). *J. Insect Physiol.* 44: 413-417.
- Schrader, Š.,** 2000. The function of the cercal sensory system in escape behavior of the cave cricket *Troglophilus neglectus* Krauss. *Pflügers Arch.* 439: 187-189.
- Schrader, Š., Horseman, G., Čokl, A.,** 2002. Directional sensitivity of wind-sensitive giant interneurons in the cave cricket *Troglophilus neglectus*. *J. Exp. Biol.* 292: 73-81.

- Seliškar, A.**, 1923. Die männlichen Duftorgane der Hohenheuschrecke *Troglophilus*. *Zool Anz* 57: 253-268.
- Song, H., Amédégnato, C., Cigliano, M. M., Desutter-Grandcolas, L., Heads, S.W., Huang, Y., Otte, D., Whiting, M.F.**, 2015. 300 million years of diversification: elucidating the patterns of orthopteran evolution based on comprehensive taxon and gene sampling. *Cladistics* 31: 621-651.
- Strauß, J.**, 2017. The scolopidial accessory organs and Nebenorgans in orthopteran insects: Comparative neuroanatomy, mechanosensory function, and evolutionary origin. *Arthropod Struct. Dev.* 46: 765-776.
- Strauß, J., Lakes-Harlan, R.**, 2008a. Neuroanatomy and physiology of the complex tibial organ of an atympanate ensiferan, *Ametrus tibialis* (Brunner von Wattenwyl, 1888)(Gryllacrididae, Orthoptera) and evolutionary implications. *Brain. Behav. Evol.* 71: 167-180.
- Strauß, J., Lakes-Harlan, R.**, 2008b. Neuroanatomy of the complex tibial organ of *Stenopelmatus* (Orthoptera: Ensifera: Stenopelmatidae). *J. Comp. Neurol.* 511: 81-91.
- Strauß, J., Lakes-Harlan, R.**, 2010. Neuroanatomy of the complex tibial organ in the splay-footed cricket *Comicus calcaris* Irish 1986 (Orthoptera: Ensifera: Schizodactylidae). *J. Comp. Neurol.* 518: 4567-4580.
- Strauß, J., Stritih, N., Lakes-Harlan, R.**, 2014. The subgenual organ complex in the cave cricket *Troglophilus neglectus* (Orthoptera: Rhaphidophoridae): comparative innervation and sensory evolution. *Roy. Soc. Open Sci.* 1: 140240
- Strauß, J., Stritih, N.**, 2016. The accessory organ, a scolopidial sensory organ, in the cave cricket *Troglophilus neglectus* (Orthoptera: Ensifera: Rhaphidophoridae). *Acta. Zool. Stockh.* 97: 187-195.
- Strauß, J., Stritih, N.**, 2017. Neuronal regression of internal leg vibroreceptor organs in a cave-dwelling insect (Orthoptera: Rhaphidophoridae: *Dolichopoda araneiformis*). *Brain. Behav. Evol.* 89: 104-116.
- Stritih, N.**, 2006. Response properties, morphology and topographical organization of the vibratory neurones in the prothoracic ganglion of the cave cricket *Troglophilus neglectus* Krauss (Orthoptera, Rhaphidophoridae). Dissertation, University of Ljubljana.
- Stritih, N.**, 2009. Anatomy and physiology of a set of low-frequency vibratory interneurons in a nonhearing ensiferan (*Troglophilus neglectus*, Rhaphidophoridae). *J. Comp. Neurol.* 516: 519-532.
- Stritih, N.**, 2014. Signaling by protrusive scent glands in cave crickets, *Troglophilus neglectus* Krauss (Orthoptera: Rhaphidophoridae), is primarily involved in male-male agonism. *J. Insect Behav.* 27: 317-332.
- Stritih, N., Čokl, A.**, 2012. Mating behaviour and vibratory signalling in non-hearing cave crickets reflect primitive communication of Ensifera. *PLoS ONE* 7(10): e47646.
- Stritih, N., Čokl, A.**, 2014. The role of frequency in vibrational communication of Orthoptera. In: Coccoft, R.B., Gogala, M., Hill, P.S.M., Wessel, A. (eds): *Studying Vibrational Communication*. Springer, Berlin, Heidelberg, pp. 375-393.

- Stritih, N., Strauß, J.** 2015. Tremulation signalling and sensory neuroanatomy of cave crickets (Rhaphidophoridae: *Troglophilus*) are consistent with ancestral vibrational communication in Ensifera. *Mitt. Dtsch. Ges. allg. angew. Ent.* 20: 333-336.
- Stritih, N., Stumpner, A.**, 2009. Vibratory interneurons in the non-hearing cave cricket indicate evolutionary origin of sound processing elements in Ensifera. *Zoology* 112: 48-68.
- Stritih, N., Žunič Kosi, A.**, 2017. Olfactory signaling of aggressive intent in male-male contests of cave crickets (*Troglophilus neglectus*; Orthoptera: Rhaphidophoridae). *PLoS ONE* 12(11): e0187512.
- Stritih Peljhan, N., Strauß, J.**, 2018. The mechanical leg response to vibration stimuli in cave crickets and implications for vibrosensory organ functions. *J. Comp. Physiol. A* 204: 687-702.
- Zhou, Z., Zhao, L., Liu, N., Guo, H., Guan, B., Di, J., Shi, F.**, 2017. Towards a higher-level Ensifera phylogeny inferred from mitogenome sequences. *Mol. Phylogenet. Evol.* 108: 22-33.

Received / Prejeto: 30. 10. 2018



**SUR DEUX CIGALES DE LA FAUNE INTERTROPICALE DEDIEES AU
CICADOLOGISTE MATIJA GOGALA, COLLEAGUE ET AMI**

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**Abstract – ON TWO CICADAS OF THE INTERTROPICAL FAUNA DEDICATED
TO CICADOLOGIST MATIJA GOGALA, COLLEAGUE AND FRIEND**

This article gives the illustrated descriptions (including CIA) of two tropical cicadas recorded and collected by the author: *Malagasia gogalai* n. sp., from Madagascar and *Pomponia matijai* n. sp., from Thailand (Hemiptera, Auchenorrhyncha, Cicadidae). These new species are dedicated to Matija Gogala, cicadologist, bioacoustician and friend.

KEY WORDS: Cicadoidea, Cicadidae, Cicadinae, Dundubini; Tibicinidae, Tibicininae, Taphurini; taxonomy, sonic ethology, new species, Madagascar, Thailand.

**Izvleček – O DVEH VRSTAH ŠKRŽADOV TROPSKE FAVNE, POSVEČENIH
ŠKRŽADOSLOVCU MATIJI GOGALA, KOLEGU IN PRIJATELJU**

V članku sta z ilustriranimi opisi, vključno z akustično prepoznavo, predstavljeni dve tropski vrsti škržadov, ki jih je posnel in nabral avtor: *Malagasia gogalai* n. sp. z Madagaskarja in *Pomponia matijai* n. sp. iz Tajske (Hemiptera, Auchenorrhyncha, Cicadidae). Novi vrsti sta posvečeni Matiji Gogalu, škržadoslovcu, bioakustiku in prijatelju.

KLJUČNE BESEDE: Cicadoidea, Cicadidae, Cicadinae, Dundubini; Tibicinidae, Tibicininae, Taphurini; taksonomija, zvočna etologija, nove vrste, Madagaskar, Tajska.

Résumé – Cet article donne les descriptions illustrées (CIA incluses) de deux nouvelles Cigales enregistrées et colligées par l'auteur: *Malagasia gogalai* n. sp., à

Madagascar et *Pomponia matijai* n. sp., en Thaïlande (Hemiptera, Auchenorrhyncha, Cicadidae). Ces deux nouvelles espèces sont dédiées à Matija Gogala, ami tout à la fois bioacousticien et cicadologiste.

Introduction

Avec enthousiasme, je m'associe à nos collègues désireux de marquer leur amitié au Professeur Matija Gogala, soulignant ainsi sa pleine vie, d'attentions et de labeurs, consacrée à la Nature et plus précisément à une surprenante famille d'Insectes « chantant » au Soleil. Lui sont dédiées dans ces pages deux Cigales originales, colligées par mes soins dans la ceinture intertropicale du Globe : l'une, à Madagascar, l'autre, en Thaïlande. Par ailleurs, il se trouve qu'elles correspondent à deux tranches s'agissant des résultats taxinomiques, distingués ici « ante- et cum-multicouches », la technique-photos d'aujourd'hui révélant une surnaturelle profondeur-de-champ et l'exécution rapide des prises de vues propres à fixer en images nos précieux types. Dans cette optique, exprimée en tranche « 1 », figurera l'espèce de Madagascar captée en 1997, mais restée inédite (comme bien d'autres dans mes cartons), puis en « 2 », la thaïlandaise capturée en 2014, récente donc et toute aussi nouvelle. Les illustrations, nécessaires dans un tel travail seront assurées : pour l'espèce malgache, suivant la macrophotographie conventionnelle (améliorée tout au long de ma carrière) et, pour l'espèce thaïe, en mettant à profit la technique du "Focus Stacking"* ou empilement de mises au point (multicouches, en français).

Enfin, argument décisif confortant mes choix, des mâles des deux Cigales furent enregistrés sur le terrain et leurs premières Cartes d'Identité Acoustique (CIA) ont pu être établies, point important à prendre en considération dans le choix des espèces à dédier à notre ami Matija: non seulement il est un cicadologiste, mais aussi un éco-éthologiste acousticien de renom.

1) *Malagasias gogalai* n. sp. (fig. 1 à 9)

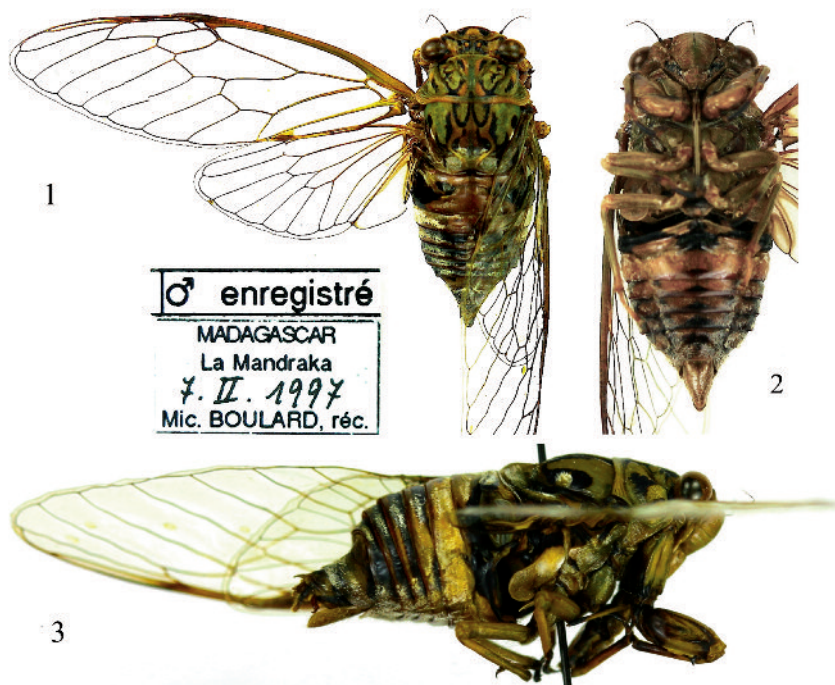
HOLOTYPE : ♂, Madagascar, Réserve forestière de La Mandraka environ 70 km à l'est d'Antananarivo), 7.II.1997, Michel Boulard réc. (au filet, après enregistrements).

PARATYPES : allotype ♀, 25.I.1997; 3 ♂, 2 ♀, idem holotype, au Muséum national d'Histoire naturelle, Paris (MNHN).

Dimensions principales en millimètres du mâle holotype.

Envergure = 76 ; longueur totale, ailes comprises = 37,5 ; longueur de l'avant-corps = 12 ; longueur de l'abdomen = 12 ; longueur du corps = 24 ; longueur Lh des ailes antérieures = 32 ; plus grande largeur lh des ailes antérieures = 10 ; rapport Lh/lh = 3,20 ; largeur t de la tête, yeux inclus = 8 ; largeur m du mésonotum = 7,5 ;

* Focus Stacking : Les prises de vues sont réalisées sur un statif Kaiser RTX avec un boîtier Canon EOS 6 D équipé d'un Macro lens Canon EF 100 mm f/2.8 et géré avec le logiciel Canon EOS. Les photos multicouches sont assemblées avec le logiciel Helicon focus 6 et retouchées avec Adobe Photoshop CS4. Aux manettes, au Muséum national d'Histoire naturelle de Paris (MNHN), notre technicien et ami M. Laurent Favre [LF].



Figures 1 à 3: *Malagasia gogalai* n. sp. 1 & 2) Holotype ♂, recto-verso et 3) paratype ♂ de profil ; (MB Photos).

rapport t/m = 1,07 ; plus grande largeur de l'abdomen : 9 ; distance d1 entre un œil composé et l'ocelle le plus proche = 1 ; distance d2 entre les ocelles latéro-postérieurs = 0,5 ; rapport d1/d2 = 2.

Description de l'holotype mâle (fig. 1 à 7). [Spécimen sec et desséché, aux couleurs dénaturées].

Espèce appartenant au genre *Malagasia* créé par W.L. Distant en 1882, pour *M. inflata*, grosse Cigale aux mâles ventrus, lesquels cymbalisent en basses fréquences. Genre restant à ce jour endémique et ne répertoriant actuellement que 5 ou 6 espèces quelque peu disparates et en cours de révision.

Tête. Plus large que le mésonotum (rapport t/m = 1,07), au postclypéus large, la plage dorso- clypéale quelque peu proéminente en un arrondi souligné en noir. Vertex ocré y compris le territoire ocellaire ; ocelle anté-médian en position subfrontale, cerclé d'un liseré noir ; ocelles latéraux plus largement entourés de noir d'où s'échappent, en oblique un mince trait noir rejoignant chaque œil en s'élargissant, puis un court et large trait noir s'élargissant jusqu'à atteindre, quelque peu latéralement, le bord du pronotum. Arcades antennaires et scapes ocrés, pédicelles et flagelles brun noir, puis se terminant en blanchâtre. Yeux bistre, faiblement saillants sur le liseré



Fig. 4 : *Malagasia gogalai* n. sp. Holotype ♂. Vue mettant en évidence le graphisme de l'avant-corps et la cymbale du côté gauche. La Mandraka [MB Phot.].

noir des cupules, celles-ci surplombant étroitement les angles antérieurs du pronotum (fig. 1). Face clypéale ocrée, peut bombée, portant 7 paires de faibles bourrelets de part et d'autre du sillon clypéal étroit et peu profond ; joues, lames buccales et antéclypéus ocre, une petite plage s'étirant sous la courbe antéro- externe de la bordure de chaque lame ; rostre long, ocre, puis bistre, terminé de noir, son apex rejoignant l'extrémité des trochanters moyens (fig. 2).

Thorax. Pronotum près de deux fois plus long que la tête, l'aire interne ocre (encore mêlée de vert), marquée de noir sur les bourrelets profondément délimités par les sillons endophragmiques ; collerette (pronotum collar) de même teinte, s'élargissant de chaque côté en des paranota moyens, arrondis et stridulés en surface. Mésonotum ocre, les plages triangulaires antéro-médianes bien délimitées de noir, un trait se décrochant de l'arrondi de leur apex pour rejoindre les banches antérieures de l'x scutellaire (élévation cruciforme), celles-ci délimitant une large plage noire ; en revanche les longues plages externes (encore vertes) ouvertes avant d'atteindre le pronotum, leurs limites devenues fragmentées (fig. 1 et 4). Absence totale, comme chez *M. inflata*, de "palettes sternales" (Boulard, 1980), processus cuticulaires bifestonnés, mis en évidence chez plusieurs espèces, dont certaines dites aussi "*Malagasia*", sont destinées à être remplacées dans un autre genre (Boulard, *in lit.*). Opércules fort courts, en courte demi-lune, très largement séparés entre eux et masquant peu l'espace latéro-ventral des chambres acoustiques (fig. 2 et 4).

Pattes. Ocre, les hanches et les fémurs antérieurs plus ou moins envahis de noir, ainsi que l'apex des tibias et les tarses ; fémurs antérieurs normalement renflés, ne

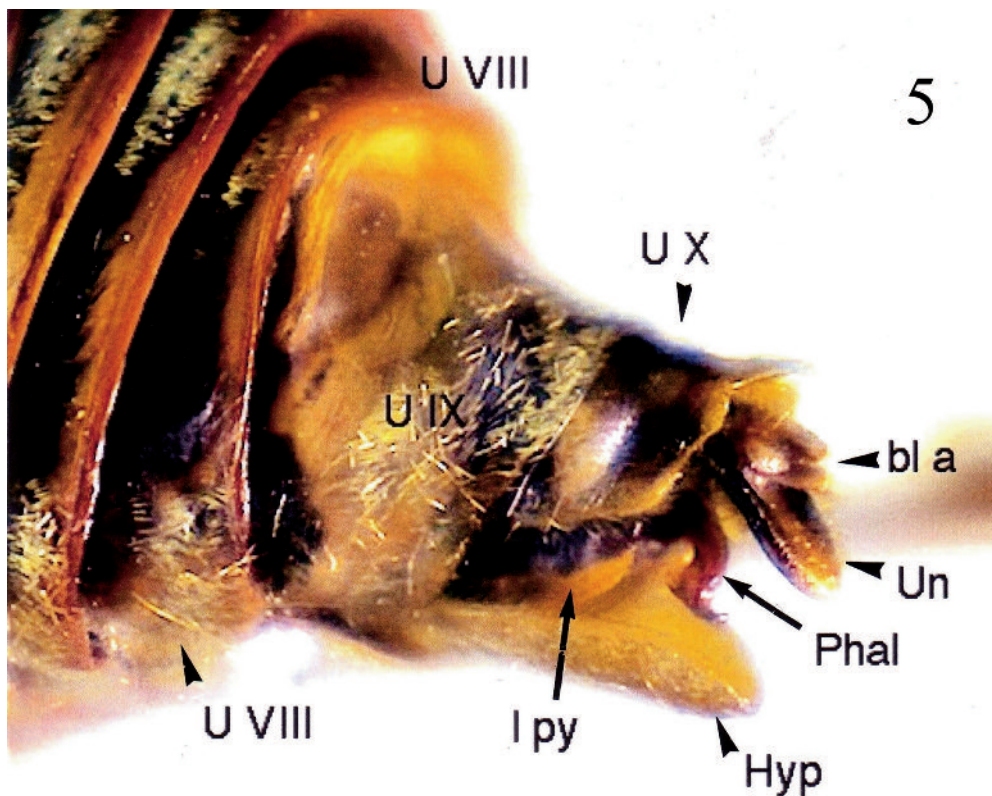


Fig. 5 : *Malagasia gogalai* n. sp. Paratype ♂. Vue rapprochée de l'apex génital légèrement ouvert : bl a, bloc anal ; Hyp, hyandrium ; l py, lobe pygophorien ; PC, processus caudal ; Phal, phallus ; Un, phallicophore (uncus) ; U VIII, urite 8 ; U IX, urite 9 ; U X, urite 10, ou pygophore (Microphotographie MB).

portant que deux faibles épines sous-carénales, la basale courte et couchée vers l'avant, la subapicale plus forte et dressée.

Ailes. Totalement hyalines, (fig. 1). Les antérieures très élancées, leur longueur comprenant 3,2 fois leur largeur ; cellule basale allongée, cellule radiale et cellule post-costale équivalentes en longueur, la moitié proximale de la seconde, quasi virtuelle ; aire apicale octoloculée nettement supérieure à la surface occupée par les trois cellules ulnaires ; nervules subapicales très obliques et parallèles. Ailes postérieures moins longues que la moitié des antérieures et relativement larges ; six cellules terminales.

Abdomen. Subcylindrique, aussi long que l'avant-corps (fig. 1 et 3), à dominante brunâtre, hormis la plage noire sur les latérotergites II (en regard des cymbales) et les 3/4 d'une ceinture grisjaunâtre teintant le sternite et les latérotergites de l'urite III ;



Fig. 6 : *Malagasia gogalai* n. sp., mâle "immortalisé" au télé-objectif de 400 mm. La Mandraka, 7 février 1997 [MB Phot. & Rec.].

latérotergites suivant noir, puis brun rouge ; Cymbales totalement exposées, composées d'une large et longue plaque dorso-médiane et de quatre baguettes de longueurs inégales et plus ou moins parallèles (fig. 4). Avant du sternite II totalement simple (fig. 2), "palettes sternales" manquantes, comme chez l'espèce type (mais telles que chez des espèces considérées comme voisines, cf. Boulard, 1980a). Cône pygophorien légèrement plus clair et dorsalement prolongé par un processus caudal effilé à apex aigu (PC) ; ceux-ci repris, figure 5, chez un paratype et détaillés selon la nomenclature proposée par Boulard en 1990, confirmée en 1995/1996.

Cette espèce se range dans la Tribu des Taphurini, Sous-famille des Tibicininae (Distant, 1905).

Notes éco-éthologiques et CIA

Le type de cette espèce riche en couleurs (fig. 6), fut enregistré et capturé avec quelques autres, mâles et femelles, en « La Mandraka », propriété de l'entomologiste **André Peyriéras**, Correspondant scientifique du MNHN. **André**, éminent spécialiste des Coléoptères malgaches, fut un « ancien » formidable, naturaliste et gestionnaire,

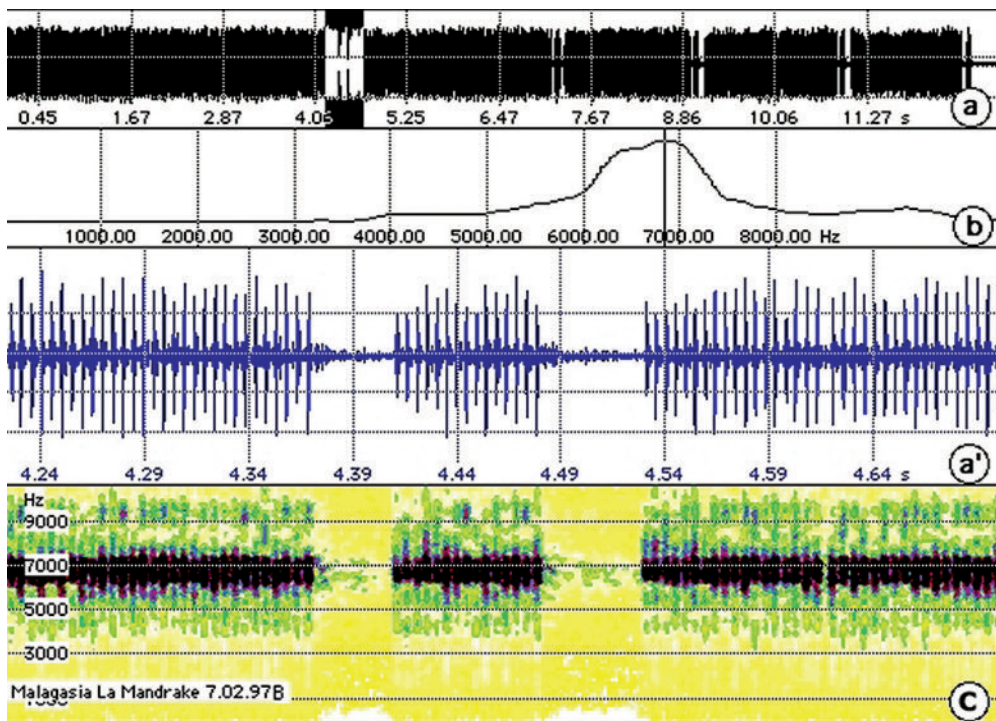


Fig. 7 : *Malagasia gogalai* n. sp. MB CIA, Carte d'identité acoustique indicative, ainsi commentée :

(a) Oscillogramme temporel transcrivant en temps réel, environ 13 secondes du plein appel comportant cinq phrases très semblables, mais inégales en durées et séparées par de courtes phases silencieuses presque égales entre elles, bien qu'enserrant plus ou moins un très court signal.

(b) Tracé du spectre moyen plaçant fondamental et formants immédiatement efficaces en un sommet commun culminant entre 6000 et 7500 Hz. (a') Oscillogramme obtenu pour un espace-temps arbitraire, transcrivant et amplifiant 1/50 s du plein signal (plage inversée, particulièrement choisie en a) mettant en évidence le passage fracturé d'une phrase à l'autre, ainsi que l'ultrastructure aux motifs quasi égaux entre eux.

(c) Spectrogramme étiré conforme à l'oscillogramme (a) et évoquant, par l'image, le spectre moyen. L'efficacité optimale du signal se trouve étroitement condensée de part et d'autre du curseur des 7000 Hz. Cependant d'autres éléments graphiques s'avèrent présents, dont on ne sait estimer la valeur opérationnelle : d'abord largement en de ça de la plage des 7000 Hz, puis au-delà et, pour certains, individualisés au-dessus de 9000 Hz.

ayant assuré la réception chez lui, en famille, des naturalistes en mission sur la Grande Île*.

* Grande Île qu'André quitta en 2005, se retirant en France montpelliéraine.

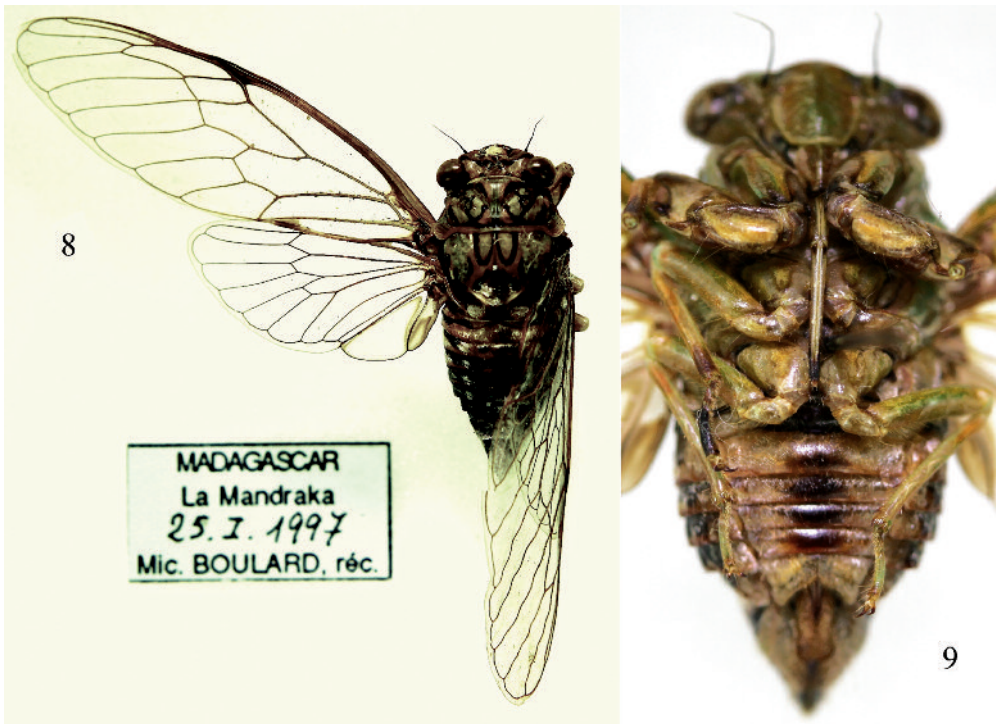


Fig. 8 et 9 : *Malagasias gogalai* n. sp. : (8) Allotype, vue dorsale, ailes gauches étalées ; (9) Paratype femelle, vue ventrale grossie [MB Photos].

Le territoire de la Mandraka, que j'eus la chance de parcourir quelque peu, englobait une très vaste partie d'une exubérante forêt primaire tropicale. Les Cigales colligées sur place sont, à ma connaissance, toutes endémiques. C'est assurément le cas de *Malagasias gogalai* n. sp., espèce dendrophile et héliophile, vigilante et peu facile à prendre au filet.

La cymbalisation des mâles fut captée avec un 'Sony Professional Cassette-Corder WM-D3, équipé d'un micro super-directionnel Sennheiser". Voici, Figure 7, la CIA, Carte d'Identité Acoustique de cette nouvelle espèce, transcrite suivant le protocole exposé par mes soins, notamment en 1995/96 et plus largement en 2005 et 2006.

Allotype femelle (Fig. 8 et 9) : Taille tout à fait comparable à celle du mâle. Avant-corps et envergure identique à celle du mâle. Abdomen à la fois plus dense, plus conique et plus court. Pygophore en cône trapus, la tarière et sa gaine, courtes, ne dépassant pas le bloc anal et, un peu moins encore, le processus caudal.

2) *Pomponia matijai* n. sp. (fig. 10 à 17)

HOLOTYPE ♂, Thaïlande centrale, Nakhon-Rachasima Province, colline du Temple de Pak Tchong, 7 avril 2014, *Michel Boulard, Khuankanok Chueata et Porn-napa Boonyu* réc. (au filet, après enregistrements).

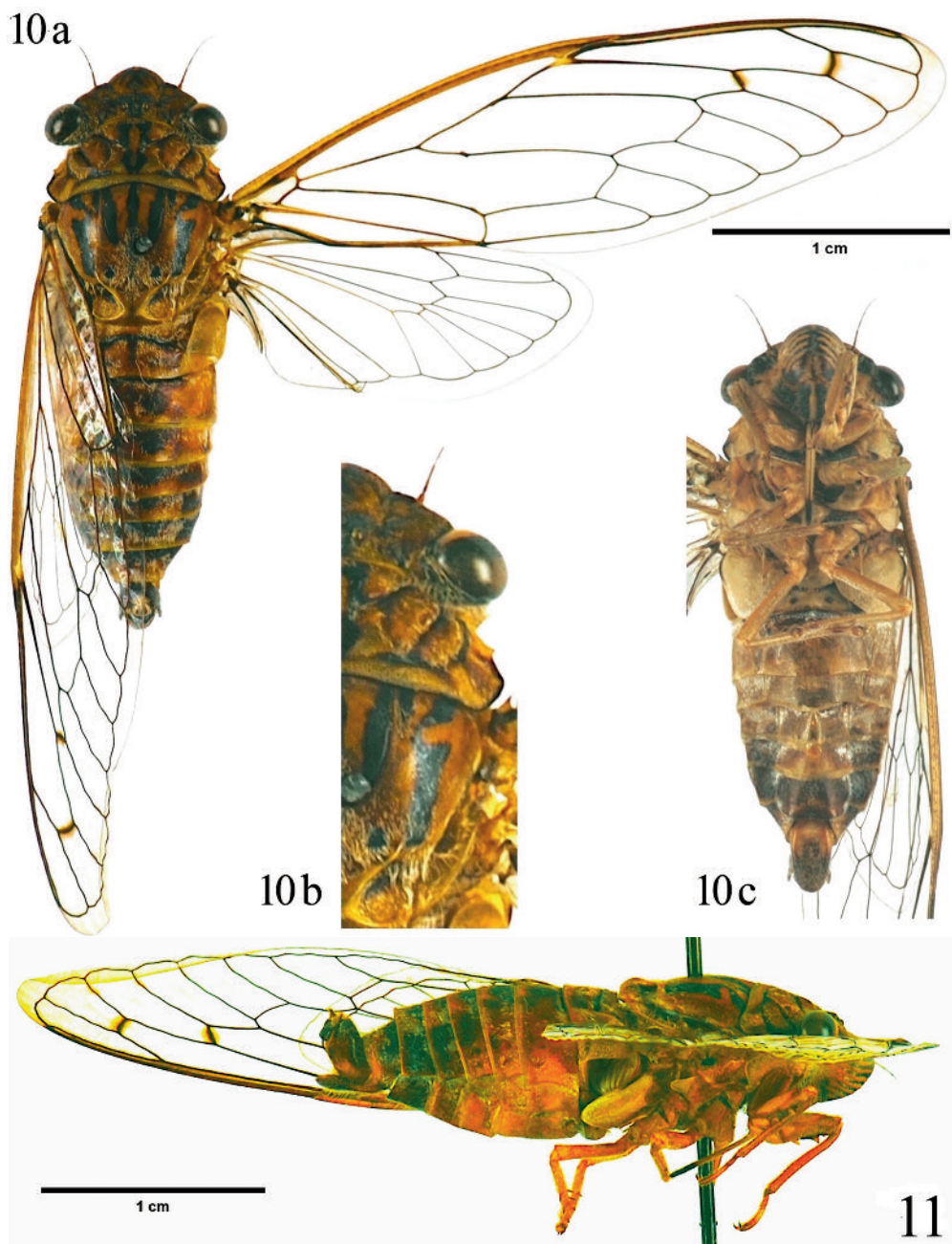


Fig. 10 et 11 : *Pomponia matijai* n. sp., Holotype mâle. **10 a et b**) Vues dorsales : totale et particulière plus agrandie ; **10 c**) Vue ventrale. **11**) Vue de profil [Paris, LF Photos].

PARATYPE : ♀ allotype, idem holotype. Muséum national d'Histoire naturelle, Entomologie, N° EH 22113 (♂) et 22114 (♀), Paris.

Dimensions principales en millimètres du mâle holotype.

Envergure = 62; longueur totale, ailes comprises = 34; longueur de l'avant-corps = 9,5; longueur de l'abdomen = 13; longueur du corps = 33; longueur Lh des ailes antérieures = 28; plus grande largeur lh des ailes antérieures = 8; rapport Lh/lh = 2,66; largeur t de la tête, yeux inclus = 7; largeur m du mésonotum = 6; rapport t/m = 1,7; distance d1 entre un œil composé et l'ocelle le plus proche = 1,65; distance d2 entre les ocelles latéro-postérieurs = 0,56; rapport d1/d2 = 2,94.

Description de l'holotype mâle (Fig. 10 à 15). [Spécimen sec et desséché, aux couleurs dénaturées].

Proche de *Pomponia quadrispinae* Boulard, 2002, mais de taille nettement moindre, cette nouvelle espèce s'en distingue ensuite par sa tête triangulaire plus longue accentuant la saillance des yeux, la livrée de l'avant-corps moins densément fasciée de bistre, tandis que l'aire apicale des ailes antérieures ne présente aucune des six macules terminales, appréciables chez l'espèce voisine.

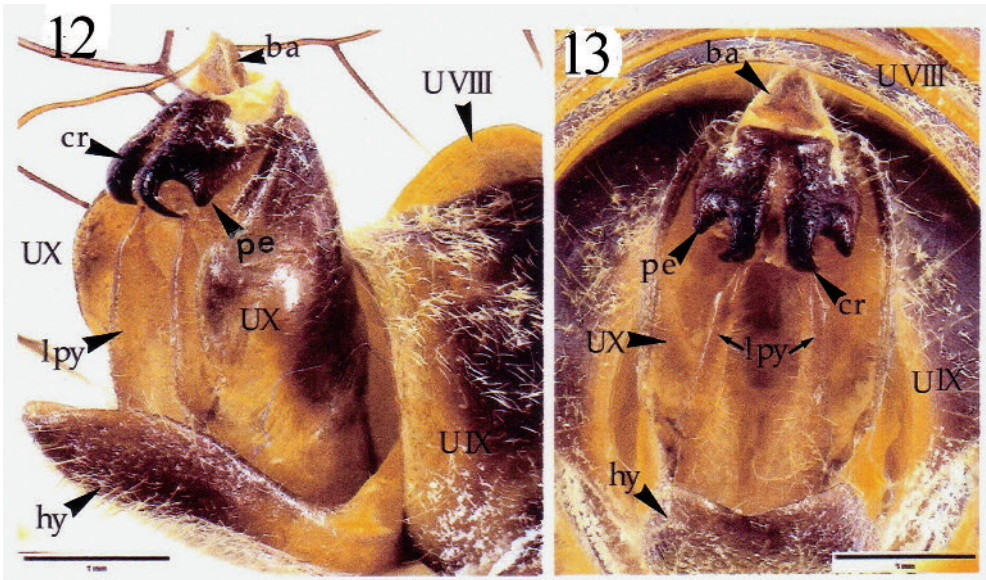


Fig. 12 et 13 : *Pomponia matijai* n. sp., Holotype mâle, aspect et nomenclature des genitalia externes, vus de profil (12), puis de l'arrière (13). Explication des lettres : b a, bloc anal ; Hyp, hyandrium, ou sternite 8 ; l py, lobes pygophoriens ; UVIII, urite 8 ; UIX, urite 9, ou phallicophore (uncus) ; UX, urite 10, ou pygophore. [Paris, LF Photos].

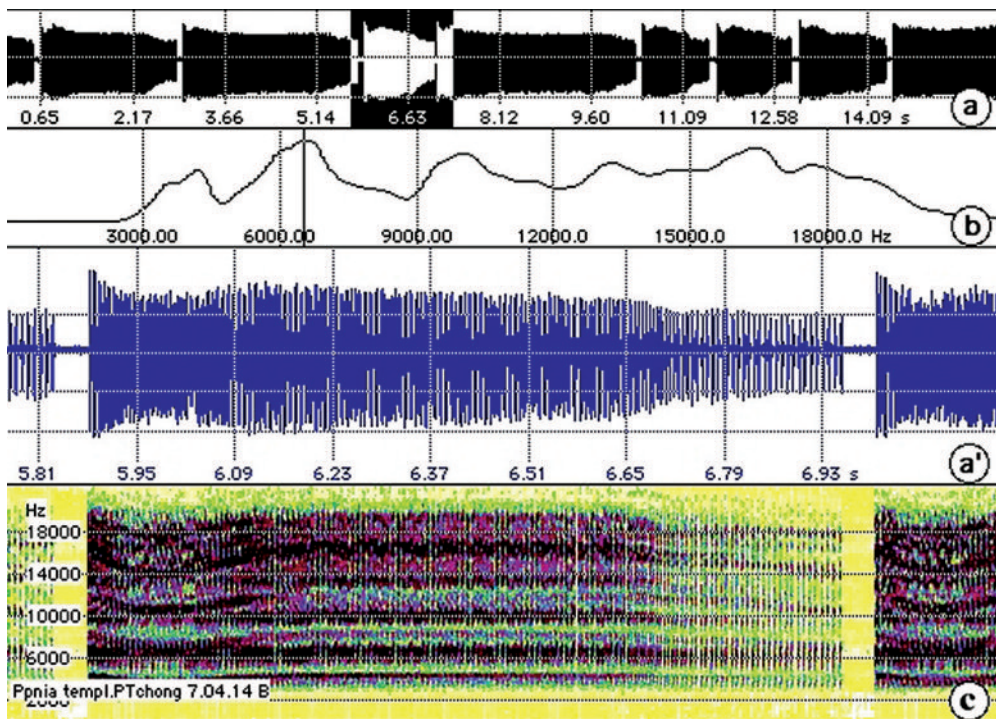


Fig. 14 : *Pomponia matijai* n. sp., CIA, Carte d'identité acoustique indicative, commentée comme il suit :

(a) Oscillogramme temporel fondé sur l'enregistrement d'une quinzaine de secondes de la cymbalisation d'appel, transcrivant en temps réel un train de séquences habituellement émises d'un même point, chacune plus ou moins prolongée et lancée sans alternance précise, par un mâle apparemment sans inquiétude.

(b) Tracé du spectre moyen, précisant une efficacité sonore maintenue longtemps autour d'un maximum étonnamment étalé, de 3500 Hz jusqu'à passer quelque peu les 18000 Hz, la fréquence dominante se situant aux alentours des 6500 Hz.

(a') Oscillogramme partiel, étiré dans un espace-temps arbitrairement choisi de manière à détailler l'une des courtes séquences (plage inversée en a) en faisant apparaître distinctement les composantes ultra-structurales, plus rapides (motifs télescopés) au moment de l'attaque et de la reprise, durant quelque 0,15 seconde, pour ensuite laisser l'individualisation de motifs forts, puis de plus faibles... Jusqu'à un court arrêt total, et relancer un appel avec force.

(c) Spectrogramme fondé sur le sonogramme (a') et retranscrivant l'occupation fréquentielle des sons alors émis par *P. matijai* n. sp. Le fondamental est assez bas et court, entre 3200 et presque 3400 Hz, que rehaussent des harmoniques s'échelonnant de 4000 en 4000 Hz jusqu'aux 18000 Hz. Il est par ailleurs remarquable, et apprécié spécifique, que la première composante, où les motifs télescopés n'apparaissent pas, se montre spectaculairement incurvée.

Tête. Vue de dessus, plus large que le mésonotum ($t/m = 1,7$), nettement triangulaire en rendant plus oblique les marges du vertex avec le clypéus proéminent ; longueur sagittale de la plage dorso-clypéale équivalente, axialement, à celle du vertex. Yeux subsphériques, fort saillants (fig. 10 a, b), bistre multi-pointé de noir. Ocelle médian occupant une position sub dorsale ; ocelles latéro-postérieurs beaucoup plus rapprochés entre eux que chacun de l'œil correspondant ($d1/d2 = 2,94$). Arcades antennaires noires, très obliques, en courbe à fort rayon ; scapes noires, pédicelle et flagelle brunâtres. Plage dorso-clypéale plate, marquée d'un épais v noir, marginé de 2+2 bourrelets noirs axialement jointifs ; face clypéale fortement globuleuse, foncièrement noire, mais striée de 10 paires de bourrelets ocrés transversaux, la dernière très courte ; sillon médian à peine creusé, mais relativement large ; antéclypéus et lames buccales largement envahis de noir plus ou moins masqué par une pruine cireuse rousse, de même que les joues ; rostre ocreux et long, son apex, noirâtre, atteignant à mi-hauteur les hanches postérieures.

Thorax. Pronotum à peine moins long que la tête ; aire interne brune, faciée de noir selon les sillons endophragmiques et deux épais traits parasagittaux se rejoignant juste avant l'aire externe (collerette), celle-ci médialement ocre, puis maculée de brun sur les lobes suprahuméraux ; ceux-ci relativement développés, le bord latéral produisant une petite dent (fig. 10b) à direction postérieure (absente chez l'espèce voisine). Mésonotum ocre, le scutum longitudinalement rayé de sept facies plus ou moins longues, épaisses ou incomplètes ; x scutellaire (élévation cruciforme) ocre, les branches antérieures englobant deux macules noires. Opercules subtriangulaires, courts, ocreux, ourlés de bistre sur leur côté externe et largement écartés l'un de l'autre (fig. 11).

Pattes. Entièrement ocreuses, les tarsi légèrement plus sombres ; fémurs antérieurs normalement renflés, ne dressant que deux faibles dents claires sur une arête sous-carénale noirâtre.

Ailes. Hyalines (fig. 10a), les antérieures très élancées, leur longueur comprenant près de trois fois leur largeur ($Lh/lh = 2,66$) ; cellule basale en trapèze allongé, non parcheminée ; cellule radiale juste moins longue que la cellule postcostale, cette dernière très étroite, presque virtuelle ; nervuration ocreuse, les nervules subapicales, la r (suborthogonale) et la r-m très surlignées de brun ; aire apicale octocolulée, les nervules fortement obliques, sans macules subapicales (contrairement à l'espèce voisine). Ailes postérieures transparentes, moitié moins longues que les antérieures ; six cellules terminales.

Abdomen. Subcylindrique, un peu plus long que l'avant-corps, portant des alignements de taches noirâtres au contour irrégulier axialement et sur chaque latérotergite. Cymbacalyptes seulement développés dorsalement, en plaques à peine bombées, leur limite latérale étant largement distante des opercules, laissant ainsi apercevoir les cymbales (fig. 12). Pygophore (U X) dépourvu de pointe caudale, lobes pygophoriens (1 py) parfaitement développés, mais à peine sclérifiés, larges et terminés en pointes ;

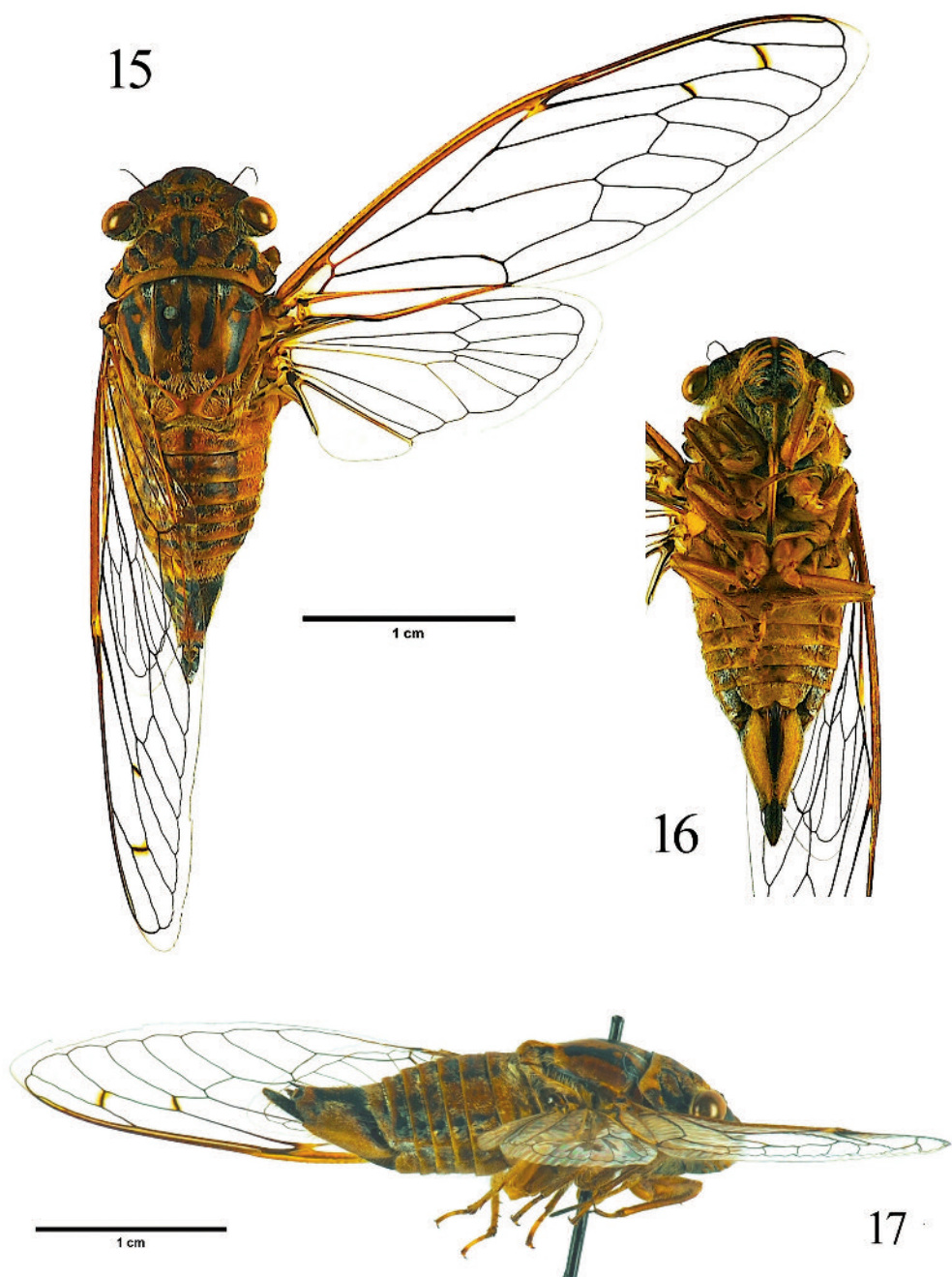


Fig. 15 à 17 : *Pomponia matijai* n. sp., Allotype femelle vu recto (fig. 15) - verso (fig. 16), puis de profil (fig. 17) (LF Photos).

phallicophore (*uncus*) isolant, de part et d'autre de sa base, une forte protubérance chaussée d'une pointe trapue sclérifiée en noir (p e), puis se terminant par une paire de longs et robustes crochets (cr) de même sclérifiés (fig. 12 et 13), l'ensemble évoquant les quadrispicules de l'espèce voisine.

Cette espèce se range dans la Tribu des Dundubiini, Sous-famille des Cicadinae (Boulard, 2013).

Notes éco-éthologiques et C.I.A.

Héliophile et de basse futaie, *Pomponia matijai* n. sp. est une espèce rencontrée dans le vaste environnement épargné d'un temple bouddhiste dans la cité de Pak Chong (Thailand, Nakon-Rachasima Province), où fut historiquement décelé le mâle de l'exceptionnelle Cigale-marteau, *Cicadmalleus micheli* Boulard et Puissant, 2013 (Boulard & Puissant, 2016).

Dendrophiles, privilégiant les branchettes, les *P. matijai* mâles se manifestent de loin en loin, les pleines journées ensoleillées, par une cymbalisation au timbre rauque, le plus souvent émise de concert. Pour cymbaliser, les mâles abaissent quelque peu les ailes, en tendant rythmiquement l'abdomen. Suivant l'un des caractères apparemment génériques, les mâles changent de place après avoir émis plusieurs phrases d'appel. Captée à l'aide d'un « DAT Sony TCD-D8, équipé d'un micro super-directionnel Sennheiser », voici (Figure 14) la transcription sonographique de la cymbalisation d'appel de *Pomponia matijai* n. sp.

Allotype femelle (Fig. 15 à 17) : Taille comparable à celle du mâle, mais légèrement plus forte. Avant-corps et envergure quasi identique à celui et celle du mâle. Abdomen à la fois plus dense, plus effilé et plus long. Pygophore en cône trapus, terminé dorsalement par un éperon noir ; la tarière et sa gaine, relativement longues dépassent nettement le bloc anal ; de longs poils raides garnissent l'apex visible de la gaine (fig. 16).

Summary

With enthusiasm, I join our colleagues who wish to mark their friendship with Professor Matija Gogala, thus highlighting his full life, attentions and labors, devoted to Nature and more specifically to a surprising family of insects "tymbalizing" under the sun. To him are dedicated in these pages two original Cicadas, collected by me in the inter-tropical belt of the Globe: one in Madagascar, the other in Thailand. Moreover, it turns out that they correspond to two periods in regard to the taxonomic results, here distinguished "ante- and cum-multilayer", the photo-technic of today revealing the supernatural depth-of-field and the fast execution of the photos for the visual fixation of our precious types. In this perspective, the period expressed in part "1", is illustrated by the species of Madagascar captured in 1997, but remained unpublished (like many others in my files); then in "2", the Thai species captured in 2014, recent and also new. The necessary illustrations in such a work are ensured: for the Malagasy species, following conventional macrophotography (improved throughout my career)

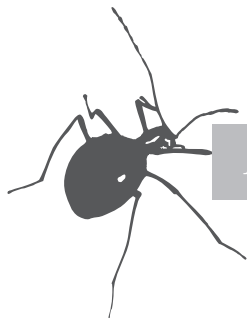
and, for the Thai species, using the multilayer technic. Finally, decisive argument supporting my choices, males of the two Cicadas were recorded in the field and their first CIA (Acoustic Identity Cards) are established: not only Matija is a cicadologist, but he is also an acoustician eco-ethologist.

Auteurs cités

- Distant, W.L.**, 1882: Description of new species and new genus of Cicadae from Madagascar.- *Transactions of the Entomological Society of London* 1882.- **Part II**: 335-338, Pl. XV.
- Distant, W.L.**, 1905: Addition to a knowledge of the Homopterous Family Cicadidae.- *Transactions of the Entomological Society of London* 1905.- **Part I**: 191-202, Pl. XI.
- Boulard, M.**, 1980: Un dispositif protecteur secondaire inédit pour le système acoustique chez quatre Cigales malgaches (Hom. Cicadoidea).- *Bulletin de la Société entomologique de France*, **85** (12), 1980: 44-53, 10 fig.
- Boulard, M.**, 1990: Appareils génitaux des Cigales, dans : Contribution à l'Entomologie générale et appliquée, **2**, Cicadaires (Homoptères Auchenorrhynques), 1ère partie : Cicadoidea.- *EPHE, Travaux du Laboratoire Biologie et Évolution des Insectes*, **3**, Janvier 1990: 55-245, Pl. 5-26 (2 en couleurs) et 41 fig. dans le texte.
- Boulard, M.**, 1995: *Vies et Mémoires de Cigales*.- Barbentane (Bouches du Rhône), Éditions de l'Équinoxe, 157p., 250 figs. Livre accompagné d'un disque compact original : "Chants" de Cigales méditerranéennes (17min.). [*Collaboration de Bernard Mondon pour la partie « Cigales et Symboles »*].
- Boulard, M.**, 1996: *Vies et Mémoires de Cigales. Provence, Languedoc, Méditerranée*.- Éditions de l'Équinoxe, Seconde édition revue et augmentée, 160p., 336 fig. [*Audio CD et Apport de B. Mondon, non modifiés*].
- Boulard, M.**, 2002: Éthologie sonore et Cartes d'Identité Acoustique de dix espèces de Cigales thaïlandaises, dont six restées inédites, ou mal connues (Auchenorrhyncha, Cicadoidea, Cicadidae).- *Revue française d'Entomologie* (N.S.), **24** (1), 2002: 35-66, 19 Pl.
- Boulard, M.**, 2005: Acoustic Signals, diversity and Behaviour of Cicadas (Cicadidae, Hemiptera).- In Drosopoulos & Claridge M.F., *Insect Sounds and Communication*, Chapter **25**: 331-349 (also in DVD). Taylor & Francis Publisher.
- Boulard, M.**, 2006: Facultés acoustiques, éthologie sonore des Cigales, entomophonateurs par excellence / *Acoustic faculties and sonic ethology of cicadas, entomophonators par excellence*.- *EPHE, Biologie et Evolution des Insectes*, **16**, 2006 [édition bilingue] : 1-182, 117 figs., 1 colour Pl. + 1 Audio CD bringing together the tymbalisations issued by 99 species.
- Boulard, M.**, 2013: *The Cicadas of Thailand. Volume 2, Taxonomy and Sonic Ethology*.- Manchester, Siri Scientific Press: 436 p., 487 B. & W. figs, 96 colour Plates, 111 Audio tracks available in line.

Boulard, M. et Puissant S., 2016: Description du mâle de la Cigale-marteau, *Cicad-malleus micheli* Boulard & Puissant, 2013 et position systématique de l'espèce (Hemiptera, Cicadoidea, Cicadidae). *Bulletin de la Société entomologique de France*, **121** (3): 313-321, 10 figs.

Received / Prejeto: 5. 3. 2018



**A NEW SPECIES OF *NABALUA* (HEMIPTERA: CICADIDAE)
FROM MOUNT KINABALU, BORNEO**

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Abstract – The cicada *Nabalua gogalai* sp. nov. (Hemiptera: Cicadidae) from Mount Kinabalu, Borneo, Malaysia, is described as new to science. Pictures of the male body in dorsal and ventral view are provided together with drawings of the male genitalia and the male opercula.

KEY WORDS: Cicadidae, *Nabalua gogalai*, new species, morphology, Borneo, Malaysia

Izvešček – NOVA VRSTA IZ RODU *NABALUA* (HEMIPTERA: CICADIDAE) Z GORE MOUNT KINABALU NA BORNEU

Opisana je nova vrsta škržada *Nabalua gogalai* sp. nov. (Hemiptera: Cicadidae) z gore Mount Kinabalu, Borneo, Malezija. Poleg fotografije holotipa samca podajava tudi risbe dorzalnega in ventralnega pogleda telesa samca ter samčevih genitalij in operkula.

KLJUČNE BESEDE: Cicadidae, *Nabalua gogalai*, nova vrsta, morfologija, Borneo, Malezija

Introduction

Since about 1995 scientists from Malaysia, Slovenia and the Netherlands, their students and some others are cooperating in the study of the singing cicadas (Hemiptera, Cicadidae) of Malaysia (Duffels & Zaidi 2000, Duffels & Trilar 2012, Gogala & Riede 1995, Gogala & Trilar 2007, Gogala et al. 2004, Kos & Gogala 2000, Prešern et al. 2004, Trilar 2006, Trilar & Gogala 2002, 2004). In the years 1996, 1999 and 2003 the first author investigated the cicadas of Mount Kinabalu by

hand collecting, collecting on light and bioacoustics. In 1996 and 1999 he collected a new species of the genus *Nabalua*, which is described here.

Material and methods

In the periods from June 26th to 29th and July 2nd, 1996, in April 9th to 14th and 17th to 19th, 1999, and in March 8th to 13th and April 2nd to 4th, 2003 the first author visited Kinabalu National Park. During the night we were checking the lights in the head-quarter area. All the collected males of cicadas were put in a cage mounted on the branch of a leafy tree, hoping that the cicadas would start singing provoked by the cicadas singing in the neighbourhood forest.

The most interesting specimens collected on light in the Kinabalu National Park Headquarters were three males of a new *Nabalua* collected on respectively 29.vi.1996, 11.iv.1999 and 14.iv.1999. Unfortunately these cicadas did not sing in the cage.

Taxonomy

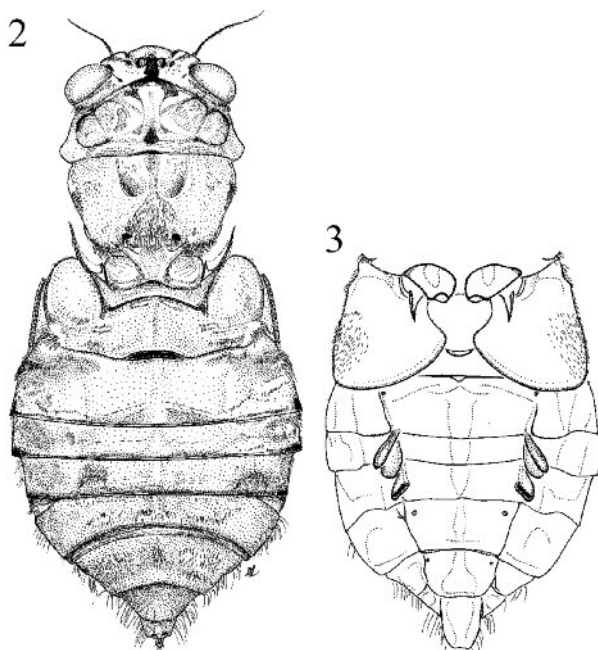
In 1923, Moulton published an excellent overview of the cicadas of so-called Malaysia that comprised the Malay Peninsula, Java, Borneo and Sumatra. In this publication Moulton erected the new genus *Nabalua* for two species: *N. mascula* (Distant, 1889) and the new species *N. neglecta*, both from northern Borneo. In a more recent revision of *Nabalua* Duffels (2004) added four new species to the genus: *N. borneensis* and *N. maculata* from Borneo, *N. zaidii* from the Malayan Peninsula and *N. sumatrana* from Sumatra. A supposed apomorphy for these species of *Nabalua* is the presence of three (or four) pairs of tubercles on the ventral side of the male abdomen, viz., one pair of long and narrow tubercles on sternite 3 and two or three pairs of short and thick tubercles on sternites 4 and 5 (and 6) (Duffels, 2004). These characters are also found in the new species *N. gogalai*.

Initially we have hesitated in attributing this new species to *Nabalua* since the males of this species have some peculiar features that are not found in other *Nabalua* species, viz., a very broad male abdomen, a brownish, instead of black marking of



Fig. 1: *Nabalua gogalai*, male holotype.

Figs. 2-3: *Nabalua gogalai*, male holotype.
– 2, body in dorsal view;
3, body in ventral view.



lines and spots on head, thorax and abdomen and a distinct marking on the basal veins of the 2nd, 3rd, 4th, 5th and 7th apical areas of the tegmina. Nevertheless, we think that the tubercles on the sternites of the abdominal segments 3-5 of *N. gogalai* provide a convincing apomorphy for the allocation of this species in *Nabalua*.

***Nabalua gogalai* Duffels & Trilar n. sp.**

Holotype male: ‘Malaysia, Sabah’/ Kinabalu Nat. park / Park headquarters / 11.iv.1999, Trilar leg. **Paratypes:** same data as the holotype but with different date: 14.iv.1999, 1 male; Malaysia, Sabah: Kinabalu Nat. Park, Park Headquarters, 1500 m, 29.vi.1996, T. Trilar, K. Prosenc leg., 1 male.

Description of the male

Markings on head, pronotum and mesonotum light brown but some parts darker brown.

Head (Fig. 2). Vertex with trefoil shaped median marking enclosing the ocelli that is anteriorly broadly connected with the frontoclypeal suture. A pair of curved, dark brownish, semicircular fasciae reach from half-length of vertex to the vertex lobes. Inner margin of eye black with a recurved posterior end. Genae with black, transverse fascia reaching from postclypeus to half or two thirds of width of gena. Anterior and ventral parts of postclypeus with two series of 7-8 transverse brown streaks, medial ends of these streaks connected by a brown line.

Thorax (Fig. 2). Pronotum with very narrow to narrow central fasciae that widen strongly to the anterior margin of the pronotum. Posterior ends of central fasciae fused in a distinct darker brown spot in front of the pronotum collar. Pronotum collar light brown to black-brown, its posterior margin black. One paratype with very narrow dark brown streaks above anterior oblique fissures. Areas between ambient fissure and posterior oblique fissures and between posterior and anterior oblique fissures dark coloured.

Mesonotum (Fig. 2) light brown to brown with a narrow and vague median fascia, a pair of sharply delimited, slightly diverging, dark brown paramedian fasciae reaching to about half length of mesonotum, some yellowish colouring along outside of paramedian fasciae and a pair of dark brown dots in front of anterior angles of cruciform elevation. Lateral fasciae indistinct.

Legs. Fore femur with an appressed spine at half length of underridge and a triangular spine close to the distal end. Outer side of fore femur with brown marking and with deep black spot distally of the triangular spine. Middle and hind femora with two long brownish lines. Apical part of tarsi of fore and middle legs dark brown.

Operculum (Fig. 5) triangular with rounded right-angled laterodistal corner reaching to one third or one fourth of length of abdominal segment 3. Operculum 0.94–1.02 times as long as wide. Shortest distance between opercula 0.21–0.31 times as wide as operculum. Lateral margin very weakly undulate, distal margin fairly convex, medial margin rounded. Operculum without black-brown margin as found in other species of *Nabalua*.

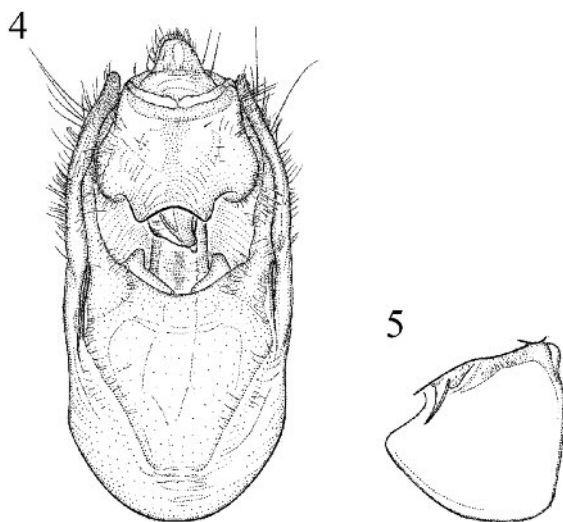
Tegmina with brown spots on basal veins of 2nd, 3rd, 4th, 5th and 7th apical areas and with smaller, lighter brown spots at the apices of the longitudinal veins of all apical areas.

Abdomen (Fig. 3) very broad. The abdomen of the two paratypes are in natural position, with tergite 4 1.6 times as broad as width of head. The ventral side of the abdomen of the holotype is weakly incurved probably due to pressure from below on the abdomen during and after mounting. The abdomen of the holotype is therefore slightly more widened than the abdomen of the paratypes, with tergite 4 1.7 times as broad as width of head.

Tergites 2–7 shining brown, tergites 6–7 somewhat darker than other tergites. Tibial coverings ochraceous to light brownish with weakly convex or weakly undulate lateral margin, a weakly convex medial margin and a broadly rounded apical margin. Tergites 3–6 with a pair of sublateral brown patches enclosed by silvery or golden pilosity. Middle parts of posterior margins of all tergites with a narrow black-brown line. Sternites brown with exception of lateral parts of sternite 3 and medial parts of sternites 4 and 5. Sternites of abdominal segments 3, 4 and 5 with a pair of brown to dark brown tubercles. Tubercles on segment 3 long and narrow and attached to posterolateral corner of the sternite, those on segments 4 and 5 are short and thick and attached to two-thirds of lateral sternite margin.

Genitalia (Fig. 4). Lateral lobes of pygofer very slightly protruding, apical part of lobes black-brown. Uncus very broad, laterally convex and subapically narrowing to the broad apex.

Figs. 4-5: *Nabalua gogalai*, male holotype. – 4, male genitalia in ventral view; 5, male opercula in ventral view.



Measurements in mm (n=3). Body length: 27.5–29.4; tegmen length: 38.2–40.7; head width: 8.0–8.6; pronotum width: 8.3–9.5; head width : pronotum width 0.90–0.96.

Ecology. All three specimens were collected in the Kinabalu Park Headquarter area. Two were collected on light, and the third one was sitting during the day on the leaf of a wild banana tree in the forest understorey and collected with an entomological net.

The Kinabalu Park Headquarter is located in the Lower Mountain Vegetation Zone which is covered with forest dominated by species of oaks (Fagaceae), conifers (especially *Dacrycarpus* and *Phyllocladus*) and the myrtle (Myrtaceae) and tea (Theaceae) families. These trees reach a height of 25–30 m. The temperature in this area is in average between 24°C to 18°C.

Etymology. This species is dedicated to our esteemed colleague and friend Matija Gogala at the occasion of his 80th birthday.

Bioacoustics. All three *N. gogalai* males collected were put in a cage mounted on a branch of a leafy tree, hoping that it will start singing provoked by the wild cicadas singing in the neighbourhood. We had success with some other species but not with *N. gogalai*, so we do not know how the species is singing.

Biogeography. The new species has been collected on Mount Kinabalu, like four other species of the genus that are all restricted to higher localities in northern Borneo like Mt Kinabalu and Mt Dullit. One species of *Nabalua* seems to be endemic to the Cameron Highlands in the Malayan Peninsula and one species is only known from one locality in North Sumatra.

The holotype is deposited in the Slovenian Museum of Natural History, Ljubljana, Slovenia; both paratypes are deposited in the Centre for Insect Systematics of the Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia.

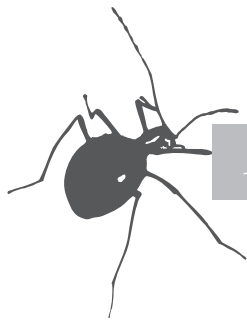
Acknowledgements

We are grateful to Dick Langerak (Zoological Museum, University of Amsterdam) for making the drawings of the male body, the male opercula and the male genitalia (Figs. 2-5) and to Jan van Arkel (University of Amsterdam) for the photograph given in fig. 1. We thank Dr. Masami Hayashi for critically reading the manuscript and for suggestions that improved this paper. Special thanks goes to MSc. Katarina Prosenč Trilar, the wife of the first author, for her enormous effort during the fieldwork. We are also thankful to Dr. Andrej Gogala, who did the preparation of the collected specimens for the collection.

References

- Duffels, J.P., Zaidi, M.I.**, 2000: A revision of the cicada genus *Orientopsaltria* Kato (Homoptera, Cicadidae) from Southeast Asia. *Tijdschrift voor Entomologie* 142: 195-297.
- Duffels, J.P.**, 2004: Revision of the cicada genus *Nabalua* (Hemiptera: Cicadidae) from Southeast Asia. *Oriental Insects* 38: 463-490.
- Duffels H., Trilar T.**, 2012: Taxonomy and song of the cicada *Aysha serva* (Walker, 1850) from the coasts of northern Sundaland. *Tijdschrift voor Entomologie* 155(2-3): 269-283.
- Gogala M., Riede K.**, 1995: Time sharing of song activity by cicadas in Temengor Forest Reserve, Hulu Perak, Malaysia. *Malayan Nature Journal* 48: 297-305.
- Gogala M., Trilar T.**, 2007: Description of the song of *Purana metallica* from Thailand and *P. latifascia* from Borneo (Hemiptera, Cicadidae). *Tijdschrift voor Entomologie* 150: 389-400.
- Gogala M., Trilar T., Kozina U., Duffels H.**, 2004: Frequency modulated song of the cicada *Maua albigutta* (Walker 1856) (Hemiptera: Cicadoidea) from South East Asia. *Scopelia* 54: 1-15.
- Kos M., Gogala M.**, 2000: The cicadas of the *Purana nebulilinea* group (Homoptera, Cicadidae) with a note on their songs. *Tijdschrift voor Entomologie* 143: 1-25.
- Moulton J.C.**, 1923: Cicadas of Malaysia. *Journal of the Federated Malay States Museum* 11: 69-182.
- Prešern J., Gogala M., Trilar T.**, 2004: Comparison of *Dundubia vaginata* (Auchenorrhyncha: Cicadoidea) songs from Borneo and Peninsular Malaysia. *Acta entomologica slovenica* 12(2): 239-248.
- Trilar T.**, 2006: Frequency modulated song of the cicada *Kalabita operculata* (Auchenorrhyncha: Cicadoidea) from Borneo. *Russian Entomological Journal* 15(3): 103-107.
- Trilar T., Gogala M.**, 2002: Description of the song of *Purana sagittata* Schouten & Duffels (Homoptera, Cicadidae) from peninsular Malaysia. *Tijdschrift voor Entomologie* 145: 47-55.
- Trilar T., Gogala M.**, 2004: Biodiversity of Cicadas in Malaysia - bioacoustic approach. *Serangga*, 9(1/2): 63-81.

Received / Prejeto: 1. 10. 2018

**REMARKABLE RECORDS OF NINE RARE AUCHENORRHYNCHA SPECIES FROM AUSTRIA (HEMIPTERA)**Gernot KUNZ¹ & Werner E. HOLZINGER^{1,2}¹ Karl-Franzens-University Graz, Institute for Biology,
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Abstract - We present records of nine very rare and poorly known true hopper species from Austria and a record of *Myndus musivus* from Croatia. *Glossocratus foveolatus* and *Calamotettix taeniatus* are reported from Austria for the first time. New records of *Trigonocranus emmeae*, *Criomorphus williamsi*, *Euides alpina* and *Dorycephalus baeri* are presented. New discovered habitats of *Pseudodelphacodes flaviceps* at floodplains of the Inn river are strongly influenced by hydropower utilization. Two different “ecotypes” of *Ommatidiotus dissimilis* are reported; they might represent different “cryptic species”.

KEY WORDS: Austria, Biogeography, new records, planthoppers, leafhoppers, true hoppers, Cicadina, Fulgoromorpha, Cicadomorpha, Cixiidae, Cicadellidae, Delphacidae, Caliscelidae

Izvešček – IZJEMNE NAJDBE DEVETIH REDKIH VRST ŠKRŽATKOV (AUCHENORRHYNCHA) V AVSTRIJI (HEMIPTERA)

Predstavlja podatke o devetih zelo redkih in slabo poznanih vrstah škržatkov iz Avstrije in najdbo vrste *Myndus musivus* na Hrvaškem. *Glossocratus foveolatus* in *Calamotettix taeniatus* sta prvič zabeleženi v Avstriji. Predstavljeni so novi podatki za vrste *Trigonocranus emmeae*, *Criomorphus williamsi*, *Euides alpina* in *Dorycephalus baeri*. Novo odkrite habitate vrste *Pseudodelphacodes flaviceps* na poplavnih ravninah reke Inn močno ogroža hidroenergetska izraba. Predstavljena sta dva različna “ekotipa” vrste *Ommatidiotus dissimilis*; morda predstavljata različni “kriptični vrsti”.

KLJUČNE BESEDE: Avstrija, biogeografija, nove najdbe, škržatki, Cicadina, Fulgoromorpha, Cicadomorpha, Cixiidae, Cicadellidae, Delphacidae, Caliscelidae

Introduction

The distribution and ecology of the Auchenorrhyncha species of Central Europe and especially Austria is well known (e.g. HOLZINGER 2009a, b). Nevertheless, in the course of various projects, unexpected discoveries have been made that have provided new information on distribution and ecology of some species. These are summarized in this paper.

Methods, material

Auchenorrhyncha were collected by sweep-net, suction sampler and with pitfall traps. Voucher specimens are deposited in the collection of the Karl-Franzens-University Graz, Institute for Biology (coll. G. Kunz) and of the Oekoteam - Institute for Animal Ecology and Landscape Planning (coll. OEKO/Holzinger).

Results and discussion

Cixiidae SPINOLA, 1839

Myndus musivus (GERMAR, 1825)

This cixiid species is known from riverine sites; adults are usually found on willows (*Salix* spp.), rarely also on other shrubs and trees. Nymphs are living subterraneously and are obviously restricted to wet soil conditions. The species is threatened due to river regulations and hydropower utilization. In the last decades, only few records from Central Europe were published and none from Austria after 1950. Here we present two new Austrian records and one remarkable record from a temporarily flooded Dolina in Croatia, where hundreds of adults could be found on willows.

New records: Austria, Lower Austria, Donauauen National Park, riverbank vegetation, on *Salix* sp. 48°07'26"N, 16°42'89"E, 146m a.s.l., 1 ♂, 04.08.2014, G. Kunz leg. -- Austria, Burgenland, riverbank of Leitha near Potzneusiedl, 48°03'14"N, 16°55'06"E, 140m a.s.l., 1 ♂, 18.06.1998, W.E. Holzinger leg. -- Croatia, Istria NE Buje, E Čepići, collapse sinkhole „Malinska“, 45°25'3"N, 13°49'4"E, 330m a.s.l., hundreds of adults on *Salix* spp. within a grazed, temporarily flooded area, 25.07.2013, W.E. Holzinger, P. Holzinger & B. Komposch leg.

Trigonocranus emmeae FIEBER, 1876

This is the most enigmatic Cixiidae in the Central European fauna. Its range extends from Great Britain and France to Sweden in the North and the Caucasus region in the south-east, but only very few records have been published throughout this range - mainly of long-winged, migrating females (see e.g. HOLZINGER et al. 2003, MUSIK et al. 2013, EMELJANOV 2015). Adults are usually short-winged, pale

and have reduced compound eyes. They sustain in the soil, usually in habitats with sparse vegetation cover, and reproduce there (see HOCH et al. 2013, DE HAAS & DEN BIEMAN 2018). Only migrating individuals (females) are known to be able to fly. Short-winged specimens and thus development habitats are almost unknown.

Only a single record was known from Austria to date (MOOSBRUGGER 1946). Recently, we found a short-winged male and a nymph in a rural site in Tyrol and thus a breeding site of this species, and, in addition, a long-winged female in Lower Austria.

New records: Austria, North Tyrol, Trankhütte near Roppen, rural habitat near an old waste disposal site, 47°14'06''N 10°49'33''E, 840m a.s.l., 1 nymph, 21.05.2013, T. Kopf leg., and 1 short-winged ♂ in a pitfall trap, 26.06.-15.07.2013, J. Schied & T. Kopf leg. -- Austria, Lower Austria, stone quarry 1 km south of Schwarzensee, ruderal vegetation 48°00'01''N; 16°03'48''E, 481m a.s.l., 1 ♀, 12.06.2011, G. Kunz leg.

Delphacidae LEACH, 1865

Pseudodelphacodes flaviceps (FIEBER, 1866)

This species is endemic to gravel and sand banks in the Alps, feeding monophagously on *Calamagrostis pseudophragmites*. Records are only known from four rivers: Rhine (near Lustenau, Vorarlberg, Austria; MOOSBRUGGER 1946, NICKEL 1999), Rhône (Salgesch, Wallis, Switzerland; MÜHLETHALER et al. 2016), Lech (near Augsburg, Bavaria, Germany; FISCHER 1972) and Isar (floodplains near Lenggries/Vorderriss, Krün, Fall, Ascholding and Wallgau, Bavaria, Germany; FRÖHLICH 1996, NICKEL 1999). No previous record was published from any residual water bed. We could find the species in two sites along the Inn river in Tyrol. This river is strongly influenced by hydropower utilisation: both sites by daily hydropeaking and one is, in addition, situated in a residual water bed.

New records: Austria, North-Tyrol, gravelbank of the Inn river near Fließ, 47°06'48''N 10°38'40''E, 845m a.s.l., 8 ♂ 22 ♀, 11.08.2009, and 4 ♀, 14.07.2010, W. E. Holzinger leg.; several ♂ & ♀, 18.08.2010, G. Kunz leg. -- Austria, North-Tyrol, riverside of Inn near Arzl/Pitztal, 47°13'04''N, 10°46'04''E, 710m a.s.l., pitfall trap, 1 ♀, 18.07.-03.08.2013 and 4 ♂ 2 ♀, 03.08.-28.08.2013, both J. Schied & T. Kopf leg.

Criomorphus williamsi CHINA, 1939

This is again a very rare species with only few published records, scattered from northern Germany and the Czech Republic to eastern Europe and to the Kyrgyz Republic (summarized by SCHLOSSER & HOLZINGER 2017). Here we present the second record from Austria. The species is obviously restricted to wet meadows with extensive mowing or grazing.

New record: Austria, Lower Austria, SW of Laab im Walde, wet meadow (Molinion), 48° 08'43-44''N, 16°10'08-44''E. 391m a.s.l., 1 ♂, 07.06.2015, J. Gunczy & G. Kunz leg.

Euides alpina (WAGNER, 1948)

This eurosiberian species is known from few localities in Central Europe only (see HOLZINGER et al. 2003), but also occurs in the Caucasus region and Central Asia (e.g. DUBOVSKIY & TURGUNOV 1971). In Austria, it was recorded once at the type locality in westernmost Austria (Frastanz, Vorarlberg; WAGNER 1948). Now we found another site in the eastern part of the country:

New record: Austria, Lower Austria, east of Laab im Walde, spring-fed meadow, on *Phragmites australis*, 48°09'13"N, 16°12'31"E, 338m a.s.l., 1 ♂, 07.06.2015; 5 ♂ 1 ♀ 1 nymph, 30.06.2017, J. Gunczy & G. Kunz leg.

Caliscelidae AMYOT & SERVILLE, 1834

Ommatidiotus dissimilis (FALLÉN, 1806)

This species is distributed throughout Europe, but ecological information published from different countries show different preferences concerning the habitat of this species. Authors from Northern and Central Europe consider it as tyrphobiotic, i.e. occurring in peat bogs and feeding only on *Eriophorum* spp. (e.g. NICKEL 2003, SUSHKO & BORODIN 2009). In contrast, records from southern part of Europe originate from moist meadows and salty habitats, where the species feeds on *Carex* spp. (e.g. GUGLIELMINO & al., 2005, GUGLIELMINO & BÜCKLE 2015). Despite its variability in colouration, no morphological differences between these two “ecotypes” are recognisable (GUGLIELMINO & BÜCKLE 2015).

Only one previous record from Austria exists (HOLZINGER 2009a). In fact, both ecotypes occur: We found *Ommatidiotus dissimilis* in inner-alpine peat bogs in western Austria (Vorarlberg) on *Eriophorum* and in inland salt marshes in the Pannonian parts of eastern Austria on *Carex*. Further (molecular) studies are encouraged, as it seems possible that these ecotypes represent cryptic species.

New records: Austria, Lower Austria, Baumgarten/March, inland salt marsh, 48°17'37-50''N 16°52'15-29''E, numerous Adults and nymphs, 01.06.2000, W. E. Holzinger leg., 20.08.2008, G. Kunz & R. Kunz leg. – Austria, Burgenland, Lake Neusiedl National Park, Lange Lacke 3km NE Apetlon, inland salt marsh, 47°45'28"N, 16°51'47"E, 118m a.s.l., 1 ♀ 12.06.2012, G. Kunz leg. -- Austria, Burgenland, Lake Neusiedl National Park, Sandeck, wet meadow, 47°43'58"N, 16°46'02"E, 115m a.s.l., 3 ♂ 01.06.2017, G. Kunz leg.; 5 ♀ 07.06.2018, G. Kunz & A. L. Rodenkirchen leg. – Austria, Vorarlberg, Doren-Moos NW Krumbach, peat bog, 47°29'54''N 9°54'41''E, 660m a.s.l., 2 ♂ 5 ♀, 04.09.2014, L. Schlosser & J. Egger leg. – Austria, Vorarlberg, Farnachmoos S Oberbildstein, peat bog, 47°27'28-30''N, 9°48'35''E, 890m, 12 ♂ 8 ♀, 25.07.2013, L. Schlosser & J. Egger leg.

Cicadellidae LATREILLE, 1825

Dorycephalus baeri KOUCHAKEVITCH, 1866

This species is known from the Steppe regions of Eastern Europe (NOVIKOV et al. 2006); DMITRIEV (2007) classified it as “Western Scythian species”. It is known from very few localities in Russia, Hungary, Czech Republic and Austria only (ZAHNISRER 2018). The only previous record from Austria (Mödling, Lower Austria) is about 100

years old (WAGNER & FRANZ 1961). Now we found it in another two steppe-like habitats in eastern Austria:

New records: Austria, Lower Austria, Hexenberg near Hundsheim, 48°07'33''N 16°56'08''E 245m, 2 ♂, 07.-26.05.1988, pitfall trap, W. Waitzbauer leg. – Austria, Burgenland, Lake Neusiedl National Park, SE Weiden am See, dry grassland, on *Stipa*, 47°55'05''N, 16°53'07''E, 155m, 9 Ad., 14.06.2012, G. Kunz leg.; 9 Ad., 01.06.2017, A. Koblmüller, K. Sefc & G. Kunz leg.

Glossocratus foveolatus FIEBER, 1866

This is a southern central palaeartic steppe species recorded only a few times from Europe (Hungary, Czech Republic, Slovakia, southern Russia, Serbia; EMELJANOV 1964, STOJANOVIĆ & MARKOVIĆ 2014). It lives in steppe biotopes and inland sand dunes, feeding on grasses (Poaceae). Here we present the first record from Austria.

New record: Austria, Burgenland, Lake Neusiedl National Park, Zitzmannsdorfer Wiesen, wet meadow, 47°53'12''N, 16°52'06''E, 118m, 10 ♂ 15 ♀, 06.06.2013, H. Nickel, J. Gunczy & G. Kunz leg.

Calamotettix taeniatus (HORVATH, 1911)

This species is monophagous on *Phragmites australis* and distributed throughout northern, central and southern Europe (see WALCZAK & JEZIOROWSKA 2015, GUGLIELMINO & BÜCKLE 2015). Although its host plant is common and widespread, *C. taeniatus* is rare and considered to be threatened in Red Lists (e.g. NICKEL et al. 2016). Here we present the first record from Austria.

New record: Austria, Burgenland, Lake Neusiedl National Park, Illmitz Biological Station, lighttrap, 47°46'09'' N, 16°45'58''E, 120m, more than 100 Adults, 04.-05.06.2017, G. Kunz leg.

Acknowledgements

We thank Viktor Hartung (Berlin) for the Russian translation of the abstract and Vladimir Gnezdilov (St. Petersburg) and Gabrijel Seljak (Nova Gorica) for helpful comments on the manuscript. We are grateful to Lydia Schlosser, Johanna Egger, Timo Kopf, Johannes Schied and Wolfgang Waitzbauer for providing us material and data, INATURA Dornbirn for funding parts of the presented research, and to the Governments of Lower Austria, Burgenland and Vorarlberg for collecting permits.

Zusammenfassung

Die Arbeit enthält Nachweise von neun sehr seltenen und wenig bekannten Zikadenarten aus Österreich und einen interessanten Nachweis von *Myndus musivus* aus Kroatien. *Glossocratus foveolatus* und *Calamotettix taeniatus* werden erstmals aus Österreich gemeldet. Für *Trigonocranus emmeae*, *Criomorpus williamsi*, *Euides alpina* und *Dorycephalus baeri* werden die Zweitfunde für Österreich präsentiert. Zwei

neue Fundorte von *Pseudodelphacodes flaviceps* an den Ufern des Inn werden von Wasserkraftnutzung (Restwassersituation und Schwallbetrieb) geprägt. Zwei unterschiedliche "Ökotypen" von *Ommatidiotus dissimilis* kommen in Österreich vor; möglicherweise handelt es sich auch um unterschiedliche "kryptische Arten".

Резюме

Представлены находки девяти редких и малоизученных видов цикадовых из Австрии и любопытная находка *Myndus musivus* из Хорватии. *Glossocratus foveolatus* и *Calamotettix taeniatus* обнаружены в Австрии впервые, для *Trigonocranus emmeae*, *Criomorpha williamsi*, *Euides alpina* и *Dorycephalus baeri* представлены новые находки. Два новых местонахождения *Pseudodelphacodes flaviceps* находятся в пойме реки, интенсивно используемой в гидроэнергетике. *Ommatidiotus dissimilis* представлен в Австрии двумя различными экотипами; возможно, они представляют собой криптические виды.

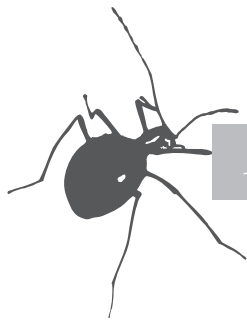
References

- De Haas M., den Bieman K.**, 2018: ecology and distribution of Dutch lacehoppers (Hemiptera: Fulgoromorpha: Cixiidae). *Nederlandse faunistische Mededelingen* 50: 39-54.
- Dmitriev D. A.**, 2007: Zoogeographical analysis and spatial distribution of Auchenorrhynchs (Homoptera, Cicadina) in the Central Chernozem Region. *Entomological Review* 87(9): 1201-1217.
- Dubovskiy G.K., Turgunov M.T.**, 1971: On the leafhoppers (Homoptera, Auchenorrhyncha) of the Inner Tien Shan. *Entomological Review* 50: 193-195.
- Emeljanov A.F.**, 1964: Homoptera Подотряд Cicadinea (Auchenorrhyncha). Определитель насекомых европейской части СССР. Т. 1. М.; Л., 337-437. [English version published 1967 in: Bei Bienko G.Ya. (Ed): Keys to the Insects of the European USSR, Vol. I: 421-551]
- Emeljanov A.F.**, 2015: Planthoppers of the family Cixiidae of Russia and adjacent territories. KMK Scientific Press Ltd., St. Petersburg-Moscow, 253 pp.
- Fischer H.**, 1972: Die Tierwelt Schwabens. 21. Teil: Die Zikaden. *Berichte der Naturforschenden Gesellschaft Augsburg* 27: 103-143.
- Fröhlich W.**, 1996: Zikaden-Nachweise aus dem Gebiet des Neusiedler Sees (Österreich, Burgenland) und aus angrenzenden Gebieten (Insecta: Auchenorrhyncha). *Linzer Biologische Beiträge* 28/1: 335-347.
- Guglielmino A., Bückle C. & Remane R.**, 2005: Contribution to the knowledge of the Auchenorrhyncha Fauna of Central Italy (Hemiptera Fulgoromorpha et Cicadomorpha). *Marburger Entomologische Publikationen* 3(3): 13-98.
- Guglielmino A., Bückle C.**, 2015: Remarks on the composition of the Auchenorrhyncha fauna in some moist areas in Southern Apulia (Italy). *Biodiversity Journal* 6(1): 309-322.

- Hoch H., Mühlethaler R. & Wessel A.**, 2013: Acoustic communication in the sub-troglophile planthopper *Trigonocranus emmeae* Fieber, 1876 (Hemiptera: Fulgoromorpha: Cixiidae: Oecleini). *Acta Musei Moraviae, Scientiae biologicae* 98: 155-162.
- Holzinger W.E.**, 2009a: Rote Liste der Zikaden (Hemiptera: Auchenorrhyncha) Österreichs. In: Zulka K.P. (Ed.): Rote Listen gefährdeter Tiere Österreichs. Grüne Reihe des Lebensministeriums 14/3, 41-317.
- Holzinger W.E.**, 2009b: Auchenorrhyncha (Insecta). *Checklisten der Fauna Österreichs, Biosystematics and Ecology Series* 26: 41-100.
- Holzinger W.E., Kammerlander I. & Nickel H.**, 2003: The Auchenorrhyncha of Central Europe. Vol. 1: Fulgoromorpha, Cicadomorpha excl. Cicadellidae. Brill Academic Publishers, Leiden, 673 pp.
- Moosbrugger J.**, 1946: Die Zikadenfauna von Vorarlberg. *Zentralblatt für das Gesamtgebiet der Entomologie* 1(3): 65-75.
- Mühlethaler R., Trivellone V., van Klink R., Niedringhaus R. & Nickel H.**, 2016: Kritische Artenliste der Zikaden der Schweiz (Hemiptera: Auchenorrhyncha). *Cicadina* 16: 49-87.
- Musik K., Walczak M., Depa L., Junkiert L. & Jedynowicz A.**, 2013: *Trigonocranus emmeae* Fieber, 1876 (Hemiptera, Fulgoromorpha, Cixiidae) - a new species for Poland. *ZooKeys* 319: 249-253.
- Nickel H.**, 1999: Life strategies of Auchenorrhyncha species on river floodplains in the northern Alps, with description of a new species: *Macropsis remanei* sp. n. (Hemiptera). *Reichenbachia* 33: 157-169.
- Nickel H.**, 2003: The Leafhoppers and Planthoppers of Germany (Hemiptera Auchenorrhyncha): Patterns and strategies in a highly diverse group of phytophagous insects. Pensoft Publishers, Sofia-Moscow, 466 pp.
- Nickel H., Achtziger R., Biedermann R., Bückle C., Deutschmann U., Niedringhaus R., Remane R., Walter S. & Witsack W.**, 2016: Rote Liste und Gesamtartenliste der Zikaden (Hemiptera: Auchenorrhyncha) Deutschlands. *Naturschutz und Biologische Vielfalt* 70(4): 247-298.
- Novikov D.V., Novikova N.V., Anuvrief G.A. & Dietrich C.H.**, 2006: Auchenorrhyncha (Hemiptera) of Kyrgyz Grasslands. *Russian Entomological Journal* 15(3): 303-310.
- Schlosser L., Holzinger W.E.**, 2017: Zur Zikadenfauna (Hemiptera: Auchenorrhyncha) der Lafnitzwiesen bei Wörth (Steiermark, Österreich). *Cicadina* 17: 53-61.
- Stojanović A., Marković Č.**, 2014: First finding of *Glossocratus foveolatus* Fieber, 1866 (Hemiptera: Cicadellidae) in Serbia. *Acta Entomologica Serbica* 19(1/2): 73-75.
- Sushko G.G. & Borodin O.I.**, 2009: Cicadas (Homoptera, Auchenorrhyncha) of the peatbogs of Belarus. *Vestnik Belorusskogo Gosudarstvennogo Universiteta* 2(3): 28-32.
- Wagner W. & Franz H.**, 1961: Unterordnung Homoptera Überfamilie Auchenorrhyncha (Zikaden). In: Franz H. (Ed.) Die Nordostalpen im Spiegel ihrer Landtierwelt 2: 74-158.

- Wagner W.**, 1948: Neue deutsche Homopteren und Bemerkungen über schon bekannte Arten. *Verhandlungen des Vereins für naturwissenschaftliche Heimatforschung Hamburg* 29: 72-89.
- Walczak M. & Jeziorowska M.**, 2015: First record of *Calamotettix taeniatus* Horváth, 1911 (Hemiptera: Cicadellidae: Paralimnini) in Poland, with some remarks on the distribution and biology of the species. *Acta Entomologica Silesiana* 23: 1-6.
- Zahniser J.N.**, 2018: An online interactive key and searchable database of Deltocephalinae (Hemiptera: Cicadellidae). <http://zahniser.speciesfile.org>; last access 10.07.2018

Received / Prejeto: 13. 8. 2018

**NOTABLE NEW FINDINGS OF AUCHENORRHYNCHA (HEMIPTERA)
IN SLOVENIA**

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Abstract - Three planthopper and six leafhopper species are recorded for the first time for the fauna of Slovenia: *Cixius similis*, *Nothodelphax albocarinata*, *Acanalonia conica*, *Metidiocerus impressifrons*, *Tautoneura polymitusa*, *Euscelis distinguendus*, *Streptopyx tamaninii*, *Arocephalus grandii* and *Allygus communis*. Additional distributional data for three rare and little-known species *Limotettix carniolicus*, *Jassargus dentatus* and *Cosmotettix costalis* are provided and discussed too. *Acanalonia conica* and *Tautoneura polymitusa* are new alien species that have spread into Slovenia recently.

KEY WORDS: Hemiptera, Auchenorrhyncha, fauna, Slovenia

Izveček - POMEMBNE NOVE NAJDBE ŠKRŽATKOV V SLOVENIJI (HEMIPTERA, AUCHENORRHYNCHA)

Objavljeni so podatki o devetih novih vrstah škržatkov za favno Slovenije: *Cixius similis*, *Nothodelphax albocarinatus*, *Acanalonia conica*, *Metidiocerus impressifrons*, *Tautoneura polymitusa*, *Euscelis distinguendus*, *Streptopyx tamaninii*, *Arocephalus grandii* in *Allygus communis*. Dodani in komentirani so novi podatki o razširjenosti treh redkih in malo znanih vrst škržatkov – *Limotettix carniolicus*, *Jassargus dentatus* in *Cosmotettix costalis*. *Acanalonia conica* in *Tautoneura polymitusa* sta novi tujerodni vrsti, ki sta se pred kratkim razširili na ozemlje Slovenije.

KLJUČNE BESEDE: Hemiptera, Auchenorrhyncha, favna, Slovenija

Introduction

With the author's latest accounts on the fauna of planthoppers and leafhoppers of Slovenia, the number of species increased by 82 species and raised to 565 altogether

(SELJAK, 2016 and 2017). Recently, several additional species have been discovered that have not been recorded yet. These new findings may be of special significance, because some of the species dealt with are considered as rare or with a very limited distribution range, or they are new aliens and have spread into the territory of Slovenia only recently.

Material and methods

Specimens were collected by sweep-netting of plants or with a suction sampler or by light trapping. Voucher specimens of all species were dry mounted and are stored in the author's private collection.

List of species

Cixiidae

***Cixius similis* Kirschbaum, 1868** (Figure 1 and 11)

Material examined: Hotedršica - 590 m (45°56'28" N, 14°09'25" E), 15.5.2017; 3 ♂♂ and 2 ♀♀ swept from a tree of *Salix eleagnos* in an intermediate bog.

This species has a predominantly boreo-alpine distribution in Europe. Further south it is confined to bogs and mountains (HOLZINGER & al. 2003; NICKEL, 2003). The record given above is the first from Slovenia. The species may be more common, but so far, its habitats have been subject to little investigation, notably at the time of adults' flight in May and June.



Fig. 1: *Cixius similis* (size 4.7-6.5 mm)



Fig. 2: *Acanalonia conica* – adult (size 8.2 – 11.0 mm)



Fig. 3: *Acanalonia conica* - 5th instar nymph

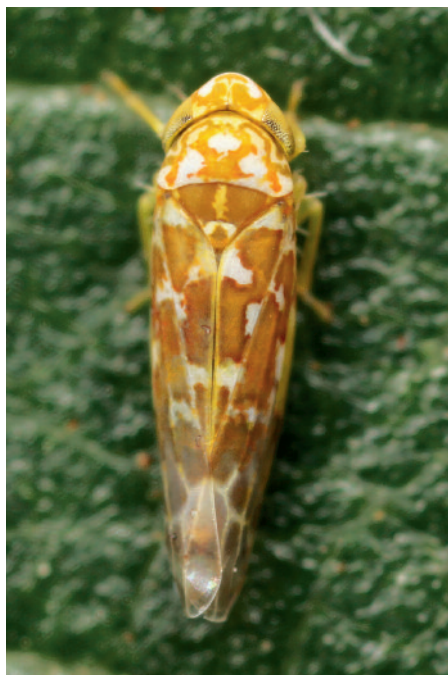


Fig. 4: *Tautoneura polymitusa* (dorsal view; size 2.4-2.7 mm)

Delphacidae

***Nothodelphax albocarinata* (Stal, 1858)** (Figure 11)

Material examined: Zakraj (Bloška planota) - 750 m (45°47'53" N, 14°32'07" E), 17.7.2017; 5 ♂♂ and 5 ♀♀; in an intermediate bog.

Like the previous, this species is also considered to have a predominantly boreal distribution range in Europe, Asia and North America. In Central Europe it mainly occurs in very scattered populations (HOLZINGER & al. 2003; NICKEL, 2003). The locality above, which is the first record for Slovenia, is among the southernmost in Europe. In the Alpine raised bogs of Slovenia, only the sister species *N. distincta* (Flor 1861) has been found so far. However, it seems that both species might be rather rare.

Acanaloniidae

***Acanalonia conica* (Say, 1830)** (Figures 2, 3 and 11)

Material examined: Miren - 60 m (45°54'04" N, 13°36'53" E), 30.6.2017 - 1 ♀, 11 nymphs, 11.7.2017 - 1 ♀, 2 ♂♂ and 21.8.2017 - 1 ♂; Nova Gorica - 105 m (45°57'27" N 13°39'15" E), 24.6.2018 - 1 nymph.

In Europe this Nearctic species was first recorded in 2003 in North Italy, being captured on the light near Padua (D'URSO & ULIANA, 2004). Afterwards it has spread gradually in North Italian provinces (D'URSO & ULIANA, 2006, ALDINI et al., 2008; ZANDIGIACOMO & al., 2009), reaching southern Switzerland (Ticino) in 2014 (TRIVELLONE & al., 2015). Recently, an accidental introduction to Romania has also been

recorded (CHIRECEANU & al., 2017). As early as in 2010, its occurrence has been reported barely 10 km away from the Slovene border in Friuli Venetia Giulia in Italy (ZANDIGIACOMO & al., 2009), hence its spread to the western areas of Slovenia has been expected. At the end of June 2017, several nymphs of fourth and fifth instar and the first adult specimen were caught in an abandoned sand pit area close to the Italo-Slovene border. The presence of pre-imaginal stages clearly shows that it has spread to this locality at least a year earlier. Later, during the summer months of 2017, several other places along the Italian border around Nova Gorica were visited, but no further positive localities found. In June 2018, a nymph of the forth instar was swept from an ornamental bush in Nova Gorica.

Cicadellidae

Metidiocerus impressifrons (Kirschbaum, 1868) (Figure 12)

Material examined: Cerkniško jezero – 550 m (45°45'43" N 14°21'43" E), 17.7.2017 - 1 ♀ on *Salix purpurea*.

This species is obviously rare in Slovenia, at least in its western part. It might be more common in the continental part of the country, which was little investigated so far and where its host plants occur more commonly. It is also possible that this species has been overlooked in the past. THEN (1886) recorded it from Raibl (nowadays Cave del Predil) in Italy, a locality very close to the north-western Slovene border.

Tautoneura polymitusa Oh & Jung, 2016 (Figures 4 - 7 and 12)

Material examined: Nova Gorica – 105 m (45°57'28" N, 13°39'14" E), 14.9.2010 - 2 ♀♀, 28.6.2011 - 1 ♂, 11.7.2011 - 1 ♀, 26.8.2011 - 1 ♂, 6.7.2013 - 1 ♀, 13.7.2013 - 3 ♀♀ and 22.6.2018 – 1 ♀; Kromberk – 125 m (45°57'48" N, 13°39'33" E), 13.7.2013 - 4 ♂♂, 31 ♀♀ and 11.8.2013 - 3 ♀♀.



Fig. 5: *T. polymitusa* (lateral view)

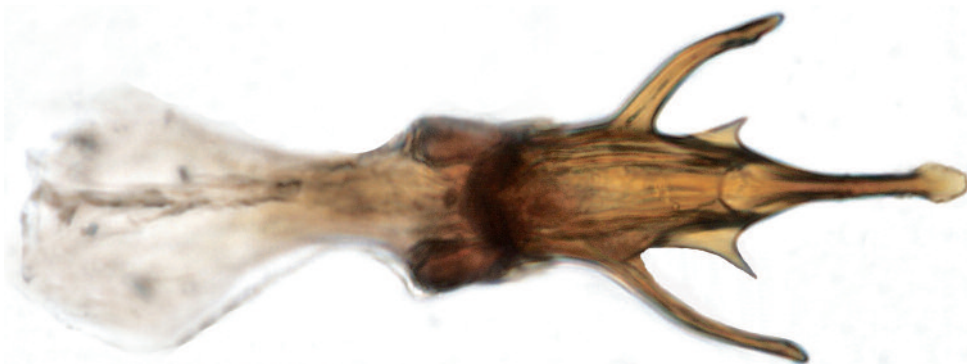


Fig. 6: *T. polymitusa* – aedeagus (posteroventral view)

This species has been described very recently in South Korea (OH & al., 2016). Only a year later, the occurrence of this unambiguously East-Palaeartic species has been recorded in Hungary (TOTH & al., 2017). However, the presence of this species in Europe had already been detected as early as before 2010 in northern Italy and in Spain (Francesco Poggi, Italy, pers. comm.) and since 2010 in western Slovenia as well. From the very beginning, this species was suspected as to be a new, still undescribed one, which is, however, alien to Europe. Nevertheless, an original description based on the European material has not been accomplished.

In Slovenia, most of the material was trapped on the light, partly also collected by sweep-netting from the canopies of *Ulmus minor* trees. *Ulmus* spp. are obviously the host plants of this species, which was already suspected by the earlier authors (OH & al., 2016; TOTH & al., 2017). Among the material collected in Slovenia, females



Fig. 7: *T. polymitusa* – styli, connexiv and subgenital plates

Fig. 8: *Streptopyx tamaninii* – female



markedly prevailed. Out of 48 specimens being caught, only 6 were males. Adults have been collected from end of June to mid of September. The exact number of annual generations is still unknown, but it is thought that only one generation might occur. In western Slovenia, the population was always rather small and after 2013 a single female was caught in June 2018 again.

A good description and illustrations of *T. polymitusa* are given by the Korean and Hungarian authors (OH & al, 2016; TOTH & al., 2017). Thus, there is no reason to repeat them here. The photos added may illustrate this colourful species even better.

Euscelis distinguendus (Kirschbaum, 1868) (Figure 12)

Material examined: Cerknjsko jezero – 550 m (45°46'3,9" N, 14°21'32" E), 17.7.2017 - 6 ♂♂, 3 ♀♀.

The only earlier record of this species that could refer also to the territory of Slovenia was by GRÄFFE (1903). His generalized distributional statement for this species "Auf Wiesen in April und Mai" in the area (Küstenland) that encompassed Istria and a wider area around Trieste and Gorizia (Görz) in Italy, and also included areas of the western parts of nowadays Slovenia, only allowed a certain level of probability for its actual occurrence in Slovenia too. Even an incorrect interpretation of this species by Gräffe cannot be excluded, due to the immense taxonomic changes inside the genus *Euscelis* that followed. The above-mentioned locality is the only one confirmed so far. The specimens were collected on a temporarily flooded meadow. It

seems to be rare, but it also might be overlooked in the past due to great similarity with the common and widely distributed *E. incisus*.

***Streptopyx tamaninii* Linnavuori, 1958** (Figures 8 and 12)

Material examined: Mangartsko sedlo - 2030 m (46°26'38" N, 13°38'51" E), 7.7.2017 - 3 ♀♀ and 03.07.2018 – 3 ♀♀.

So far, this rare oreophilous leafhopper has only been recorded in a few Alpine localities in northern Italy, south-eastern France, and in Tirol and Carinthia in Austria (LINNAVUORI, 1958; HELLER, 1989; DELLA GIUSTINA, 1989; HOLZINGER, 1996; HOLZINGER, 2009; ALMA & al., 2009, HUBER & KUNZ, 2016). It is considered as endemic to the south-Alpine area. Earlier, I myself knew this species from a single male collected in the Mont Avic Natural Park (Italy) near the Dondena refuge (2400 m) in September 2007 (ALMA & al., 2009). Recently, this species has been collected on alpine pastures on Reißkofel in Carinthia (HUBER & KUNZ, 2016). In this context, its occurrence in the north-westernmost part of Slovenian Alps is not a surprise. This species has so far been collected only rarely, probably also because adult specimens appear as late as in September and conclude their lifespan in late spring. In Carinthia, for instance, adult specimens have only been collected in mid-May, but no longer in the third decade of June (HUBER & KUNZ, 2016). Our late findings at the beginning of July (females only) may be ascribed to a higher altitude and long snow persistence at that locality. Because of the rarity, nothing is known yet about its host plant(s).



Fig. 9: *Jassargus dentatus*

Fig. 10: *J. dentatus* – male's genital segment (ventral view)



Arocephalus grandii Servadei, 1972 (Figure 13)

Material examined: Kastelec – 320 m (45°35'9" N, 13°51'39" E), 21.9.2016 - 2 ♂♂, 1 ♀; Mahniči - 230 m (45°46'59" N, 13°53'58" E), 23.9.2017 - 1 ♂ and 28.06.2018 - 2 ♂♂, 1 ♀; Pared (Kačiče, 45°38'52.94" N, 13°58'36.92" E) - 440 m (VL25), 28.8.2018 - 1 ♂.

Like the previous species, *A. grandii* is also an endemic species of the south-Alpine region. It has been recorded in northern Italy and southern Switzerland (SERVADEI, 1972; D'URSO, 1995; GÜNTHART & MÜHLETHALER, 2002). Externally, this species is indistinguishable from *A. languidus* (Flor, 1861). It differs from the latter only in the shape of aedeagal appendages. In *A. grandii*, the recurrent apical appendages are about half as long as the shaft itself and clearly extend beyond the base of the gonopore. In posterior view they run nearly parallel to the shaft, whereas in *A. languidus*, they diverge arc-shaped from the shaft and do not exceed one third of the shaft length and do not extend beyond the base of the gonopore. In Slovenia, *A. grandii* has only been found in three localities on karstic meadows. Its host plant is unknown, but some indications point towards *Chrysopogon gryllus*.

Allygus communis (Ferrari 1882) (Figure 12)

Material examined: Dragonja - 25 m (45°27'8" N, 13°39'48" E), 31.8.2017 - 2 ♂, 1 ♀; Veli Brgud – 400 m (Croatia, 45°25'55.87" N, 14°17'27.55" E), 25.6.2008 - 1 ♂.

Although this species is widely distributed in mid-Europe according to Fauna Europaea, it has been confirmed in the territory of Slovenia only very recently. Three specimens were obtained during a light trap catching in late August on a dry sub-Mediterranean meadow with scattered trees of *Quercus pubescens*. At the same time, *A. furcatus* (Ferrari, 1882) abundantly occurred in the same locality. Another locality was recorded in Veli Brgud in Croatia, only about 5 km south from the Slovene border.

Jassargus dentatus D'Urso, 1980 (Figures 9, 10 and 13)

New records: Gradišče pri Vipavi, Mlake - 120 m (45°49'03" N, 13°57'56" E), 1.6.2018, 13.6.2018, 17.6.2018 and 16.08.2018 (several dozens of specimens).

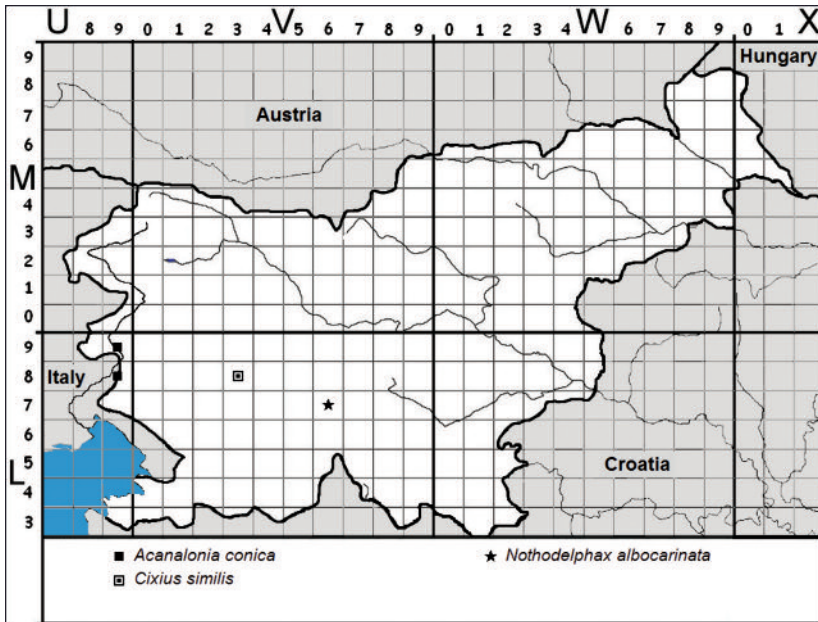


Fig. 11: Distribution map of *A. conica*, *C. similis* and *N. albocarinata*

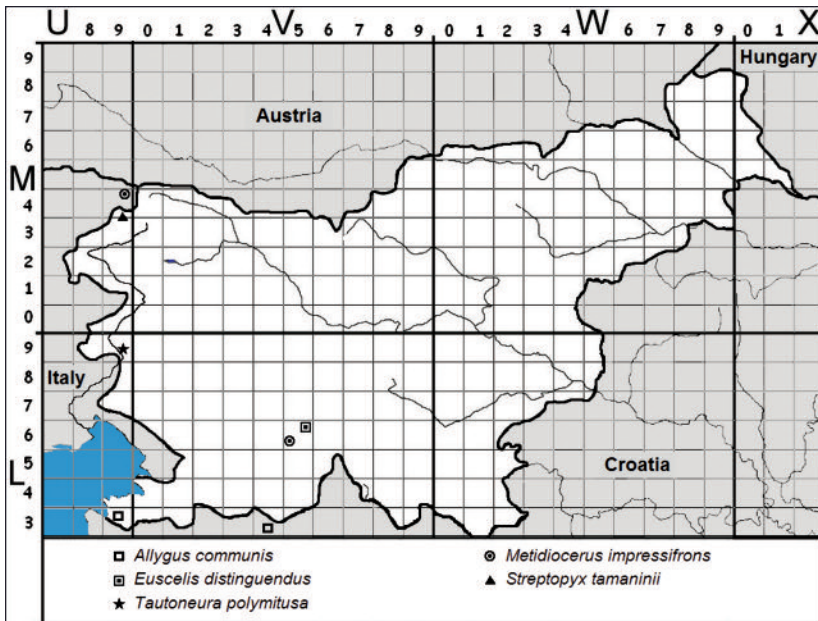


Fig. 12: Distribution map of *A. communis*, *E. distinguendus*, *M. impressifrons*, *S. tamaninii* and *T. polymitusa*

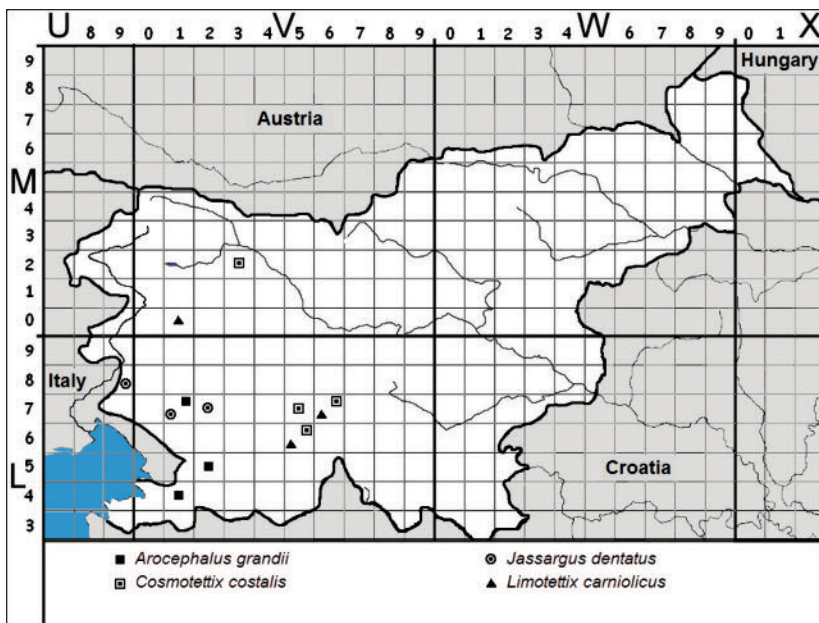


Fig. 13: Distribution map of *A. grandii*, *C. costalis*, *J. dentatus* and *L. carniolicus*

This species has long been known only from the type locality Masserano in Piedmont (Italy) (D'URSO, 1980). In June 2003, a few specimens of this species were first found in Slovenia at the cemetery lawn in Stara Gorica near Nova Gorica. This was only the second known locality of this species (SELJAK, 2004). The population, although rather small, still exist in that place. In June 2018, a much larger population was discovered near Vipava about 30 km SE from the previous locality. It populates a moderately moist meadow, which is part of the protected area Mlake pri Vipavi. If there were some suspicions of a possible introduction from elsewhere in the previous locality, this one unequivocally confirms that *J. dentatus* is indigenous here. It is just another representative of the rich fauna of endemic *Jassargus* species in the south-alpine area. Its hostplant is not unambiguously known yet, but some indications point toward the grass *Molinia caerulea*, which grows on both localities abundantly.

***Limotettix carniolicus* Seljak, 2017 (Figure 13)**

New records: Cerknjiško jezero - 550 m (45°45'45" N, 14°21'37" E), 27.6.2017 - 6 ♂♂, 1 ♀ and 17.7.2017 4 ♂♂; Velike Bloke - 740 m (45°47'35" N, 14°29'42" E), 17.7.2017; Zakraj - 750 m (45°47'53" N, 14°32'07" E), 17.7.2017 and 16.8.2018; Volčje - more than 100 specimens.

In the original description of this newly discovered species only the type locality was recorded, as no other findings were known at that time (SELJAK, 2017). Further field investigations in 2017 and 2018 gave three new localities, all inside the Dinaric area, suggesting a bit wider Dinaric distribution. Further potential sites of its occurrence have to be expected towards the Croatian mountainous region Gorski Kotar. The

species lives on *Eleocharis quinqueflora*, but it is not quite clear yet, whether some other species from the genus *Eleocharis* are used too.

Cosmotettix costalis (Fallén, 1826) (Figure 13)

New records: Laze pri Gorenjem Jezeru - 550 m (45°43'30" N, 14°24'11" E), 17.7.2017 - 4 ♀♀; Ulaka - 750 m (45°47'34" N, 14°28'9" E), 17.7.2017 - 1 ♀; Velike Bloke - 740 m (45°47'37" N, 14°29'38" E), 17.7.2017 - 3 ♀♀.

This species is considered as to have a more northern distribution ranging from Britain through Fennoscandia and middle Europe towards central Russia and Kazakhstan. The most southern findings have been recorded from the south-eastern Alpine area (NICKEL, 2003; SELJAK, 2016). These new findings have shifted the known range considerably towards the south. In all cases the specimens were obtained from tall sedge vegetation by using the suction collecting method. According to LAUTERER (1986), this species may develop two generations a year; one from the beginning of June to mid-August and the second from August to late autumn. It looks like in our case the first generation already faded out in mid-July, as only females were caught.

References

- Aldini R.N., Mazzoni E., Mori N., Ciampitti M.**, 2008: On the distribution in Italy of the Nearctic hopper *Acanalonia conica*, with ecological notes. *Bulletin of Insectology* 61 (1): 153-154.
- Alma A., Bocca M., Čermak V., Chen P., D'urso V., Exnerová A., Goula M., Guglielmino A., Kunz G., Lauterer P., Malenovský I., Mazzoglio P.J., Aldini R.N., Ouvrard D., Remane R., Rintala T., Seljak G., Söderman G., Soulier-Perkins A., Štys P., Tavella L., Tedeschi R., Wilson M.**, 2009: Insecta Hemiptera collected in the Mont Avic Natural Park (Aosta Valley, Northwest Italy). *Revue Valdôtaine d'Histoire Naturelle*, 63: 109-124.
- Chireceanu C., Teodoru A., Gutue M., Dumitru M., Anastasiu P.**, 2017: Two new invasive hemipteran species first recorded in Romania: *Orientalus ishidae* (Matsumura 1902) (Cicadellidae) and *Acanalonia conica* (Say 1830) (Acanaloniidae). *Journal of Entomology and Zoology Studies* 5(2): 824-830.
- D'Urso V.**, 1980: *Jassargus dentatus* nuova specie di Deltocephalinae della Brughiera Piemontese (Insecta, Homoptera, Cicadellidae). *Animalia* 7 (1/3): 123-133.
- D'Urso V.**, 1995: Homoptera Auchenorrhyncha. In: *Checklist delle specie della Fauna Italiana* 42: 1-35.
- D'Urso V., Uliana M.**, 2004: First record of *Acanalonia conica* (Issidae) in Italy. – *Third European Hemiptera Congress, Abstracts, St. Petersburg*, 26–27.
- D'Urso V., Uliana M.**, 2006: *Acanalonia conica* (Hemiptera, Fulgoromorpha, Acanaloniidae), a Nearctic species recently introduced in Europe. *Deutsche entomologische Zeitschrift*. 53(1):103-107.
- Gräffe E.**, 1903: Beiträge zur Cicadinenfauna des Österr. Küstenlandes. *Bolletino della Società Adriatica di Scienze Naturali in Trieste*, 21: 41-63.

- Günthart, H., Mühlethaler, R.,** 2002: Provisorische Checklist der Zikaden der Schweiz (Insecta: Hemiptera, Auchenorrhyncha). *Denisia 04, zugleich Kataloge des OO. Landesmuseums, Neue Folge*, 176: 329-338.
- Heller F.R.,** 1989: *Streptopyx tamaninii* Ly., der zweite Fund nach fast 40 Jahren und andere Zikaden aus Norditalien Homoptera-Auchenorrhyncha. *Mitteilungen des entomologischen Vereins Stuttgart*, 24: 120-125.
- Holzinger W. E.,** 1996: Kritisches Verzeichnis der Zikaden Österreichs (Ins.: Homoptera, Auchenorrhyncha). *Carinthia II*, 186/106: 501-517.
- Holzinger W. E., Kammerlander I., Nickel H.,** 2003: The Auchenorrhyncha of Central Europe/ Die Zikaden Mitteleuropas; Fulgoromorpha, Cicadomorpha excl. Cicadellidae. Brill, Leiden - Boston, 673 pp.
- Holzinger W.E.,** 2009: Auchenorrhyncha (Insecta). *Checklisten der Fauna Österreichs, Biosystematics and Ecology Series* 26: 41-100.
- Huber E., Kunz G.,** 2016: Die Biodiversität der Zikadenfauna der Hochwiese am Reißkofel mit besonderem Augenmerk auf (sub-)endemische und Rote Liste-Arten. *Carinthia II*. 206/126: 459–478
- Lauterer P.,** 1986: New and interesting records of leafhoppers from Czechoslovakia. *Acta musei Moraviae*, 71, 179-187.
- Linnavuori R.,** 1958: On some new or little known Mediterranean Homoptera. *Bollettino della Società Entomologica Italiana* 88(3-4): 34-38.
- Nickel H.,** 2003: The Leafhoppers and Planthoppers of Germany (Hemiptera Auchenorrhyncha): Patterns and strategies in a highly diverse group of phytophagous insects. Copublished by Pensoft Publishers, Sofia-Moscow and Goecke & Evers, Keltern, 460 pp.
- Oh, S., Pham, H.T., Jung, S.,** 2016: Taxonomic review of the Genus *Tautoneura* Anufriev (Hemiptera: Auchenorrhyncha: Cicadellidae: Typhlocybinae) from Korea, with description of one new species. *Zootaxa*, 4169 (1): 194–200.
- Seljak G.,** 2004: Contribution to the knowledge of planthoppers and leafhoppers of Slovenia (Hemiptera, Auchenorrhyncha). *Acta Entomologica Slovenica*, 12 (2): 189-216.
- Seljak G.,** 2016: New and little-known plant- and leafhoppers of the fauna of Slovenia (Hemiptera: Fulgoromorpha And Cicadomorpha). *Acta Entomologica Slovenica* 24 (2): 151–200.
- Seljak G.,** 2017: *Limotettix carniolicus* sp. nov., a new west-palaeartic leafhopper species (Hemiptera, Cicadomorpha, Cicadellidae). *Acta Entomologica Slovenica* 25 (1): 65–74.
- Servadei A.,** 1972: I Rincoti di Valmalenco (Heteroptera e Homoptera Auchenorrhyncha). *Bollettino dell'Istituto di Entomologia dell'Università di Bologna* 31: 13-26.
- Then F.,** 1886: Katalog der Österreichischen Cicadinen. *Programm des k. k. Theresianischen Gymnasiums Wien*: 1-59.
- Tóth M., Orosz A., Rédei D.,** 2017: Another alien on the horizon? First European record of *Tautoneura polymitusa*, an East Asian leafhopper (Hemiptera: Auchenorrhyncha: Cicadellidae). *Zootaxa* 4311 (1): 137–144.

- Trivellone V., Knop E., Turrini T., Andrey A., Humbert J.Y., Kunz G., 2015:** New and remarkable leafhoppers and planthoppers (Hemiptera: Auchenorrhyncha) from Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 88(3, 4): 273-284.
- Zandigiaco P., Cargnus E., Pavan F., 2009:** Primi reperti della cicalina *Acana-
lonia conica* (say) in Friuli-Venezia Giulia. *Notiziario ERSA* 4/2009: 52-54.

Received / Prejeto: 25. 9. 2018



***AMELES DECOLOR* (CHARPENTIER, 1825) (DICTYOPTERA: MANTIDAE), THIRD SPECIES OF THE SLOVENIAN MANTID FAUNA**

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Abstract - *Ameles decolor* (Charpentier, 1825), new to Slovenian fauna, was found in the coastal area of Slovenia, on Brič near Dragonja river, close to Croatian border in Istria. In Croatian coastal region, this species is usually common late in the season. 3 specimens, 2 males and one nymph, were observed coming to the UV light trap for Lepidoptera observation in the evening of August 14th 2017 and 9 adults were observed on August 18th 2018 on the same locality. As immature and mature specimens were found on more spots in the locality, we assume that a small population already thrives there, as females and nymphs are brachypterous. In 2017 specimens were observed on two light traps located in a small patch of a dry south-oriented meadow, surrounded with sub-Mediterranean forest. In 2018 more specimens were observed on the remaining grassland patches in succession across the locality. Although we were looking for this species intensively since many years, this is the first confirmed report of the species in Slovenia. Other two mantid species occurring in Slovenia are *Mantis religiosa* (Linnaeus, 1758), which is common and is extending its territory due to the influence of global climate change and raising temperatures and *Empusa fasciata* Brullé, 1839, which is declining due to abandonment and urbanisation of meadows in the seaside areas. The last one is present mainly in the warmer coastal part of the country.

KEY WORDS: mantids, Mantodea, Mantidae, Slovenia, fauna, new records

Izvešček - *AMELES DECOLOR* (CHARPENTIER, 1825) (DICTYOPTERA: MANTIDAE), TRETJA VRSTA BOGOMOLKE V SLOVENSKE FAVNI

Na Briču ob Dragonji na Primorskem smo našli bogomolke vrste *Ameles decolor* (Charpentier, 1825), ki je nova vrsta za favno Slovenije. Lokacija je tik ob hrvaški meji, kjer je vrsta razširjena v večjem delu Istre. V priobalnem pasu Hrvaške je vrsta navadno pogosta, pojavlja pa se kasneje v sezoni, navadno od julija naprej. 3 osebk, 2 samci in ena nimfa, so opazovane pri svetlobni pasti za Lepidoptera opazovanja zvečer 14. avgusta 2017 in 9 odraslih na 18. avgusta 2018 na isti lokaciji. Ker so nezrele in zrele osebe najdene na več mestih v lokalnosti, predpostavljamo, da tam že obstaja majhna populacija, saj so samice in nimfe brachypterous. Leta 2017 so osebe opazovane na dveh svetlobnih pasteh, ki sta v majhnem delu suhega južno-orientiranega mešana, obkroženega s submediteransko goščavo. Leta 2018 so opazovane na preostalih travnatih delcih v sukcesiji po lokalnosti. Čeprav smo iskali to vrsto intenzivno že več let, je to prvi potrjen poročilni zapis vrste v Sloveniji. Druge dve vrsti mantid, ki sta prisotni v Sloveniji, sta *Mantis religiosa* (Linnaeus, 1758), ki je pogosta in se razširja zaradi vpliva globalne klimatske spremembe in povišanih temperatur, in *Empusa fasciata* Brullé, 1839, ki se upada zaradi opuščanja in urbanizacije mešan na območjih ob morju. Poslednja je prisotna predvsem v toplem obalnem delu države.

2 samčka in eno ličinko smo opazovali zvečer, 14. avgusta 2017, na UV svetlobnih šotorih za opazovanje močnih metuljev, 9 osebkov pa nam je uspelo najti 18. avgusta 2018 na več mestih iste lokacije podnevi. Zaradi najdb ličinke in brezkrilih samic na več mestih iste lokacije predvidevamo, da se vrsta na lokaciji razmnožuje, saj brezkrila samica in ličinka ne moreta leteti. Leta 2017 smo prve primerke opazovali na dveh od 11 svetlobnih šotorov, naslednje leto pa na več mestih preostanka zaplat travišč v sukcesiji. Traviščna vegetacija kot tudi submediteranski prisojni gozd ležita na južnem prisojnem pobočju, 200 m nad dolino Dragonje in sta toplejša od preostalega dela območja. Čeprav smo vrsto iskali že vrsto let, je to prva potrjena najdba za Slovenijo. Drugi dve vrsti bogomolk v Sloveniji sta navadna bogomolka - *Mantis religiosa* (Linnaeus, 1758), ki je pogosta in širi areal zaradi vpliva klimatskih sprememb z globalnim segrevanjem in krpasta grabežljivka - *Empusa fasciata* Brullé, 1839, ki je ogrožena vrsta in izginja zaradi opuščanja in zaraščanja travnatih površin ob morju in zaradi pozidave turistično zanimivega območja ob obali. Krpasta grabežljivka je prisotna le na najbolj termofilnih legah Primorja, en podatek pa je potrjen tudi z Goriškega krasa.

KLJUČNE BESEDE: bogomolke, Mantodea, Mantidae, Slovenija, favna, nove najdbe

Introduction

So far, only two mantid species were known in the Slovenian fauna (Us, 1967, 1992; Gomboc, 2000). *Mantis religiosa* (Linnaeus, 1758), which is widely distributed and is spreading its territory in the last 20 years due to the influence of climate change with warmer temperatures (personal observation in Gorenjska and Štajerska region) and *Empusa fasciata* Brullé, 1839, which is a rare and cryptic species. The territory of *E. fasciata* is declining as many meadows in the coastal region were abandoned and overgrown with shrubs and forest in recent 20 years (personal observations). The urbanisation of the seaside area interesting for tourist accommodations is the second main reason for declining of *E. fasciata*. This species is present at the coast (Gomboc, 2000) with one find in Goriški kras in recent years. Climate change with unstable winters and late spring storms with snow at the end of April in 2016 and 2017 at the coast are also affecting the abundance of *E. fasciata* in recent years. Since several years, we have been observing this phenomenon in Sečovelje Salina Nature Park and on the south slopes of Osp climbing areas, where *E. fasciata* was formerly common. After 2013, when we found many nymphs in the Sečovelje Salina Nature Park, species abundance declined due to cold winter storms. We found one larva here in 2018.

In the past years we were looking intensively for another species, *Ameles decolor* (Charpentier, 1825) in Slovenia, which is common in the Croatian part of Istria, but without any success, although we spent more than 200 field days in the Slovenian part of Istria. There was, however, a posted photo of *A. decolor* on the web page BioLib.cz by Blaž Šegula from Hrastovlje (Šegula, 2005), but without any collected material on which we could confirm presence of the species as *A. decolor* or *A. hel-*

Fig. 1: Male of *Ameles decolor* on light trap, Slovenia, Istria, Dragonja, Brič, August 14th, 2017. Foto: S. Gomboc.



dreichi Brunner von Wattenwyl, 1882, which are closely related. As climate changes are promoting the spread of some Mediterranean Orthoptera species (*Aiolopus thalassinus* (Fabricius, 1781), *Aiolopus strepens* (Latreille, 1804), *Anacridium aegyptium* (Linnaeus, 1764) (personal observations, Stani, 2016, Zuna-Kratky *et al.*, 2017), we were looking also for presence of *A. decolor* in the region. The search was finally successful in 2017 and in 2018 we found additional specimens on Brič hill above the Dragonja river, close to the Croatian border.

In Europe 8 *Ameles* species are present, mainly in the Mediterranean area (Agabiti *et al.* 2010, Battiston *et al.*, 2000; Battiston & Fontana, 2005, Harz & Kaltenbach, 1976). This number remains the same also after the revision of some species of *Ameles* (Battiston *et al.*, 2018), where one species was synonymised and one relocated to the genus *Ameles*. Battiston *et al.* (2018) also discussed status of some species and difficult separation characters inside the genus also in cases of brachypterous males, which makes identification even more difficult. In Italy 5 *Ameles* species are known (Battiston *et al.*, 2000; Battiston & Fontana, 2005, Stoch, 2003), in Croatia only 3 (Kranjčev, 2013; Rebrina *et al.*, 2014). In the nearest part of Croatia in Istria all 3 species, *A. decolor*, *A. heldreichi* and *A. spallanzania* (Rossi, 1792; Rebrina *et al.*, 2014) are occurring. The closely related *A. heldreichi* and *A. decolor* can be reliably separated on a few morphological characters, like the eye shape in male, pronotum index ratio and the examination of male genitalia (Agabiti *et al.* 2010, Battiston *et al.*, 2000; Battiston & Fontana, 2005). Just external morphological characters are not always sufficient for reliable identification, so we also dissected collected male specimens.



Fig. 2: Female of *A. decolor* on Brič, August 18th, 2018. Foto: S. Gomboc

Material and methods

In 2017 specimens of *A. decolor* were observed at UV light traps, used for observing night active moths. These were pyramid-like tents with UV Philips LD/05

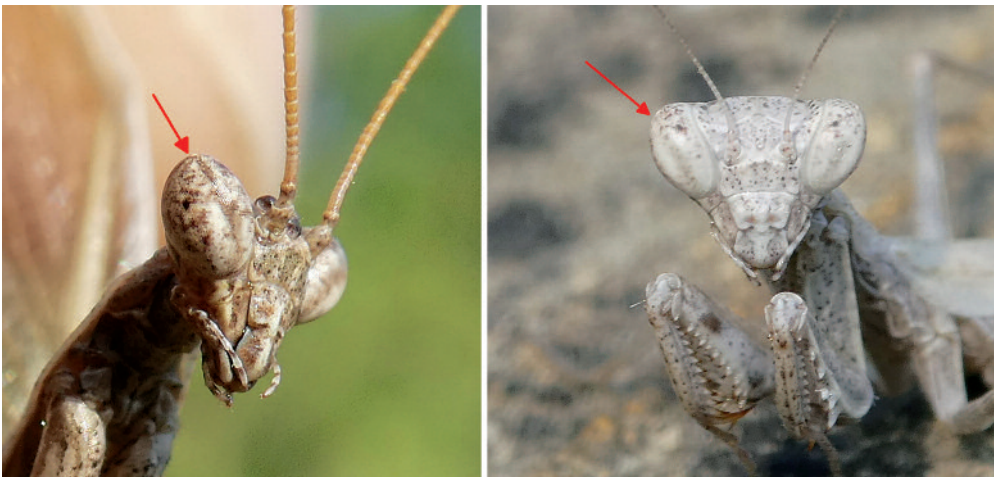


Fig. 3: Eye shapes of *A. decolor* male (left) and female (right), Brič, August 18th, 2018. A rounded shape of composite eyes supports the species identification as *A. decolor*. Foto: S. Gomboc

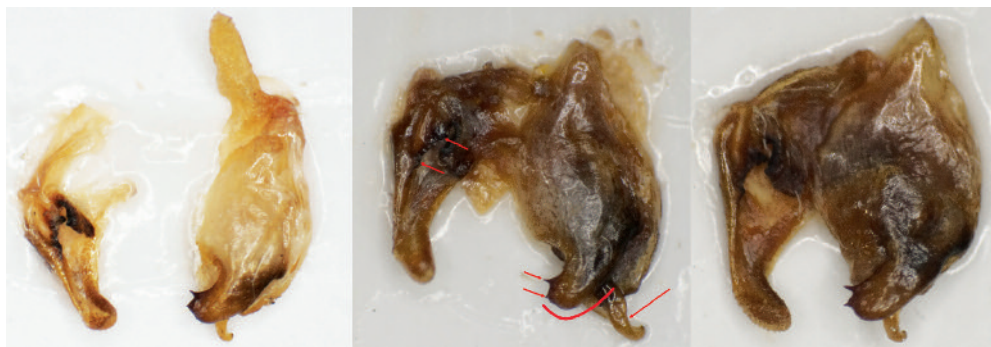


Fig. 4: Male genitalia of collected specimens: left – male from Brič, August 14th, 2017, middle – male nr. 2 from Brič, August 18th, 2018 (red line and arrows indicate the identification characteristics described in results), right - male nr. 3 from Brič, August 18th. Foto: S. Gomboc

light tubes. Three specimens were observed on only two of 11 light traps arranged in a length of 600 m, following macadam forest road.

To confirm identification and presence of species in Slovenia further specimens we searched for on the same locality in August 2018 during the daytime. All remaining grassland patches in succession on the locality were surveyed and few specimens could be confirmed on a few spots on the locality. Butterfly net was used to catch specimens, especially flying males, which could fly for shorter distances and were difficult to catch. 3 additional male specimens were collected to prove species identification. Photos of habitat and specimens were taken using Lumix DMC TZ80 and Sony a55 cameras.

Coordinates of all specimens were collected and detailed distribution maps are created in ARC GIS PRO (fig. 5 and 6). As basemap layers for distribution maps Digital Orto photo of Slovenia from 2016 and Digital Terrain Model was used and slightly modified (map source: The Surveying and Mapping Authority of the Republic of Slovenia 2018: <http://egp.gu.gov.si/egp/>).

Specimens were identified based on detailed photos of morphological characters and collected specimens, which were used for dissection and preparation of genitalia. Olympus stereomicroscope SZ60 was used for specimens identification and for photography of dissected male genitalia in combination with Sony a7 digital camera. Dry specimens are stored in the authors private collection. For identification, keys of Battiston *et al.* (2000), Battiston & Fontana (2005) and Agabiti *et. al* (2010) were used, as well as specimens in the authors' comparative collection.

Results

On August 14th 2017 three specimens of *A. decolor*, 2 males and 1 nymph were observed during the night observation of Lepidoptera on the south slope of the Brič hill above the Dragonja river, next to the Croatian border in Istria (WGS84: 1 male –

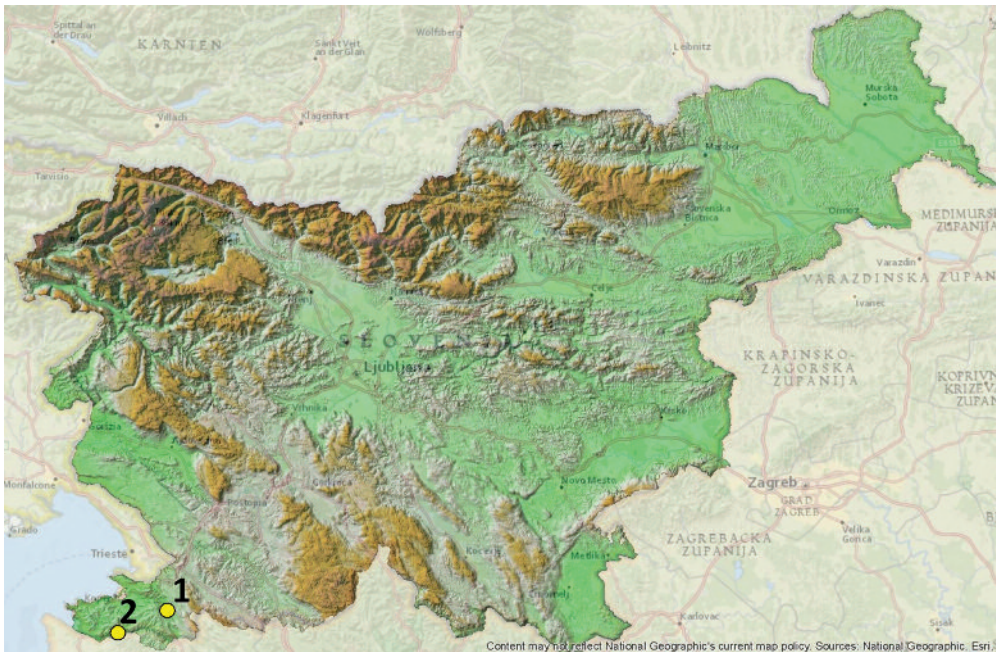


Fig. 5: Map of Slovenia with the records of *A. decolor*: 1 – Hrastovlje 2005, 2 – Brič 2017 and 2018.

45.46269854 N, 13.73388311 E, 208 m; 1 male and 1 nymph – 45.46279516 N, 13.73448195 E, 220 m). This is the first confirmed record of *A. decolor* in Slovenia. The locality is not far from the coast of the Adriatic Sea in the Mediterranean part of Slovenia. All specimens were attracted to UV lights, which were placed on the south slope of the hill, in a submediterranean dry patch of grassland in succession, surrounded with the south oriented sub-Mediterranean shrubs and oak forest. A small stripe of grassland is situated next to the macadam road leading to Brič estate with vineyards and olive groves on the top of the hill.

Specimens of *A. decolor* were observed on the UV light traps shortly after dusk, from 20.20 to 21.00 hour. This was a warm night with many observed insects.

On August 18th 2018 additional 9 adult specimens of *A. decolor* were confirmed on the same locality, 5 males and 4 females. They were difficult to find in dry remaining grassland patches next to the macadam forest road and on the steep slope of the south exposed hillside. Specimens were found on the lower herb and grass vegetation, surrounded by shrubs and young trees like *Cotinus coggygria*, *Spartium junceum*, *Pinus nigra*, *Quercus cerris*, *Quercus petraea*, *Quercus pubescens*, *Ostrya carpinifolia*, *Cornus sanguinea*, *Ligustrum vulgare* and others. During the longer heat period in August, the remaining grassland vegetation was almost dry. The specimens were found only based on movements in vegetation, as they were similar colours as dried meadow plants. Finding of specimens at multiple sites (fig. 6) on the

same locality supports the presumption that the species is already established on the site.

Investigation of collected specimens and photos showed that they all have rounded compound eye shape, which is typical for *A. decolor*, without the distinct ocular spine like in *A. heldreichii*. The male genitalia of all 4 male specimens also confirmed typical form for *A. decolor* (fig. 4). The apex of hypophallus is rounded on outside margin with two smaller inner tooth in the inner margin. Ventral left phallomers are long, with long elongated phalloid apophysis (character description according to Battiston & Fontana, 2005 and Agabiti *et. al.*, 2010).

Table 1: Exact decimal coordinates of *A. decolor* specimens found on Brič, August 18th, 2018.

WGS84 N	WGS84 E	Altitude m (a.s.l.)	Comment
45.46295484	13.73860685	208	1 male
45.46296398	13.73861943	208	1 female
45.46312537	13.73856468	219	1 male
45.46322533	13.73865197	219	1 female, 1 male
45.46322872	13.73895884	221	1 female, 1 male
45.46338365	13.73913443	227	1 female
45.46356089	13.74296724	256	1 male

Discussion

With *A. decolor* 3 mantid species are now confirmed for Slovenia. In the neighbouring Mediterranean Croatia 7 mantid species are present (Rebrina *et al.*, 2014), in Italy 12 (Battiston *et al.*, 2010; Stoch, 2003; Wikipedia, 2017), in Austria only *M. religiosa* (orthoptera.at, 2017). All together 30 mantid species are present in Europe (Battiston *et al.*, 2010; Wikipedia, 2017).

As males, females and a nymph of *A. decolor* were found on the locality and the females are brachypterous, the population should exist here for some time. This is also proved by the find of additional specimens in 2018. The location is isolated from the nearby meadows, which are not close to the forest road itself. This additionally speaks in favour of the longer existence of the species at the locality, which was not visited by us before 2017. This also shows that species can be present at other thermophile sites next to the Croatian border in Istria. In addition, the specimen on the photo by Blaž Šegula (Šegula, 2005) from Hrastovlje could be *A. decolor*, but just the photo itself is not enough for species confirmation as it is closely related to *A. heldreichii*. Anyhow, we have used this data in the distribution map in the paper (fig. 5). As adults appear relatively late in the season, from July onwards, search for additional specimens in the region should focus on the period from July to September. In September and October 2017, we performed additional night observations with light



Fig. 6: Detailed map of *A. decolor* specimens distribution on Brič: green dots - August 14th, 2017; red circles - August 18th, 2018.

traps on the same locality, but no additional specimens of *A. decolor* were found, probably because of a small suitable habitat on the locality and a small number of present specimens.

In July and August 2018 we have searched in some similar habitats for presence of *A. decolor* in the Koper surroundings, Sečovlje Salina Nature Park, slopes on Sv. Peter near Dragonja and also the Dragonja valley but without confirming the presence of species on that localities. As specimens are cryptic and similar to the colour of dry plants, they are difficult to spot in the vegetation. On Brič we saw that they prefer dry and sunny places. Even here, they were very local and difficult to find. Because the localities in Slovenia are at the very edge of the species distribution, *A. decolor* will not be common and easy to find. It can also be present on already visited localities, which look similar to that on Brič, but we could not confirm this during our survey. In addition, *A. heldreichii* could also be expected in Slovenia, as it is present in Croatian Istria (Rebrina et al., 2014). This closely related species is not easy to separate from *A. decolor*. At least one male specimen per location should be collected to confirm species identification. Both species can even hybridise, which makes identification even more difficult.

The population of *A. decolor* on Brič is already endangered as the remaining meadow, where specimens were found, is already abandoned and in succession, to be overgrown with shrubs and forest. The locality was more open with larger meadow



Fig. 7: Habitat of *A. decolor* on Brič, August 18th, 2018. The orange arrows indicate the exact location of 3 observed specimens. Foto: S. Gomboc

on the same slope in 1994 (Digital Orto photo from 1994, The Surveying and Mapping Authority of the Republic of Slovenia). Other meadows in the Dragonja valley, where species could occur, are in a similar state as many farmers are not keeping animals on the farms or they are turned into the fields or olive plantations, which bring more income.

Acknowledgments

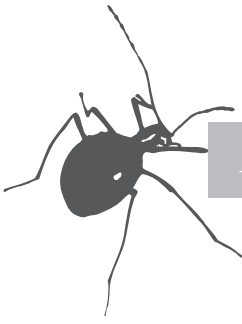
I would like to thank my friends with whom we performed the night observation of moths in 2017, Slavko Polak and Cristian Wieser. In the year 2018, PhD. student Anja Danielczak helped me with the search for additional specimens on Brič, as also on other localities, where we could not confirm the presence of the species.

References

Agabiti, B., Salvatrice, I., Lombardo, F., 2010: The Mediterranean species of the genus *Ameles* Burmeister, 1838 (Insecta, Mantodea: Amelinae) with a biogeographic and phylogenetic evaluation. *Boletín de la Sociedad Entomológica Aragonesa* (S.E.A.) 47: 1–20.

- Battiston R., Correas J., Lombardo F., Mouna M., Payne K., Schütte K., 2018:** Morphological convergences in *Ameles* Burmeister and *Pseudoyersinia* Kirby: Taxonomic implications of wing reduction and flight predisposition in some West-Mediterranean Amelini (Insecta: Mantodea). *Zootaxa* 4377(1): 21-38.
- Battiston, R. & Fontana, P., 2005:** A contribution to the knowledge of the genus *Ameles* Burmeister, 1838, with the description of a new species from Jordan (Insecta Mantodea). *Atti della Accademia Roveretana degli Agiati - Classe di Scienze Matematiche Fisiche e Naturali* 5: 173–197.
- Battiston, R., Picciau, L., Fontana, P., Marshall, J., 2010:** Mantids of the Euro-Mediterranean area. World Biodiversity Association ONLUS, Verona. 240 pp.
- Rebrina, F., Battiston R., Skejo J., 2014:** Are *Empusa pennata* and *Bolivaria brachyptera* really present in Croatia? A reply to Kranjčev (2013) with a critical review of the mantid taxa found in Croatia. *Entomologia Croatica*: 18(1–2): 17–25.
- Gomboc S., 2000:** Bionomie, Verbreitung und Zuchtungsversuche an *Empusa fasciata* Brulle, 1836 (Mantodea, Empusidae) in Slowenien. *Articulata* 15(1): 1-6
- Harz, K. & Kaltenbach, A., 1976:** Die Orthopteren Europas III. Series Entomologica, Dr. W. Junk Series. 440 pp.
- Kranjčev, R., 2013:** Fauna bogomoljki (Dictyoptera: Mantodea) u Hrvatskoj. *Natura Croatica*, 17(1–4): 41–52.
- Us, P., 1967.** Catalogus faunae Jugoslaviae – III/6 Orthopteroidea. Academia Scientiarum et Artium Slovenica, Ljubljana. 47 pp.
- Us, P., 1992:** Favna ortopteroidnih insektov Slovenije. Slovenska akademija znanosti in umetnosti, Razred za prirodoslovne vede, Ljubljana, (32)12: 1-314.
- Wikipedia 2017:** Mantodea <https://it.wikipedia.org/wiki/Mantodea> (Accessed at 13. 12. 2017).
- Lombardo, F., 2017:** Checklist of the species of the Italian fauna: Mantodea. <http://www.faunaitalia.it>, <http://www.faunaitalia.it/checklist/invertebrates/Mantodea.html> (Accessed at 13. 12. 2017).
- Othoptera.at 2017:** Artenliste der Heuschrecken und Fangschrecken Österreichs. <http://www.orthoptera.at/arten/index.html> (Accessed at 13. 12. 2017).
- Stani, W., 2016:** Erste gesicherte Vorkommen der Braunen Strandschrecke *Aiolopus strepens* (Latreille, 1804) in der Steiermark bzw. in Österreich. *Joannea Zoologie* 15: 181-186.
- Stoch, F., 2003:** Checklist of the Italian fauna on-line: Mantodea. <http://www.faunaitalia.it/checklist/invertebrates/Mantodea.html#Mantodea> (Accessed at 30. 12. 2017).
- Šegula, B., 2005:** Photo of *Ameles decolor* on BioLib.cz. <https://www.biolib.cz/en/tax-onimage/id6020/?taxonid=44415> (Accessed at 13. 12. 2017).
- Zuna-Kratky, T., Landmann, A., Ilich, I., Zechner L., Esslm F., Lechner K., Ortner A., Weißmair W., Wössm G., 2017:** Die Heuschrecken Österreichs. Biologiezentrum des Oberösterreichischen Landesmuseums. *Denisia* 39: 1-872.

Received / Prejeto: 8. 3. 2018, revised / predelano: 2. 11. 2018



**ECOLOGICAL REQUIREMENTS AND FEATURES ADAPTING
THE KARINTHIAN MOUNTAIN GRASSHOPPER *MIRAMELLA
CARINTHIACA* TO LIVE IN MEADOWS AT THE ALPINE TREELINE**

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Abstract – The Karinthian Mountain Grasshopper, *Miramella carinthiaca* (Obenberger, 1926) (Orthoptera: Catantopidae), was investigated at the alpine treeline in the Seckau Alps (Styria, Austria). Field studies show that because they are flightless, these grasshoppers cannot easily move to a new habitat to escape harmful environmental influences. The readiness to feed on non-preferred plants in addition to preferred plants seems to be an adaptation in this case. Feeding experiments showed that the fresh leaves of more than thirty grass, wildflower and woody plant species in the habitat can serve as food sources. It is critical for *M. carinthiaca* females to find oviposition sites in open patches of earth surrounded by the fresh leaves of evergreen plants that provide a food source for early nymphs. At the treeline, *M. carinthiaca* shares the habitat with *Chorthippus* species, *Omocestus viridulus*, *Euthystira brachyptera* and *Gomphocerus sibiricus*. The ecological niche of the latter seems similar to that of *M. carinthiaca*.

KEY WORDS: *Miramella carinthiaca*, alpine treeline, habitat, oviposition site, food plants

Izvleček – EKOLOŠKE ZAHTEVE IN ZNAČILNOSTI ALPSKE KOBILICE *MIRAMELLA CARINTHIACA* NA TRAVNIKI OB DREVESNI MEJI

Raziskovali smo alpsko kobilico vrste *Miramella carinthiaca* (Obenberger, 1926) (Orthoptera: Catantopidae) ob drevesni meji na območju Seckauskih Alp (Štajerska, Avstrija). Ker je kobilica brez kril, se ne more enostavno preseliti v nov habitat, da bi ubežala pred neugodnimi okoljskimi razmerami. Na osnovi terenskih opazovanj sklepamo, da je pripravljenost, da se kobilica hrani z rastlinami, ki jih po navadi ne izbira, adaptacija na omenjene razmere. V prehranjevalnih poskusih smo ugotovili,

da vir njene hrane predstavljajo listi več kot trideset rastlinskih vrst – od trav do lesnatih rastlin. Za kobilico *M. carinthiaca* je odločilno, da izbira mesta za leženje jajčec na zaplatah zemlje, ki jih obdajajo listi zimzelenih rastlin, ki predstavljajo vir hrane za izlegle nimfe. Ob drevesni meji si kobilica *M. carinthiaca* deli habitat še z vrstami *Chorthippus* sp., *Omocestus viridulus*, *Euthystira brachyptera* in *Gomphocerus sibiricus*. Videti je, da je ekološka niša slednje vrste podobna kot za *M. carinthiaca*.

KLJUČNE BESEDE: *Miramella carinthiaca*, alpska drevesna meja, habitat, lokacija ovi-pozicije, hranilne rastline

Introduction

Species and subspecies of the genus *Miramella* (Catantopidae; see BELLMANN, 2006) are found in the Pyrenees, Western and Eastern Alps, Julian and Karavanke Alps, Slavonian Mountains, Carpathians, Balkan Mountains and other European mountainous regions such as the higher altitudes of the Black Forest, Bavarian Forest and Bohemian Forest (HARZ, 1957, 1975, 1982; NADIG, 1989; PILS, 1992; DETZEL, 1995, 1998; KÖHLER & INGRISCH, 1998; KÖHLER & al., 1999; ILLICH & WINDING, 1999; ILLICH, 2003; NAGY, 2003; ZECHNER & al., 2005; BELLMANN, 2006; IORGU & al., 2008; HELFERT & KREHAN, 2009; SZÖVÉNYI & PUSKÁS, 2012; IMIELA & al., 2016; KENYERES & al., 2017; ZUNA-KRATKY & al., 2017). These grasshoppers occur in sub-montane, montane, subalpine and alpine habitats in large contiguous areas as well as in fragmented and even completely isolated small areas. *Miramella* habitats are located at altitudes up to a maximum of 2800 m (in the Swiss Alps). During excursions over a number of years at and above the alpine treeline in the Seckau Alps (Styria, Austria) (Figure 1), I have observed *Miramella* grasshoppers in pastures and meadows between 1600 and 2100 m (K. KRAL, unpubl. obs.). It should be noted that in the Seckau Alps, in addition to *M. alpina*, *M. carinthiaca* can also be present, and both can be overlapping, with possible intergrades (FORSTHUBER & ZACHERL, 2005; ZUNA-KRATKY & al., 2017; T. ZUNA-KRATKY, pers. comm.). This mountain range, with a maximum altitude of 2417 m, is located south of the Liesing and Palten valleys and

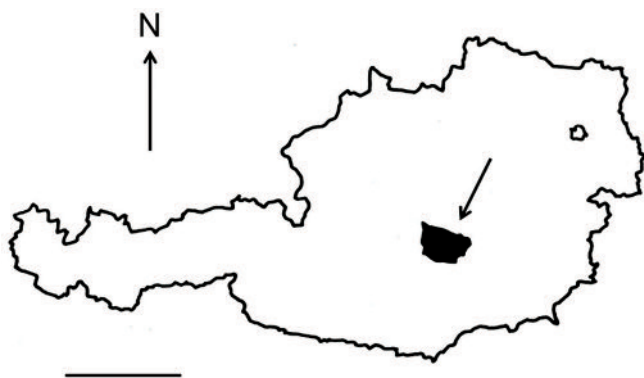


Fig. 1: Map of Austria showing the location of the Seckau Alps (arrow). Scale bar: 100 km.



Fig. 2: Photograph illustrating alpine meadows in the Seckau Alps as a typical habitat of *M. carinthiaca*. Note that the alpine meadows are separated from one another by areas of mountain pine and scree. The picture was taken in mid-July.

north of the Upper Mur valley. It consists mainly of granite and granite gneisses surrounded by para-gneisses and biotite gneisses (METZ, 1976). Toward the Upper Mur valley, the climate is characterised by continental influences, with cold winters, relatively warm summers and lower precipitation (~800 mm per year) than in the western part of the Niedere Tauern. The *Miramella* grasshoppers observed seemed to prefer open areas that had rather wet soils with distinctive wildflowers and/or low woody plants, stones and patches of bare earth. The grasshoppers often occurred in sites that were separated by areas of mountain pine and scree (see Figure 2). The aim of the present study was to obtain more detailed information about such habitat conditions and how *Miramella carinthiaca* adapts to them in light of its restricted mobility due to flightlessness.

Material and methods

The grasshoppers investigated here were clearly determined to be *Miramella carinthiaca*, on the basis of a morphological analysis of the male genitals. The study was carried out in the most easterly part of the Seckau Alps (47° 19' 18" N / 14° 48' 11" E) in the year 2017. The study site was located on a slope facing southeast at about 1710 m, at the treeline formed by mountain spruce (*Picea abies*), larch trees

(*Larix decidua*), mountain pine (*Pinus mugo*) and juniper bushes (*Juniperus communis* subsp. *nana*). The study site was monitored from the beginning of May to the middle of September. The plant species were identified with the aid of morphological keys and the advice of botanists (e.g., SCHAUER & CASPARI, 1975; ANGERER & MUER, 2004; I. PAUŠIČ, pers. comm.). Plant flowers and fruits facilitated species determination. As a measure of *M. carinthiaca* population density, the number of adult females was calculated by direct observation, or by netting within an area of 20 x 15 m. In addition, the presence of other grasshopper species was considered. Species identification was performed with the aid of sonograms, and structural and optical features of the body (BELLMANN, 2004, 2006).

For *M. carinthiaca*, the site and time of emergence, development and maturity were recorded. Particular attention was focused on the external appearance and body size. Body weight was measured with a touch screen pocket scale (G&G GmbH, Neuss, Germany). Photographs of nymphs and adults in their natural environment were taken with a Nikon D90 digital camera equipped with the macro lenses AF Micro Nikkor 60 mm, 1:2.8 D (Chiyoda, Tokyo, Japan).

Feeding experiments were carried out. Direct observations in the field were used to record how many early instar *M. carinthiaca* nymphs were found on what plant species. Fresh leaves of the preferred plants were then placed in a plastic tube (4.6 x 10 cm) together with a specimen of an early instar nymph in order to study the feeding behaviour. Each plant species was tested with three specimens.

The acceptability of plants in the habitat as food was systematically investigated for adult females in the years 2017 and 2018. For this purpose, freshly caught *M. carinthiaca* females were kept in a laboratory room (at 16 to 20°C) in the nearby village of Seckau. During the first two days no food was provided. In this starvation phase, a lack of further defecation indicated that the gut was empty. This was always the case after two days. The *M. carinthiaca* females were then placed singly in aerated transparent plastic feeding chambers (18 x 12 x 7 cm) with absorbent paper on the bottom. In each case, one plant species from the study site was provided. Each feeding experiment lasted two days, to give the grasshoppers the opportunity to adjust to the plants offered. All of the plants used for the feeding experiments were potted, so that fresh leaves could be provided for the duration of the trials. Due to the limited number of females, each specimen was tested with three different plant species selected at random (with the exception of one specimen that was tested with two plant species). As far as possible, grasses, wildflowers and woody plants were mixed, and the plants were offered in random order. For each plant species, three specimens were tested. After each trial the females were kept for another two days without food, for fitness control, and to prepare for subsequent trials if necessary. It was recorded only whether the plants or parts of them were ingested within two days. This was indicated by a reduction in or damage to the plant material, as well as by the production of fecal pellets. The amount of food consumed by the grasshoppers was not assessed, because previous feeding behaviour in the field could not be taken into account (FREELAND, 1975).

Results

At the study site the meadow was rich in wildflowers, low woody plants and grasses, which often formed tussocks (Table 1). There were pebbles, small exposed rocks, traces of juniper roots, and patches of bare earth on flat or uneven ground surrounded mainly by *Vaccinium* species and *Geum montanum* (see Figure 3). At the end of July, the estimated density of adult females was 0.13/m².

M. carinthiaca females used patches of moist bare earth as oviposition sites. The pH values measured at various possible oviposition sites ranged from 4.8 to 6.6. Following overwintering of the egg pods, early instar nymphs could be observed in May. The first adult females and males appeared toward the end of June and in the first half of July. Postembryonic development comprised five nymph instars in both genders. Adults could be distinguished from nymphs in the last instar via the complete overlap of the very short brownish wings (absolutely unsuited to flight). This is illustrated in images (d) and (e) in Figure 4. During postembryonic development, female nymphs were already larger and heavier than male nymphs (e.g. in mid-instar, female: body weight 0.20 g, body length 16.5 mm; male: body weight 0.08 g, body length 12 mm).



Fig. 3: View of part of the meadow at the study site in the second half of July. The study site provides patches of bare earth for oviposition and exposed stones for basking, as well as wildflowers and woody plants. The green colour of their leaves ensures camouflage for *M. carinthiaca* throughout the season.

Table 1: Plant species from the study site at the alpine treeline accepted as food by female *M. carinthiaca* adults in the feeding experiments

Scientific name	Common name
Poaceae	Sweet grasses
<i>Agrostis</i> sp.	Bent grass
<i>Agrostis stolonifera</i> L.	Creeping bent grass
<i>Festuca</i> sp.	Fescues
<i>Phleum rhaeticum</i> (Humphries) Rauschert	Alpine timothy grass
<i>Phleum</i> sp.	Timothy grass
<i>Sesleria</i> sp.	Blue grass
Cyperaceae	Sedges
<i>Carex caryophyllea</i> Latourr.	Spring sedge
<i>Carex curvula</i> All.	Curved sedge
Juncaceae	Rushes
<i>Luzula</i> sp.	Woodrush
<i>Luzula multiflora</i> L.	Common woodrush
Asteraceae	Composite plant family
<i>Achillea millefolium</i> agg.	Common yarrow
<i>Antennaria dioica</i> (L.) Gaertn.	Mountain everlasting
<i>Arnica montana</i> L.	Mountain arnica
<i>Crepis pontana</i> (L.) Dalla Torre	Mountain hawkbeard
<i>Homogyne alpina</i> (L.) Cass.	Alpine coltsfoot
Ericaceae	Heather plant family
<i>Calluna vulgaris</i> (L.) Hull	Common heather
<i>Loiseleuria procumbens</i> (L.) Desv.	Trailing azalea
<i>Vaccinium myrtillus</i> L.	European blueberry
<i>Vaccinium uliginosum</i> L.	Bog bilberry
<i>Vaccinium vitis-idaea</i> L.	Lingonberry, cowberry
Campanulaceae	Bellflower family
<i>Campanula scheuchzeri</i> Vill.	Bellflower
<i>Phyteuma</i> sp.	Rampion
Caryophyllaceae	Pink family
<i>Cerastium</i> sp.	Mouse-ear chickweed
Rubiaceae	Bedstraw family
<i>Galium anisophyllum</i> L.	Bedstraw, gaillet
Gentianaceae	Gentian family
<i>Gentiana acaulis</i> L.	Stemless gentian
Rosaceae	Rose family
<i>Geum montanum</i> L.	Alpine avens
<i>Potentilla aurea</i> L.	Dwarf cinquefoil
Orchidaceae	Orchid family
<i>Gymnadenia conopsea</i> (L.) R.Br.	Fragrant orchid, marsh fragrant orchid
Orobanchaceae	Broomrape family
<i>Pedicularis</i> sp.	Lousewort
Primulaceae	Primrose family
<i>Primula villosa</i> Wulfen	Mountain primrose
Ranunculaceae	Buttercup family
<i>Pulsatilla alpina</i> (L.) Delarbre	Alpine anemone
<i>Ranunculus montanus</i> Willd.	Buttercup
Lamiaceae	Labiata family
<i>Thymus pulegioides</i> agg.	Broad-leaved thyme
Plantaginaceae	Plantain family
<i>Veronica chamaedrys</i> L.	Germander speedwell

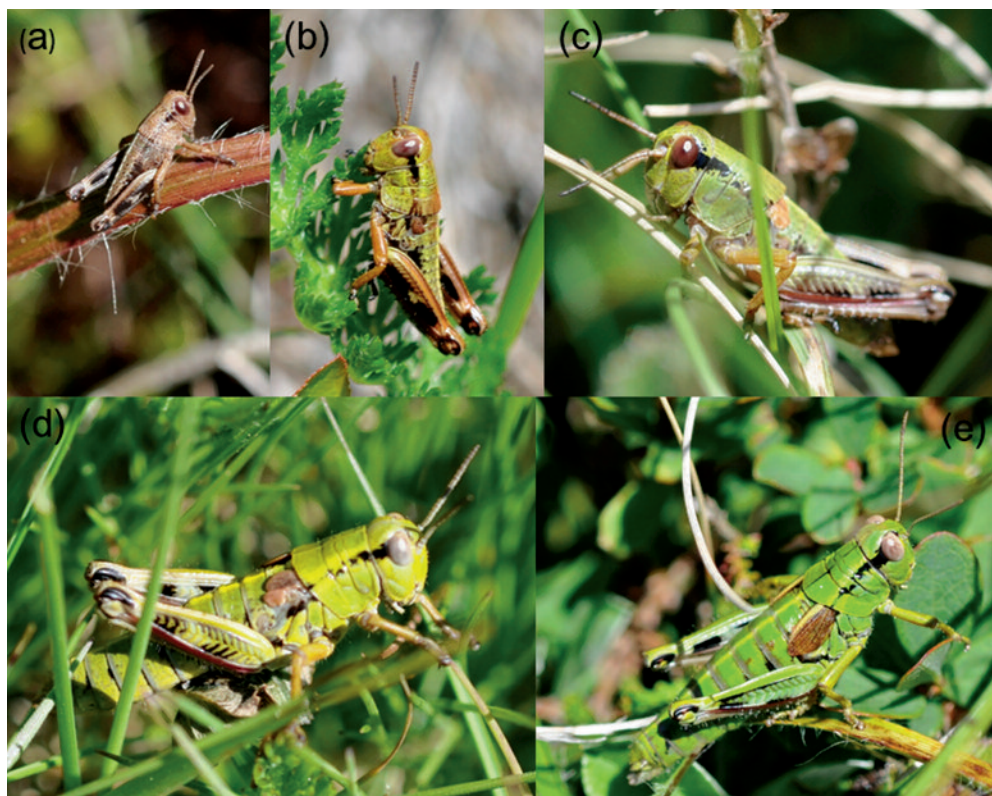


Fig. 4: Body colour and patterns in *M. carinthiaca* females during postembryonic development. Different individuals were photographed under similar lighting conditions. Images (a, b) early instar nymphs: body length 5 mm and 10 mm; (c) mid-instar nymph: body length 16 mm; (d) late instar nymph: body length 21 mm; and (e) adult stage: body length 24 mm.

In the first instar, *M. carinthiaca* nymphs appeared brown and dark grey, and in the case of males often almost black. In the next instar, the nymphs were usually yellow-green, however with parts of the body such as the legs still light to dark brown. The middle instar nymphs were green, and this was also the case in the later stages, including the adult stage. However, the shade of green of the body colour varied between specimens of the same stage and between specimens of different stages. The early instars had a distinct brown to black body pattern (Figure 4). According to the literature, this is caused by melanisation of the exocuticle (e.g., SUGUMARAN & BAREK, 2016). However, in male nymphs the pattern was more extensive and more evident, with the result that the male nymphs generally appeared darker than the female nymphs. This was also the case with later nymph instars and the adult stage. In Figure 5, melanin pigment can be seen in the last exuviae of a *M. carinthiaca* female and male.

Observation records of forty-four early instar *M. carinthiaca* nymphs in the field (see Figure 4) show that 45% of them were located on leaves of *G. montanum*. These leaves often had recognisable traces of feeding. The second most frequent location of early instar nymphs was on leaves of *Vaccinium vitis-idaea* (see Table 2). Feeding experiments performed with nymphs in the field during the day showed that in addition to *G. montanum* and *V. vitis-idaea*, the less frequently occupied plants *Potentilla aurea*, *Homogyne alpina* and *Achillea millefolium* were also accepted as food. It was noticeable that the leaves of *G. montanum* and *H. alpina* in particular were consumed readily by the nymphs. Grass leaves were eaten only sparingly, after the nymphs had been kept in a feeding tube for a further day. Systematic feeding experiments with adult *M. carinthiaca* females in the laboratory showed that the fresh leaves of thirty-four of the thirty-five plant species from the habitat that were offered were accepted as a food source if alternatives were not available (see Table 1). Only the pyramidal bugle *Ajuga pyramidalis* (Lamiaceae) was not eaten. Potential long-term health impacts on the grasshoppers resulting from the use of these different plant species as food could not be addressed here. Since the range of available plant species becomes more extensive later in the spring, the adults may feed on a greater variety of plant species than the nymphs do.

Five other grasshopper species (Acrididae) were found at the study site: the flying *Chorthippus biguttulus* L.; *C. dorsatus* Zett.; *Omocestus viridulus* L.; *C. parallelus* Zett., with shortened wings in females; and the emerald green *Euthystira brachyptera* Ocsk., with shortened wings in males and females. Of these, the most frequent species were *O. viridulus* and *C. parallelus*. All of these species were found mostly in grass up to 50 cm in height. *Gomphocerus sibiricus* L., capable of flight, was observed mostly in low vegetation and on patches of bare earth. In addition, *Metrioptera brachyptera* L., a member of the Tettigonioidea, was occasionally found near dwarf shrubs of *J. communis* subsp. *nana*, although only at the end of August and in September. In the case of the different *Chorthippus* species and *O. viridulus*, early instar nymphs could be observed at the end of May. *G. sibiricus* appeared later and was present at the study site only until early August.

Table 2: Plants on which early instar *M. carinthiaca* nymphs were located

Plant species	Number of early instar nymphs
<i>Geum montanum</i>	20
<i>Vaccinium vitis-idaea</i>	12
<i>Potentilla aurea</i>	6
<i>Homogyne alpina</i>	3
<i>Achillea millefolium</i>	1
<i>Luzula multiflora</i>	1
<i>Sesleria</i> sp.	1

Discussion

The meadow at the alpine treeline provides *M. carinthiaca* with a suitable environment for oviposition and foraging purposes. *G. montanum* and *V. vitis-idaea* appear to be among the most important food sources. These plants are usually found

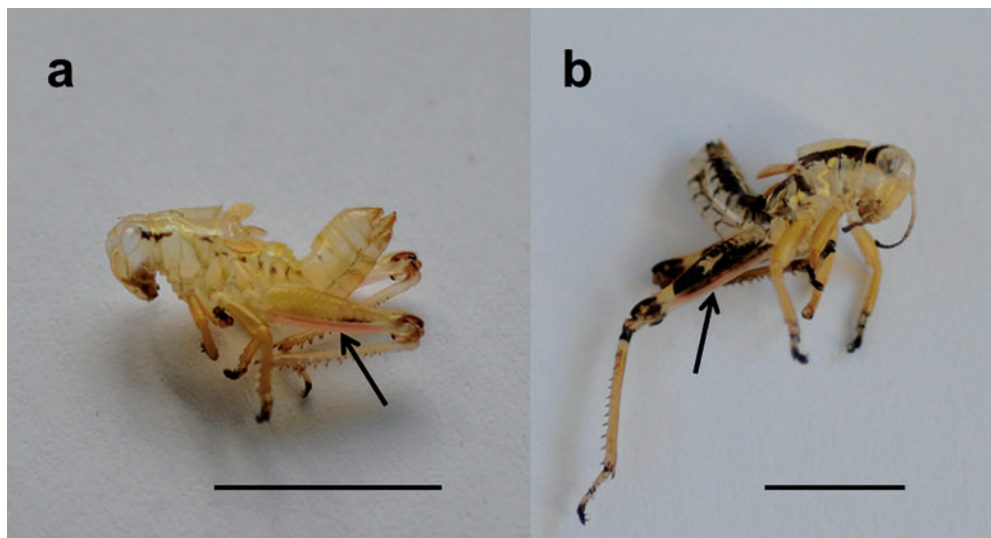


Fig. 5: Last exuviae of (a) female and (b) male *M. carinthiaca*. Scale bars: 12 mm and 6 mm, respectively. Moulting took place within one day after the nymphs had been caught in their natural environment. Note brown to black melanisation on the head, body and legs, as well as reddish melanisation on the underside of the hind femurs (indicated by arrows).

where *M. carinthiaca* is present, and the grasshoppers were frequently found on their leaves and could be observed feeding. It should be noted that this is also the case in alpine meadows with poor vegetation at higher elevations, 1900 to 2100 m above sea level. The reliability of *G. montanum* and *V. vitis-idaea* as food sources is aided by the fact that these plants are particularly stress-resistant, as shown by various studies (MANUEL & al., 1999; AUBERT & al., 2004; GLASS & al., 2005; SAARINEN & LUNDELL, 2010). These plants can tolerate the low temperatures and high levels of irradiation (including UV irradiation) that occur when the snow melts. They are also very robust with regard to drought conditions that can occur during summer heat waves on terrain that is exposed to the sun. Further evidence that *Vaccinium* species may be an important food source has been found by ASSHOFF & HÄTTENSCHWILER (2005), in the case of *M. alpina* living at the alpine treeline in the Swiss Alps. These authors clearly show that atmospheric changes such as increased carbon dioxide can have a negative effect on the nutritional quality of *V. myrtillus* and *V. uliginosum* leaves, and hence on the growth rate of *M. alpina*. In this connection, the willingness of early nymphs to eat the leaves of the alpine coltsfoot *H. alpina*, a robust plant with overwintering green leaves that is well adapted to alpine environments (STREB & al., 1998; LÜTZ & al., 2005), should also be mentioned. In addition, the importance of the role of evergreen plants in providing camouflage for the green grasshoppers is not to be underestimated. However, after snowmelt, when the whole habitat appears more brown than green the brown early nymphs may be better protected from predators.

The feeding experiments in the laboratory show that, if necessary, female *M. carinthiaca* adults can accept the leaves of a relatively large number of plant species of various families growing in the habitat as food sources (see Table 1). The leaves consumed in the experiments have a wide range of tissue hardness and toughness, from needle-like to thick and fleshy. The grasshoppers are clearly able to use their strong mandibles to overcome the physical defences of the plants (KUŘAVOVÁ, 2015). This robust feeding behaviour may be a necessary adaptation in cases where the preferred plants lose their nutritional quality (see above, ASSHOFF & HÄTTENSCHWILER, 2005) or are unavailable. Plants which are rejected as a food source may be inedible or harmful (BERNAYS & CHAPMAN, 2000). Thus, it may be that *Ajuga pyramidalis* is avoided because this plant contains phytoecdysones which can disturb the hormone-controlled moulting of insect larvae (ANUFRIEVA & al., 1995; CHAUBEY, 2018). It was interesting to observe that the *M. carinthiaca* females touched the leaf surface of *A. pyramidalis* with their mouthparts without biting it, presumably to evaluate the quality of the food via external mechanical and/or chemical sensory information. However, the female *M. carinthiaca* adults did not reject the leaves of *Thymus pulegioides* as food, although in the case of the herbivorous bush cricket *Leptophyes punctatissima* it has been found that monoterpenes of the common thyme plant *Thymus vulgaris* can deter feeding (LINHART & THOMPSON, 1999). In *M. carinthiaca*, a possible reason for terpene tolerance could be good body condition, perhaps even with detoxification capability (see REID & PURCELL, 2011). However, in this study it was not possible to determine the long-term health effects on the grasshoppers that might result from feeding on such plants with secondary compounds as well as other non-preferred plants. Polyphagous behaviour similar to that of *M. carinthiaca*, with a preference for certain plant species, is also described in the case of *M. alpina* by HÄGELE & ROWELL-RAHIER (1999; see also IBANEZ & al., 2013). Food selection experiments with the grass-feeding grasshopper *O. viridulus* conducted by BERNER & al. (2005) suggest that *O. viridulus* can compensate for the low protein content of grass via selective feeding on grasses with contrasting protein content. In this way, the grasshoppers can balance their intake of protein and energy. It was not possible to investigate individual feeding behaviour in the field within the *M. carinthiaca* population. What remains to be addressed is the specific basis upon which the grasshoppers recognize a plant as suitable food.

Finally, the question arises concerning the role played by competition with other grasshopper species that share the habitat of *M. carinthiaca*. My initial impression was that *G. sibiricus* occupies an ecological niche similar to that of *M. carinthiaca*. *G. sibiricus* females also prefer low plants, and in the literature it has been reported that they require open patches of earth for oviposition. However, *M. carinthiaca* eggs seem to need higher humidity levels for successful development, and appear to be more sensitive to dehydration than is the case with *G. sibiricus* eggs (see also ILLICH & WINDING, 1999). This is supported by the fact that I found more *M. carinthiaca* oviposition sites in wetter areas. Nevertheless, it is possible that *M. carinthiaca* may be more xerophilic than *M. alpina* (T. Zuny-Kratky, pers. comm.). I observed that *G. sibiricus* had disappeared from the study site by early August. It should also be noted

that I was not able to observe *G. sibiricus* at the study site in the years prior to 2017, when the study took place. According to Thomas Zuny-Kratky (pers. comm.), *G. sibiricus* does not often occur together with *M. alpina* or *M. carinthiaca*. ILLICH & WINDING (1999) found that *G. sibiricus* can exhibit wide population fluctuations in the case of unfavourable changes in the environment. Although in this study it was not possible to observe the choice of oviposition site of the three *Chorthippus* species, I know from my experience with *C. parallelus* and *C. brunneus* that they will accept a variety of soil conditions (K. KRAL, unpubl. obs.). According to CHOUDHURI (1958), *C. parallelus* may prefer loose sandy soil. In the case of *O. viridulus* and *E. brachyptera*, which prefer to live in grasses, the females usually oviposit at the base of grass stems (e.g. *Festuca* sp.) and between the leaves of grasses (REINHARDT, 1998; BELLMANN, 2006). Overall, it seems that the three *Chorthippus* species, *O. viridulus*, and *E. brachyptera* do not impact *M. carinthiaca* population dynamics significantly with respect to competition for food or oviposition sites. Due to their eurytopic character (K. KRAL, unpubl. obs.), these five species can clearly also switch to other areas that are less suitable for *M. carinthiaca*. Throughout the season, I could find only *Miramella* grasshoppers in alpine meadows on ridges exposed to the wind in the eastern part of the Seckau Alps at approximately 1900 to 2000 m above sea level. These meadows were mainly covered with lichens, mosses and carpet-like *Loiseleuria procumbens*, as well as with *P. aurea*, *G. montanum*, short *Carex curvula* and sparse low *Sesleria* sp., interspersed with open patches of earth (K. KRAL, unpubl. obs.). On the windswept ridges, it is evident that the flightlessness of these grasshoppers may be an important morphological adaptation, which prevents flight during strong winds that could cause the grasshoppers to be carried away to unsuitable or even dangerous habitats such as extensive scree areas.

Acknowledgements

I am grateful to Igor Paušič (University of Maribor) for plant identification and to Markus Sehnal (University of Vienna) for determination of the study insect as *M. carinthiaca*. I would like to extend special thanks to Veronika Kral for assistance in the field. I also wish to thank Mary Ansell (Halifax, Canada) for providing helpful comments and correction of the English text, and Dušan Devetak (University of Maribor) for critical reading of an earlier draft of this manuscript and for translating the abstract into Slovene. Valuable comments on the manuscript were provided by Thomas Zuna-Kratky (University of Vienna).

References

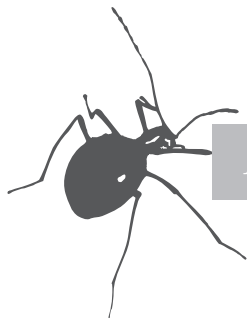
- Angerer O., Muer T., 2004: Alpenpflanzen. Verlag Eugen Ulmer GmbH & Co., Stuttgart, Germany: 447 pp.
- Anufrieva A.N., Kovler L.A., Kolegova N.A., Volodin V.V., 1995: Tissue and cell culture of phytoecdysone-producing plants as a perspective source of ecdysteroids. *European Journal of Entomology* 92: 286.

- Asshoff R., Hättenschwiler S.**, 2005: Growth and reproduction of the alpine grasshopper *Miramella alpina* feeding on CO₂-enriched dwarf shrubs at treeline. *Oecologia* 142: 191-201.
- Aubert S., Choler P., Pratt J., Douzet R., Gout E., Bligny R.**, 2004: Methyl-b-D-glucopyranoside in higher plants: accumulation and intracellular localization in *Geum montanum* L. leaves and in model systems studied by ¹³C nuclear magnetic resonance. *Journal of Experimental Botany* 55: 2179–2189.
- Bellmann H.**, 2004: Heuschrecken – Die Stimmen von 61 heimischen Arten. CD, Musikverlag Edition Ample.
- Bellmann H.**, 2006: Der Kosmos Heuschreckenführer. Die Arten Mitteleuropas sicher bestimmen. Franckh-Kosmos Verlags-GmbH & Co. KG, Stuttgart, Germany: 350 pp.
- Bernays E.A., Chapman R.F.**, 2000: Plant secondary compounds and grasshoppers: beyond plant defenses. *Journal of Chemical Ecology* 26: 1773-1794.
- Berner D., Blanckenhorn W.U., Körner Ch.**, 2005: Grasshoppers cope with low host plant quality by compensatory feeding and food selection: N limitation challenged. *Oikos* 111: 525-533.
- Chaubey M.K.**, 2018: Role of phytoecdysteroids in insect pest management: A review. *Journal of Agronomy* 17: 1-10.
- Choudhuri J.C.B.**, 1958: Experimental studies on the choice of oviposition sites by two species of *Chorthippus* (Orthoptera: Acrididae). *Journal of Animal Ecology* 27: 201-216.
- Detzel P.**, 1995: Herkunft und Verbreitung der Heuschrecken in Baden-Württemberg. *Articulata* 10: 107-118.
- Detzel P.**, 1998: *Die Heuschrecken Baden-Württembergs*. Eugen Ulmer, Stuttgart, Germany, 580 pp.
- Forsthuber L., Zacherl M.**, 2005: Spezieller Teil Caelifera – Kurzfühlerschrecken - Zobodata. – www.zobodat.at/pdf/DENISIA_0039_0489-0815.pdf.
- Freeland W. J.**, 1975: Feeding behaviour of the Australian acridid *Valanga irregularis*. *Entomologia Experimentalis et Applicata* 18: 281-289.
- Glass V.M., Percival D.C., Proctor J.T.A.**, 2005: Tolerance of lowbush blueberries (*Vaccinium angustifolium* Ait.) to drought stress. I. Soil water and yield component analysis. *Canadian Journal of Plant Science* 85: 911–917.
- Hägele B.F., Rowell-Rahier M.**, 1999: Dietary mixing in three generalist herbivores: nutrient complementation or toxin dilution? *Oecologia* 119: 521-533.
- Harz K.**, 1957: Die Geradflügler Mitteleuropas. Gustav Fischer Verlag, Jena: 494 pp.
- Harz K.**, 1975: Die Orthopteren Europas Vol. II. Verlag Dr. W. Junk, The Hague, Netherlands: 939 pp.
- Harz K.**, 1982: Der Status der Alpenschrecke, *Miramella alpina* (Koll.) 1833 im Schwarzwald. *Articulata* 19: 214-216.
- Helfert B., Krehan H.**, 2009: Massenaufreten der Kurzfühlerschrecke *Miramella* cf. *alpina* in Lärchenbeständen im Burgenland. *Forstschutz aktuell* 47: 19-21.

- Ibanez S., Lavorel S., Puijalon S., Moretti M.,** 2013: Herbivory mediated by coupling between biomechanical traits of plants and grasshoppers. *Functional Ecology* 27: 479–489.
- Illich I.P.,** 2003: Die Heuschrecken (Orthoptera: Saltatoria) des Nationalparks Nockberge (Kärnten, Österreich): Verbreitung und Ökologie. *Carinthia* II 193: 369–412.
- Illich I.P., Winding N.,** 1999: Dynamik von Heuschrecken-Populationen (Orthoptera: Saltatoria) in subalpinen und alpinen Rasen des Nationalparks Hohe Tauern (Österreichische Zentralalpen) von 1990 bis 1997. *Wissenschaftliche Mitteilungen aus dem Nationalpark Hohe Tauern* 5: 63–85.
- Imiela A., Depa L., Simka M.,** 2016: Nowe stanowisko *Miramella alpina* (Kollar, 1833) (Orthoptera: Catantopidae) w Beskidach Zachodnich. *Acta Entomologica Silesiana* 24: 1–4.
- Iorgu I., Pisciã E., Păiș L., Lupu G., Iușan C.,** 2008: Checklist of Romanian Orthoptera (Insecta) and their distribution by eco-regions. *Travaux du Muséum d'Histoire Naturelle "Gr. Antipa"* 51: 119–135.
- Kenyeres Z., Puskás G., Szövényi G.,** 2017: Data to the Orthoptera fauna of the West-Hungarian Borderland. *Folia historico-naturalia Musei Matraensis* 41: 59–77.
- Köhler G., Ingrisch S.,** 1998: Die Heuschrecken Mitteleuropas. - Die Neue Brehm Bücherei 629, Westarp Wissenschaften, Magdeburg, Germany: 460pp.
- Köhler G., Reinhardt K., Asshoff R.,** 1999: Zur Biologie der Tessiner Gebirgsschrecke *Miramella formosanta* (Fruhstorfer, 1921) (Acrididae: Catantopinae). *Mitteilungen der schweizerischen entomologischen Gesellschaft* 72: 315–328.
- Kuřavová K.,** 2015: Saranče horská – glaciální relikvium a indikátor změn v prostředí. / Alpine grasshopper – a glacial relict as an indicator of environmental change. *Živa* 1: 27–29.
- Linhart Y.B., Thompson J.D.,** 1999: Thyme is of the essence: Biochemical polymorphism and multi-species deterrence. *Evolutionary Ecology Research* 1: 151–171.
- Lütz C., Schönauer E., Neuner G.,** 2005: Physiological adaptation before and after snow melt in green overwintering leaves of some alpine plants. *Phyton* 45: 139–156.
- Manuel N., Cornic G., Aubert S., Choler P., Bligny R., Heber U.,** 1999: Protection against photoinhibition in the alpine plant *Geum montanum*. *Oecologia* 119: 149–158.
- Metz K.,** 1976: Der geologische Bau der Seckauer und Rottenmanner Tauern. *Jahrbuch der Geologischen Bundesanstalt* 119: 151–205.
- Nadig A.,** 1989: Die in den Alpen, im Jura, in den Vogesen und im Schwarzwald lebenden Arten und Unterarten von *Miramella* DOVNAR-ZAP. (Orthoptera, Catantopidae) auf Grund populationsanalytischer Untersuchungen. *Atti della Accademia roveretana degli Agiati* (1988), s. VI, v. 28 (B): 101–264.

- Nagy B.**, 2003: A revised check-list of Orthoptera-species of Hungary supplemented by Hungarian names of grasshopper species. *Folia Entomologica Hungarica* 64: 85-94.
- Pils G.**, 1992: Bemerkungen zu einigen oberösterreichischen Heuschreckenarten (Saltatoria). – *Linzer biologische Beiträge* 24: 13-17.
- Reid M.L., Purcell J.R.C.**, 2011: Condition-dependent tolerance of monoterpenes in an insect herbivore. *Arthropod Plant Interaction* 5: 331-337.
- Reinhardt K.**, 1998: Zur Eiablagepräferenz der kleinen Goldschrecke, *Euthystira brachyptera* (Ocskay) – Freiland versus Gewächshaus. *Articulata* 13: 29-37.
- Saarinen T., Lundell R.**, 2010: Overwintering of *Vaccinium vitis-idaea* in two sub-Arctic microhabitats: a reciprocal transplantation experiment. *Polar Research* 29: 38-45.
- Schauer Th., Caspari C.**, 1975: Pflanzen- und Tierwelt der Alpen. BLV Verlagsgesellschaft mbH, Munich, Germany: 252 pp.
- Streb P., Shang W., Feierabend J., Bligny R.**, 1998: Divergent strategies of photo-protection in high-mountain plants. *Planta* 207: 313-324.
- Sugumaran M., Berek H.**, 2016: Critical analysis of the melanogenic pathway in insects and higher animals. *International Journal of Molecular Sciences* 17: 1753.
- Szövényi G., Puskás G.**, 2012: A contribution to knowledge concerning the Orthoptera fauna of the Slavonian range (NE Croatia) with the first record of some species in Croatia. *Natura Croatica* 21: 403-418.
- Zechner L., Koschuh A., Berg H.-M., Paill W., Reinbacher H., Zuna-Kratky T.**, 2005: Checkliste der Heuschrecken der Steiermark mit Kommentaren zu Verbreitung und Habitatansprüchen (Insecta: Orthoptera). *Beiträge zur Entomofaunistik* 6: 127-160.
- Zuna-Kratky T., Landmann A., Illich I., Zechner L., Essl F., Lechner K., Ortner A., Weißmair W., Wöss G.**, 2017: Die Heuschrecken Österreichs. *Denisia* 39, Biologiezentrum des Oberösterreichischen Landesmuseums: 880 pp.

Received / Prejeto: 11. 8. 2018



BUMBLEBEE BROOD TEMPERATURE AND COLONY DEVELOPMENT: A FIELD STUDY

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Abstract - Careful control of the brood temperature is important in view of successful colony development in social insects. Fifteen bumblebee colonies of five common Central European species in total (*Bombus hypnorum*, *B. pratorum*, *B. lapidarius*, *B. pascuorum*, *B. humilis*) were monitored for several months and the brood temperature was recorded in regular intervals to investigate the temperature range in which the colony successfully develops to produce a new generation of queens and males. Colony size was being kept track of and parasites were always promptly removed if discovered. Ultimately, all colonies in the study were successful. We observed that the colonies were very efficient with thermoregulation during the equilibrium period of the colony, with the brood temperatures between 31 and 35°C. This study presents a foundation for more detailed studies of temperature in bumblebee nests of the above species in the future.

KEY WORDS: bumblebees, thermoregulation, nest climate

Izveček - TEMPERATURA ČMRLJEGA SATJA Z ZALEGO IN RAZVOJ GNEZDA: TERENSKA RAZISKAVA

Eden od pomembnih dejavnikov, ki vplivajo na uspešen razvoj družine čmrljev, je skrbna regulacija temperature zalege. V naši študiji smo več mesecev opazovali petnajst družin čmrljev petih pogostih vrst srednje Evrope (*Bombus hypnorum*, *B. pratorum*, *B. lapidarius*, *B. pascuorum*, *B. humilis*). Spremljali smo temperaturo zalege, da bi ugotovili, v kakšnem temperaturnem območju se družina uspešno razvije do izleta novih matic in samčkov. Poleg tega smo spremljali velikost posameznih

družin in odstranili parazite, če so se pojavili. Vseh petnajst opazovanih družin je bilo uspešnih. Ugotovili smo, da je termoregulacija učinkovitejša pri družinah in vrstah, ki imajo več delavk. V ravnovesnem obdobju je bila temperatura zalege med 31 in 35°C. Študija predstavlja temelje za podrobnejše študije pogojev v gnezdih čmrljev v prihodnosti.

KLJUČNE BESEDE: čmrlji, termoregulacija, temperatura v gnezdu

Introduction

Bumblebees (genus *Bombus* from the bee family Apidae) are important pollinators of various plants. Similar to domestic honeybees, they are social insects that live in colonies. However, they are bulkier in constitution and able to generate considerable quantities of metabolic heat, using it to maintain stable body temperatures many degrees above the ambient temperature (Goulson, 2003). This allows them to forage at lower temperatures and even in rain. In addition, bumblebees employ a technique called buzz-pollination or sonication (De Luca and Vallejo-Marin, 2013) to extract pollen from flowers of certain plants which release pollen through small openings in the anthers' tips by shaking the anthers – a technique that the honeybees are not capable of. This way, bumblebees are the key pollinators of plants such as clover or tomatoes. Bumblebee flight buzzing sounds of some common Central European bumblebee species were the focus of our previous research (Gradišek et al., 2017).

In the wild, different bumblebee species build their nests in different natural environments according to the opportunities and characteristics of the surrounding. Many species build their nests in the abandoned burrows of small rodents in the ground while other build their nests on the surface of the ground within tussocks of grass and brushwood, and even in abandoned birds' nests, squirrels' drays, and artificial cavities (Goulson, 2003). Their goal is to find a place that provides enough space for brood development and shelter from rain, predators, and temperature extremes. Insulation allows the bumblebees to conserve the metabolic energy required for thermoregulation. According to practitioner experiences (Grad et al., 2010; Grad et al., 2016), in the anthropogenic environment, the bumblebees exploit man-made objects as possible nesting sites.

In the nest, one of the most important tasks of the colony is to keep the nest temperature as constant as possible to allow successful development of the brood placed inside the comb. A queen starts building the nest in late winter or early spring, when the air temperatures can still vary for a short time from rather low temperatures approaching 0°C up to comfortable ones of about 15°C. The timing depends very much on queens' species, their natural requirements where to place the nest, and their abilities to maintain the necessary nest temperature (Goulson, 2003; Heinrich, 1979). During the cold periods, the queen (and later also the workers) provide heat to the brood by thermogenic activity of thoracic muscles (Masson et al., 2017). By modulating their metabolic activity, the adults are able to regulate their abdominal temperature and therefore maintain the brood temperature within a narrow range (Jones and Ol-

droyd, 2007). On the other hand, in late spring and summer, the outside temperatures rise and the nest has to be cooled down to prevent it from overheating – the larvae can develop malformations or die if the temperatures surpass a certain threshold. Overheating is prevented by fanning, which becomes the task of the workers that have emerged from the nest by now. The nest temperature was studied by several authors. Seeley and Heinrich (1981) note that the optimal temperature in a nest with a large number of workers is around 30-31°C. Heinrich (1994) studied *B. vosnesenskii* and *B. polaris* and found out that the brood temperature can vary from 24 to 34°C. Weidenmüller (2004) studied fanning behaviour in *B. terrestris* as being triggered by increased temperature and CO₂ concentration in the nest. In the experiment, the heating of the nest went up to about 30°C. This study marks the temperature around 27.7-28.7°C as favourable while higher temperatures resulted in increased fanning intensity. Weidenmüller et al. (2002) also found that larger bumblebee colonies (of 60 or more individuals) responded to environmental perturbations faster and more efficiently than the smaller ones. Other authors (Hagen, 1994, Hintermeier, 1997, Matheson, 1996, Witte and Seger, 1999) state that the temperature in the nest is 30-32°C while the temperature of the comb that contains no brood can be a couple of degrees lower. According to Heinrich (2001) temperatures below 30°C are generally considered to inhibit the growth and may cause developmental damage in bumblebee species. Dean (2016) studied thermal stress in *B. impatiens* by exposing late-stage larvae to sub-lethal heat and cold stress (16-35°C). The stress resulted in some workers developing abnormal colour patterns, although no statistically consistent colour change response was observed. Schultze-Motel (1991) studied temperature fluctuations in a *B. lapidarius* nest, placed in a calorimeter box connected to the outside to allow normal foraging outings. The brood cell temperatures were maintained between 27 and 32°C while the fluctuations of the heat loss were measured as well, they typically showed a sinusoidal fluctuations through the day. In 1950s, Fye and Medler (1954) performed a field study of three North American species (*B. borealis*, *B. rufocinctus*, and *B. fervidus*) using thermocouples installed in the nests to check the daily temperature fluctuations. They found that the brood temperature was about 30°C, with the temperature fluctuating more when a smaller number of workers was present.

In studies of similar social insects, Cook et al. (2016) studied fanning behaviour in honeybees (*Apis mellifera*) in response to different rates of increasing temperature; the authors state that the bees keep the temperature of the nest below 36°C. On the other hand, Höcherl et al. (2016) studied nest thermoregulation in paper wasp *Polistes dominula* that build combs without the cover and are therefore more sensitive to thermal fluctuations. They found out that instead of fanning, the main mean of cooling is the evaporation of water that the wasps bring to the nest.

In the studies mentioned above, the systematic studies of temperature variations in a nest and the bumblebee response were typically conducted in laboratory settings and over short timeframes, except for the study of Fye and Medler (1954) that took place in the field. In our observation-based field study, we were interested in the temperature in bumblebee nests developing in suitable nest-boxes (bumblebee hives) in the field over a longer time period, covering most of the lifetime of the colony, in re-

sponse to the developmental stage of the colony, outside temperatures, and other external influences, such as the infestation with parasites. We focused on the temperature of the brood cells, as the proper temperature interval of the brood allows for successful development of a new generation. Fifteen colonies of five bumblebee species in total were monitored, starting roughly with the emergence of the first workers and concluding after the first young queens and males of the new generation started to emerge from the nest, thus ensuring the survival of the species in the following year. We were monitoring the temperature of the brood, the external temperature, and the number of individuals in the nest. In accordance with the literature (Schultze-Motel, 1991), the consecutive stages of the colony development are as follows: (1) *The period of upbringing* is the time interval after the old queen has started to collect pollen for the first batch of the brood until the workers of the batch have started to forage. (2) *The equilibrium period* sees a large number of workers and ends when young queens and males start to fly out of the nest to mate. (3) *The period of decline* follows the equilibrium and ends when there is no more brood in the comb cells of the nest. Ultimately, all bumblebees, except the young queens, perish.

To our best knowledge, this is the first multi-species temperature study of some common bumblebee species of Central Europe spanning over several months. The main aim of the presented study was to look at temperature intervals which allow the bumblebee colonies to develop to the stage where they produce new queens and males, thus ensuring the survival of the new generation. Our study further presents a useful ground for more detailed studies in future, with aims in finding optimal rearing temperatures for research on bumblebees, to understand thermal requirements across species, and to understand what factors contribute to ability to control the thermal environment of the nest.

Materials and methods

Fifteen bumblebee colonies of five different bumblebee species (*B. hypnorum*, *B. pratorum*, *B. lapidarius*, *B. pascuorum*, *B. humilis*) were monitored in the study, as listed in Table 1. The colonies have been brought up by the queens that had hatched at the place the previous year and had returned back to their hatching place in spring – this determined the species and the number of colonies per individual species included in the study. The nest-boxes were made of wood, of standard design used for this purpose (see for example Prys-Jones and Corbet, 1987). Single-chambered boxes are more suitable for species that build nests on the surface of the ground (such as *B. humilis*, *B. pascuorum*, *B. ruderarius*) while double-chambered boxes (containing an ante-chamber) are more likely to be populated by the species that build nests under the surface, such as *B. lucorum*, *B. terrestris*, *B. hortorum*, *B. argillaceus*, *B. sylvarum*, *B. pratorum*, *B. haematurus*, *B. hypnorum*, but can also be populated by the surface species (author's observation).

The nest-boxes were located in the village of Petelinje, Dol pri Ljubljani municipality, Slovenia (elevation 270 m, moderate continental climate (Köppen climate classification: Cfb)). The nest-boxes were protected from direct sunlight during most

of day, receiving it only up to 9 am the latest. The study took place during the spring and summer months of 2017. The spring of 2017 in Slovenia was marked by a warm period in March, followed by an unusually cold spell in April, causing the collapse of several bumblebee colonies where the brood was already developing. The colonies in our study survived the cold.

Table 1: Bumblebee colonies monitored in the study, denoting the dates of important events for the colony (all in 2017), together with the average equilibrium brood temperature.

Colony designation	Queen enters the nest-box	Measurements begin	First new queen leaves	Parasites removed	Measurements end	Average equilibrium brood temperature
<i>B. pratorum</i>	23.3.	17.5.	21.5.	/	7.6.	31.9 °C
<i>B. hypnorum 1</i>	21.3.	18.5.	2.6.	22.7.	10.6.	34.5 °C
<i>B. hypnorum 2</i>	24.3.	18.5.	1.6.	24.7.	10.6.	33.2 °C
<i>B. hypnorum 3</i>	29.3.	18.5.	30.5.	27.7.	10.6.	34.2 °C
<i>B. hypnorum 4</i>	30.3.	18.5.	30.5.	/	10.6.	32.5 °C
<i>B. lapidarius 1</i>	23.3.	19.5.	21.7.	24.6.	25.7.	32.9 °C
<i>B. lapidarius 2</i>	10.4.	18.5.	20.7.	4.8.	25.7.	32.6 °C
<i>B. pascuorum</i>	7.4.	20.5.	16.8.	25.8.	25.7.	32.5 °C
<i>B. humilis 1</i>	3.4.	22.5.	22.7.	/	26.7.	33.9 °C
<i>B. humilis 2</i>	9.4.	22.5.	21.7.	/	26.7.	33 °C
<i>B. humilis 3</i>	10.4.	23.5.	16.7.	26.7.	26.7.	33.8 °C
<i>B. humilis 4</i>	14.4.	21.5.	9.7.	/	25.7.	33.1 °C
<i>B. humilis 5</i>	2.5.	23.5.	18.7.	/	26.7.	33.1 °C
<i>B. humilis 6</i>	1.5.	22.5.	18.7.	/	26.7.	33.7 °C
<i>B. humilis 7 *</i>	13.6.	24.6.	22.8.	/	25.7.	31.4 °C

* This colony was moved from a meadow ground into the nest-box on 13 June, already containing a queen and two workers. The average temperature for this colony spans over the whole observation period.

The brood temperature was measured using a conventional digital probe thermometer (TFA LT-101, Conrad Electronic SE). For each of the measurements, the nest-box was opened and the tip of the probe was placed on the surface of the comb

containing brood and the maximum temperature was recorded by probing several parts of the comb (it should be stressed that some parts of the comb, especially toward the edges, had temperature up to 3°C lower). For *B. hypnorum* families, with large numbers of aggressive workers, the operator had to wear a full beekeeping gear for protection, while the measurements were always carried out around noon or in early afternoon *in situ*, in order not to further provoke the workers. For other four species, the measurements were carried out in the evening or early in the night, either *in situ* or with the nest-box being carried indoors for the measurement for convenience reasons (better light conditions). Here, we always assumed that the heat capacity of the comb is sufficiently high that the temperature does not change significantly during the time required to (quickly) remove the nest insulation, push the probe inside the nest, cover the nest, and perform the measurements. In our study, the use of a probe thermometer was seen as more appropriate than the use of thermocouples – as the latter would represent a permanent foreign object in the nest while the thermometer only causes a temporal disturbance. In addition, a probe thermometer allows us to determine the parts containing the brood more precisely.

The beginning of the temperature measurements roughly coincided with the emergence of the first workers. For each of the measurements that were first carried out on weekly basis and later in 10-day intervals, the following data were recorded: brood temperature, time of the measurement, external air temperature together with daily maximum and minimum, and the number of workers in the nest. For most colonies, the measurements concluded some days after the first new queen left the nest. An exception was the *B. pascuorum* nest due to its rather long life cycle, where the measurements ended some days earlier. Following the conclusion of the temperature measurements, the nests kept being monitored for general health of the bumblebee colonies. During the course of the development, some colonies were infested by a wax moth (*Aphomia sociella*), a common bumblebee parasite. In most cases, this took place after the temperature measurements had already concluded. The parasites were removed from the nest immediately after being observed for the first time, and it appears that all colonies continued with the development normally afterwards.

At each measurement, we estimated the family size. As the measurements mostly took place in the evenings when the bees were in the nest-boxes, it was straightforward to count/estimate both the number of workers and new queens in the open box.

Results

All monitored bumblebee colonies underwent a successful development cycle – from the old queen building a nest and laying eggs, through the hatching of the first workers, to the hatching of new queens and males that left the nest. The development of the colony differs from species to species. While the *B. pratorum* colony produced first new queens already in May and declined in mid-June, other species, such as *B. humilis* and *B. pascuorum*, only started producing first workers in late May but continued to thrive well into August. In the colonies with large numbers of workers, fanning behaviour was observed when the outside temperatures exceeded 32°C in shade.

The general observation is that the temperature of the brood for all colonies was roughly between 30 and 35°C throughout the equilibrium period of the colony while the temperature was somewhat lower during the upbringing period with a small number of workers (as seen in most colonies) and during the decline (as seen in *B. pratorum*). For all colonies except for *B. pratorum*, we noticed the transition between the upbringing and the equilibrium periods when the number of workers increased significantly. When the measurements started, the *B. pratorum* colony already was in the equilibrium period and entered the decline in the last week. Other colonies were still in the equilibrium when the measurements concluded with the new queens hatching.

Figs. 1 and 2 show the measured brood temperature together with the colony size. Fig. 1 shows the data for eight colonies of four species while Fig. 2 shows the data for seven *B. humilis* colonies. Fig. 3 shows detailed measurements of selected colonies, one representative example per each species. In the following, we first look at each species individually and then at some general observations.

In the single colony of *B. pratorum* monitored, the queen moved to the nest-box in late March. The first new queens appeared in the second half of May and the colony already lost the old queen in early June. The maximum number of workers

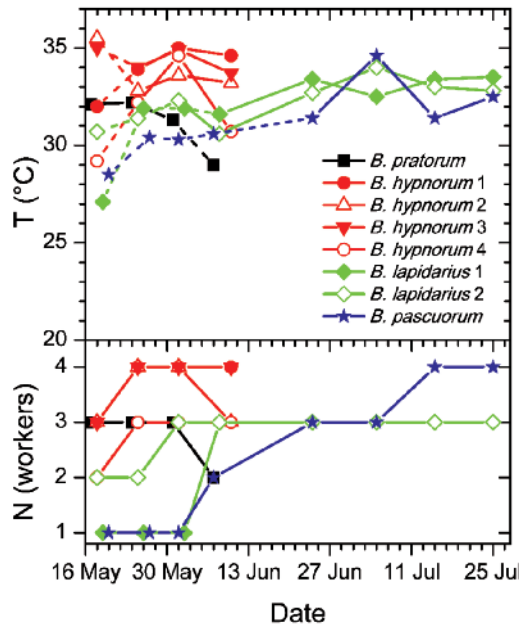


Figure 1: Top: brood temperature in the nests of *B. pratorum*, *B. hypnorum*, *B. lapidarius*, and *B. pascuorum*. Dashed line indicates the upbringing period while the solid line indicates the equilibrium period, reflecting the increase in the worker numbers. Bottom: number of workers in a colony at a given date. The legend for the number of workers on y-axis is the following: 1 is less than 10, 2 is between 10 and 20, 3 is between 20 and 100, and 4 is above 100 workers.

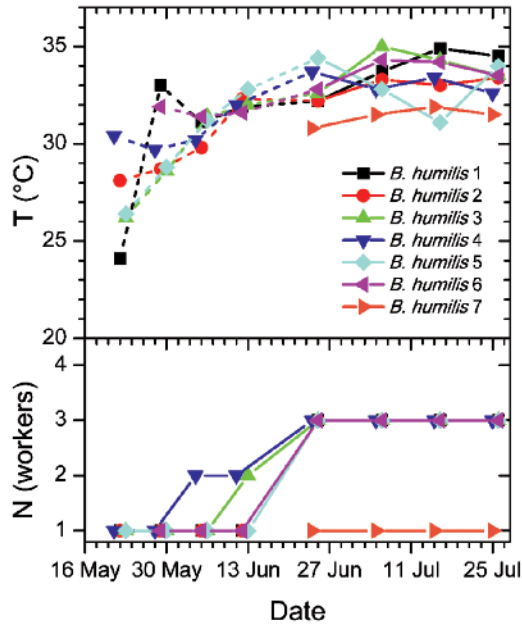


Figure 2: Top: brood temperature in the nests of seven colonies of *B. humilis*. Dashed line indicates the upbringing period while the solid line indicates the equilibrium period, reflecting the increase in the worker numbers (note that *B. humilis* 7 never exceeded 10 workers). Bottom: number of workers in a colony at a given date, the legend on the y-axis is described in Fig. 1.

recorded in the nest was about 100 and about 5 new queens hatched. The average brood temperature during the equilibrium period of the colony was 31.9°C while the temperature dropped to 29°C during the decline, when the comb was almost devoid of new larvae.

In *B. hypnorum* colonies, the queens moved to the nest-boxes within the last ten days of March and new queens emerged from all four nests at the end of May/beginning of June, within four days. In colonies 1-3, the colony development followed a very similar pattern: at the beginning of the temperature measurements on 18 May, there were around 20 workers in the nest already. Within the following weeks, the number of newly hatched workers increased above 150. About 15 to 20 new queens hatched in each colony. The average brood temperature during the equilibrium period was 34.5°C for colony 1, 33.2°C for colony 2, and 34.2°C for colony 3. Colony 4 was smaller in numbers in comparison to other three, starting with less than 20 workers at the beginning of the measurements (with consequently lower temperature of 29°C). In the following three weeks, the number of workers increased to about 80, about 5 new queens hatched. The average temperature during the equilibrium period was 32.5°C. In all four cases, the deviations from the average value were always below 2°C.

The two queens of *B. lapidarius* settled their nests with the time difference of 17 days, however, the first new queens emerged from both nests almost simultaneously. Colony 2, the queen of which settled in the nest later, grew the number of workers above 150 and about a week earlier than colony 1 with the maximum number of workers about 60. Colony 1 produced about 5 new queens and colony 2 about 20. During the equilibrium period, the average temperature was 32.9°C for colony 1 and 32.6°C for colony 2. Again, the deviations from the average were below 2°C. Colony 1 had nest infestation with the wax moth in the middle of the observation period, however, a quick discovery and removal of the parasites resulted in no apparent changes of the colony development. In comparison, other cases of nest infestation took place after the first new queens have already left the nests.

The queen of *B. pascuorum* entered the nest-box in early April. In the second half of May, there were still less than 10 workers in the nest, while by mid-July, there were over 100. About 10 new queens hatched in the colony. During the equilibrium period, the average brood temperature was 32.5°C.

B. humilis represented the largest set in the study, with seven colonies, one of which (colony 7) was moved from the field to the nest-box in mid-June as an already formed nest. The queens of colonies 1-6 moved to the hives sometime between the beginning of April and beginning of May. In late May and early June, these colonies contained small numbers of workers (about 10 or less), only on 25 June, the number of workers increased above 20. New queens emerged within the span of 10 days in mid-July, showing no apparent link to the time the old queens settled in the nest-box. In *B. humilis*, we could observe how the brood temperature is rising with the increasing number of workers until it becomes more or less constant when a large number of workers is present (equilibrium period). The maximum number of workers in these six colonies was somewhere between 60 and 80 while the number of new queens was between 5 and 10. In the early stages, the temperature could be as low as 24.1°C (colony 1). During the equilibrium period, the average brood temperature was 33.9°C for colony 1, 33°C for colony 2, 33.8°C for colony 3, 33.1°C for colony 4, 33.1°C for colony 5, and 33.7°C for colony 6. Colony 7 never grew above 10 workers and the first new queen (only two new queens emerged in total) only appeared in the second half of August. The average temperature during the observation period was 31.4°C. In all *B. humilis* nests, the deviations from the average temperature during the equilibrium period were even smaller than in other species, below 1.5°C.

Following the conclusion of the temperature measurements, the status of the colonies was checked occasionally. Six more colonies saw the infestation with the wax moth which was removed upon discovery. The life span of the colonies was similar to what was expected for particular species based on the previous observation. The old queens died before the last workers did, although it is difficult to pinpoint the time of death of the queen without opening the nest-box. The last workers of *B. pratorum* died on 12 July, *B. hypnorum* between 13-27 July, the two *B. lapidarius* colonies on 14 August and 8 October, respectively, while some individual workers of *B. humilis* and *B. pascuorum* survived up to the first week of November.

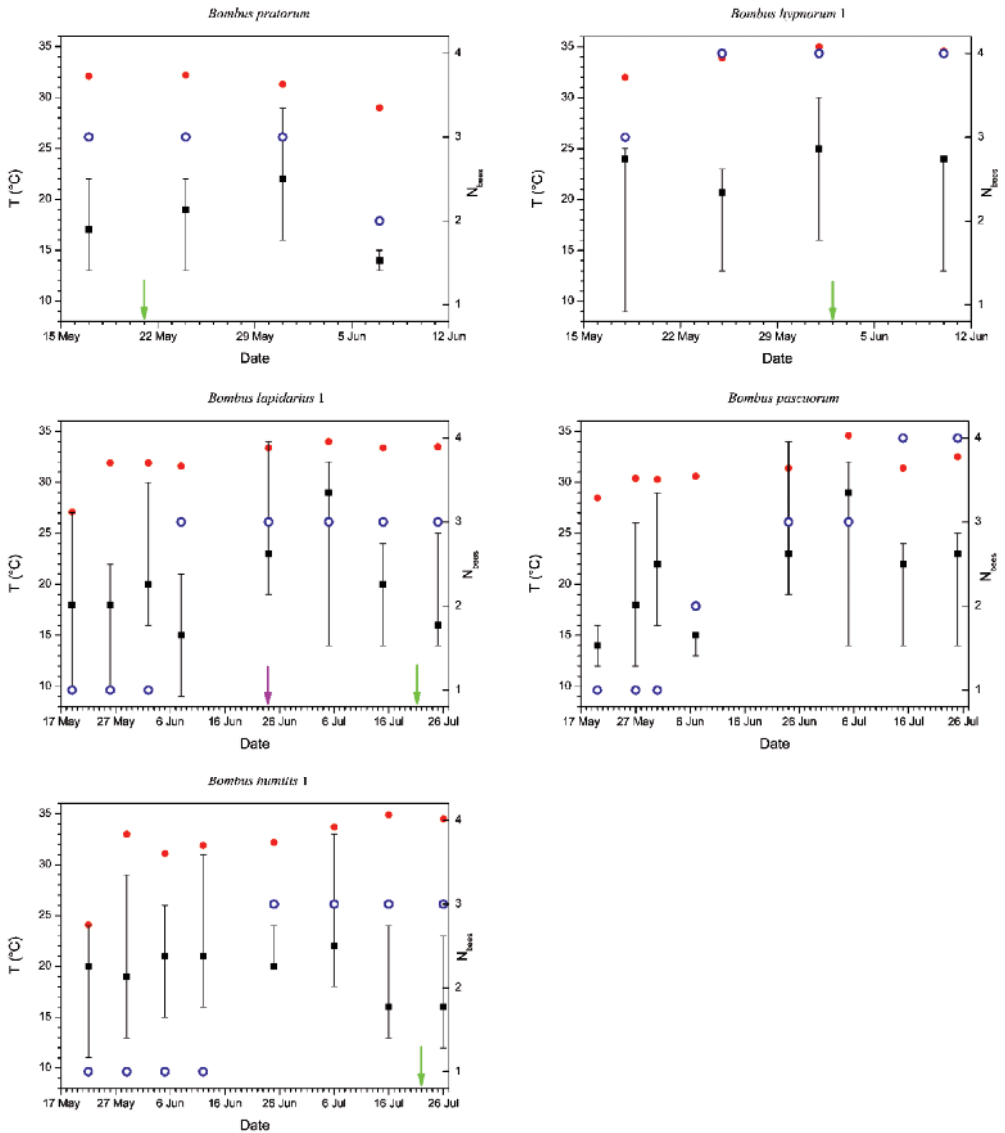


Figure 3: Colony development plots for five selected bumblebee colonies. *Red circles* represent the brood temperature. *Black squares* represent the external temperature at the time of the measurement while the error bars correspond to the maximum and minimum temperatures of the day the measurement took place. *Blue empty circles* (legend at the right side) indicate the estimate of the colony size as discussed in Fig. 1. *Green arrow* indicates the date the first new queens left the nest while the *purple arrow* in *B. lapidarius* 1 plot indicates the day the wax moth parasite was removed from the nest-box.

In all colonies, the brood temperature measurements are in a good agreement with the related work mentioned in the introduction. Throughout the equilibrium period, the brood temperature was between 31 and 35°C, the deviations from the average temperature for individual colony were less than 2°C and for *B. humilis* even below 1.5°C. Especially in *B. humilis*, the relation between the colonies size and the efficiency of thermoregulation is clearly visible, with the brood temperature being lower during the upbringing and roughly constant during the equilibrium with a large number of workers being more efficient in thermoregulation than small numbers.

Discussion

In the area around Ljubljana, based on the observations by the authors in the years 2010-17, the queens of the most common Slovenian bumblebee species (*B. lucorum*, *B. terrestris*, *B. hypnorum*, *B. hortorum*, *B. pratorum*, *B. haematurus*, *B. lapidarius*, *B. argillaceus*, *B. pascuorum*, *B. humilis*, *B. sylvarum*, and *B. ruderarius*) in general emerge from their winter hibernation sites in March and first ten days of April (Grad et al., 2010; Grad et al., 2016). Sometimes queens of *B. lucorum* or *B. terrestris* emerge already in February, queens were already observed for example on 29 February 2012 and 14 February 2014. The year 2013 was exceptional; due to a wet and snowy March the queens emerged no earlier than between 11-19 April. Later on, many of these queens would perish due to cold and wet weather intervals. As seen in Table 1, in 2017, the queens in our study entered the nest-boxes between the second half of March and early May.

The long-term studies of the temperature in the bumblebee nests of Fye and Medler (1954) and Schultze-Motel (1991) used thermocouples inserted inside the nest. When designing our experiment, we decided against this approach, as the thermocouple is a foreign object in the nest. Based on our previous experience, bumblebees tend to avoid foreign objects, which could influence the measurements. In addition, the queen after the first hatch lays eggs on top of the comb in different places, meaning that the thermocouple would no longer be at the ideal position. On the other hand, a quick measurement with a probe thermometer allows a precise measurement of the maximal brood temperature. Here, we think it is safe to assume that an occasional comb cover removal in order to place the probe thermometer on the top of the brood-containing cells and an immediate covering back the comb afterwards represents a negligible influence on the long-term dynamics of the colony and also that the heat capacity of the brood-containing comb is sufficiently high so that the temperature remains constant during the time of the measurement (that takes under five minutes). Following the analysis of the results, we decided to repeat the study in future, using thermocouples to continuously monitor the temperature in the nest-boxes. However, they should be repositioned every couple of days in order to be located close to the brood.

During the days the measurements took place, the outside temperature was almost always lower than the brood temperature. In addition, the nest-boxes were located in shade and not exposed to direct sunlight, therefore no overheating of the brood took

place – also reflected in the fact that all colonies in the study were successful in raising new queens and males. In both the studies of Fye and Medler (1954) and Schultze-Motel (1991), it was observed that the fluctuations of the temperature were typically around 2°C around the average during the day. This is also in agreement with the variations in the temperature between our individual measurements. The fanning behaviour was observed in the colonies with large number of workers when the outside temperature was above 32°C in shade, which is consistent with the reports of Weidenmüller (2004). On the other hand, in future studies, we also plan to monitor the air temperature in the nest-boxes to establish the relationship between the air and brood temperature in the observed species.

Conclusion

In the 15 bumblebee colonies of 5 species studied, the brood temperatures were between 31 and 35°C during the equilibrium period, within each colony, the temperature fluctuations were up to 2°C around the average value. As all colonies survived and successfully produced new queens and males, this temperature range is favourable for brood development, which is in agreement with previous research on the topic, although on different bumblebee species. In all species studied, the colony development cycle was in line with the observations from previous years. The brood temperature was observed to be lower during the upbringing and the decline periods when there is a smaller number of workers present in the nest. During the study, the outside temperature was typically lower than the brood temperature, indicating that the workers are efficient in thermoregulation when it comes to heating the brood. As seen well especially in *B. humilis*, thermoregulation is more efficient when there is a larger number of workers in the colony, which is reasonable. As there were no prolonged periods of heat and the nest-boxes were not exposed to direct sunlight, there were no cases of the colony overheating – although fanning behaviour was observed when the outside temperature exceeded 32°C in shade.

The study was set out as a season-long field study with as little interference as possible in order to properly reflect the field conditions. In future, we plan to equip several nest-boxes with a series of thermocouples to continuously monitor the temperature fluctuations in different parts of the nest and to study how quickly different species react to changes of the conditions outside.

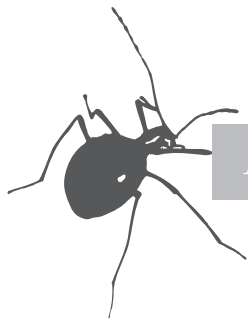
References

- Cook, C. N., Kaspar, R. E., Flaxman, S. M., Breed M. D.**, 2016: Rapidly changing environment modulates the thermoregulatory fanning response in honeybee groups, *Animal Behaviour* 115, 237-243.
- Dean, C. A. E.**, 2016: Developmental Timing of Pupation and Analysis of Colour Pattern Response to Thermal Stress in *Bombus impatiens* (Hymenoptera: Apidae), Master thesis, University of Illinois at Urbana-Champaign.

- De Luca P. A., Vallejo-Marín M.**, 2013: What's the 'buzz' about? The ecology and evolutionary significance of buzz-pollination. *Curr Opin Plant Biol.* 16, 429-435.
- Fye, R. E., Medler, J. T.**, 1954: Temperature Studies in Bumble Domiciles, *Journal of Economic Entomology*, 47, 5, 847-852.
- Goulson, D.**, 2003: Bumblebees: Their Behaviour and Ecology. Oxford University Press, Oxford.
- Grad, J., Gogala, A., Kozmus, P., Jenič, A., Bevk, D.**, 2010: Pomembni in ogroženi oprasovalci – Čmrlji v Sloveniji (Important and endangered pollinators: Bumblebees in Slovenia). Čebelarska zveza Slovenije (The Slovenian Beekeeping Association), Lukovica, Slovenia.
- Grad, J. Oštir, T., Jenič, A.**, 2016: Redkejšje vrste čmrljev v Sloveniji: Značilnosti čmrljev in zanimivosti (Sparsely inhabited bumblebee species in Slovenia: Bumblebees Characteristics and interesting things). Celjska Mohorjeva družba, Celje, Slovenia.
- Gradišek A., Slapničar G., Šorn J., Luštrek M., Gams M., Grad J.**, 2017: Predicting species identity of bumblebees through analysis of flight buzzing sounds, *Bioacoustics*, 26, 1, 63-76.
- Hagen, E. von**, 1994: Hummeln: bestimmen, ansiedeln, vermehren, schuetzen. Naturbuch Verlag, Augsburg, Germany.
- Heinrich, B.**, 1994: Bumblebee Economics. Harvard University Press, Cambridge, Massachusetts, and London, England. Fifth Printing.
- Heinrich, B.**, 2001: Der Hummelstaat – Überlebens Strategien einer uralten Tierart. Econ Ullstein List Verlag GmbH & Co.KG, Muenchen.
- Hintermeier, H., Hintermeier, M.**, 1997: Bienen, Hummeln, Wespen im Garten und in der Landschaft. Bayerischer Landesverband für Gartenbau und Landespflge, München. 2. Auflage.
- Höcherl, N., Kennedy, S., Tautz, J.**, 2016: Nest thermoregulation of the paper wasp *Polistes dominula*, *Journal of Thermal Biology*, 60, 171-179.
- Jones, J. C., Oldroyd, B. P.**, 2007: Nest Thermoregulation in Social Insects, *Advances in Insect Physiology*, 33, 153-191.
- Kearns, C. A., Thomson, J. D.**, 2001: The Natural History of *Bumblebees*: A Sourcebook for Investigations. The University Press of Colorado, Boulder, Colorado.
- Masson, W.C. S., Hedges, P. C., Devaux, B. L. J., Christal, S. J. & Hickey, J. R. A.**, 2017: Mitochondrial glycerol 3-phosphate facilitates bumble pre-flight thermogenesis. *Scientific Reports*, 7, 13107.
- Matheson, A.** (ed.), 1996: Bumblebee Bees for pleasure and profit. IBRA – International Bee Research Association, Cardiff.
- Prys-Jones, O. E. & Corbet, S. A.**, 1987: Bumblebees. Naturalists' Handbooks 6, Cambridge University Press, Cambridge.
- Schultze-Motel, P.**, 1991: Heat loss and thermoregulation in a nest of the bumblebee *Bombus lapidarius* (Hymenoptera, Apidae), *Thermochimica Acta*, 193, 57-66.

- Seeley, T. D. and Heinrich, B.,** 1981: Regulation of temperature in nests of social insects. *Insect Thermoregulation*, edited by B. Heinrich, pp. 159-234. John Wiley, New York.
- Weidenmüller, A.,** 2004: The control of nest climate in bumblebee (*Bombus terrestris*) colonies: Interindividual variability and self-reinforcement in fanning response. *Behavioural Ecology*. 15, 1, 120-128.
- Weidenmüller, A., Kleineidam, C., Tautz J.,** 2002: Collective control of nest climate parameters in bumblebee colonies, *Animal Behaviour*, 63, 1065-1071.
- Witte, G. R., Seger, J.,** 1999: Hummeln brauchen blühendes Land. Westarp Wissenschaften-Verlags-Gesellschaft mbH, Hohenwarsleben.

Received / Prejeto: 28. 5. 2018



THE ECONOMICALLY IMPORTANT ALIEN INVASIVE PLANTHOPPERS IN TURKEY (HEMIPTERA: FULGOROMORPHA)

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Abstract – Alien invasive Hemiptera species are insects of special interest in terms of their nutritional characteristics and their damage and potential effects on cultivated plants. In this study the available informations on the two planthopper species that are invasive in the western Palearctic region and are harmful polyphagically on the EPPO list are summarized and revised. The effects of *Metcalfa pruinosa* (Say, 1830) of the Flatidae family and *Orosanga japonica* (Melichar, 1898) of the Ricaniidae family are seen particularly intense in the Eastern Black Sea Region in Turkey. Host plants of these species, their possible effects, origins and geographical distribution are given.

KEY WORDS: alien invasive species, *Metcalfa pruinosa*, *Orosanga japonica*, host plants, Turkey.

Izveček – GOSPODARSKO POMEMBNI TUJERODNI INVAZIVNI ŠKRŽATKI V TURČIJI (HEMIPTERA: FULGOROMORPHA)

Tujerodne invazivne vrste reda Hemiptera so žuželke, ki nas še posebej zanimajo z vidika njihovih prehranjevalnih lastnosti in škode ter potencialnih učinkov na kulturne rastline. V tej študiji so povzete in revidirane razpoložljive informacije o dveh vrstah škržatkov, invazivnih v zahodni palearktični regiji in sta škodljivi, mnogogledi, na seznamu EPPO. Učinki vrst *Metcalfa pruinosa* (Say, 1830) iz družine Flatidae in *Orosanga japonica* (Melichar, 1898) iz družine Ricaniidae so posebno izraziti v Vzhodni črnemorski regiji v Turčiji. Navedene so gostiteljske rastline teh vrst, njihovi možni učinki, izvor in geografska razširjenost.

KLJUČNE BESEDE: tujerodne invazivne vrste, *Metcalfa pruinosa*, *Orosanga japonica*, gostiteljske rastline, Turčija.

Introduction

Alien species are species that are distributed outside of their natural geographical distribution areas for various reasons. Most of these alien species are of great importance because they exert pressure on local biodiversity, invade cultural plants, cause great economic damage and even threaten human health. Today, the number of alien species in fauna and flora is increasing worldwide due to climate change, the increase in worldwide trade without serious pest controls, and the production of plants of foreign origin, etc.

Fulgoromorpha is a large group of phytophagous insects distributed around the world. At present 14,000 species belonging to 30 families, including fossils, have been identified (Bourgoin, 2017). Since all species suck plant fluids, the relationship with host plants is very important. Plant pathogens are carried to the plant during feeding. Several Fulgoromorpha species around the world are vectors of the most devastating pests of major agricultural products. More than 150 species in various planthopper families have been listed as harmful to large economic losses for 99 cultivated plants (Wilson & O'Brien, 1987, Bourgoin, 2017). For this reason, it is very important to monitor the population density of foreign invasive species and take the necessary precautions.

219 species belonging to 12 families of planthoppers are known from Turkey (Demir, 2008). Two of these species are invasive alien species. They have been attracting attention in recent years due to the damages caused in agricultural plants especially in Eastern Black Sea Region. These are *Metcalfa pruinosa* (Say, 1830) (Flatidae) from North America and *Orosanga japonica* (Melichar, 1898) (Ricaniidae) from East Asia.

According to the European and Mediterranean Plant Protection Organization (EPPO), *Orosanga japonica* is a major plant pest, occurring mostly in tropical regions and lower tropics in the eastern hemisphere. This species was recorded from Turkey (Black Sea coast) for the first time in 2007 and published by Demir (2009). In 2010, it was recorded in the mouth of the river Veleka at the Black Sea coast of Bulgaria (Gjonov, 2011; Gjonov and Shishiniova, 2014). It was recorded from the West Palearctic region in Georgia (Krasnodar province) and Ukraine (Gnezdilov and Suggoev, 2009). It was reported that this species is a vector of fungus pathogens in chestnut forests in the Abkhazian Research Forests Experiment Station of the Caucasus (Lukmazova and Selikhovkin, 2013). It was reported that it caused major damages in tea and kiwi garden in Turkey's eastern Black Sea coast (Ak et al., 2015). It was also recorded in the western Black Sea region by Oztemiz (2018).

Like the previous species, *Metcalfa pruinosa* is listed among the major plant pests by the European and Mediterranean Plant Protection Organization (EPPO). This species was recorded by Karsavuran & Güçlü (2004) for the first time from Turkey in 2004 in Izmir (Aegean Coast). It has been identified firstly in North America (Canada, Brazil and Caribbean Islands) and seen first in Italy in Europe (1979) and later reported to cause damage in Italy, France, Switzerland and Slovenia (EPPO). It has also been reported from and to cause significant damage in Croatia (Čuljak et al,

2007), Austria (Strauss, 2010) and Romania (Preda and Skolka, 2011; Grozea et al., 2011; Ciceoi et al., 2017). Grozea et al. (2015) tried to provide biological control against this species by using Coccinellid species in ornamental plants in Romania. Camerini (2017) conducted a research on spider species to provide biological control against this species which is common in trees in the northern part of Italy. By using CLIMEX modeling software, Byeon et al. (2018) estimated that the globally predictable worldwide distribution of this species would expand in the north-eastern direction and reported that a controlled prevention system was needed. Chkhaidze et al. (2016) suggested that *M. pruinosa* could be a phytoplasma vector in Georgian vineyards; Donati et al. (2017) reported that this species may be the *Pseudomonas syringae* vector, which produces bacterial cancer in kiwi orchards in Italy. In Turkey Hantaş et al (2014) reported this species from Sakarya and Yalova; it was found on quince. This species is distributed in the Mediterranean and the Black Sea regions and has been reported to cause damage especially in kiwi gardens in agricultural areas in the Eastern Black Sea Region (Günçan, 2014). Göktürk (2017) conducted biopesticide experiments to establish a struggle strategy against this species in Artvin in the Eastern Black Sea Region.

Materials and Methods

The samples examined in this study were collected with aspirator in the hazelnut and walnut gardens in Akçakoca and Konuralp in Düzce from Western Black Sea Region. After conversion to standard museum material in the laboratory, the specimens were identified. Samples are kept in the author's collection.

Results

The locality, distribution and host plant information of the examined specimens are given below.

Orosanga japonica (Melichar, 1898)

Family: Ricaniidae Amyot & Audinet-Serville, 1843

Synonymy: *Ricania japonica* Melichar, 1898 previous combination of *Orosanga japonica* (Melichar, 1898) according to Hayashi & Fujinuma (2016): 354.

Material: Düzce, Akçakoca, Ceneviz Castle, 14.08.2017, 13♂7♀. These planthoppers were collected from the border of hazelnut gardens. On *Platanus orientalis*, *Rubus* sp., *Clematis vitalba* and *Corylus avallena*. A large number of specimens were observed on the plants (Figures 1-6).

Zoogeographic range: China, India, Japan (Honshu, Kyushu, Shikoku), Nansei-shoto (Ryukyu Islands), Taiwan, Ukraine, Turkey, Georgia (Krasnodar), Bulgarian, Abkhazia (Hoch, 2013; Bourgoïn, 2017).

Distribution in Turkey: Rize prov.: Center, (Demir, 2009), Artvin prov.: Arhavi, Hopa, Kemalpaşa, Rize prov.: Ardeşen, Çayeli, Derepaşarı, Fındıklı, Pazar, Trabzon

prov.: Araklı, Of, Sürmene (Ak et al., 2015); Düzce prov.: Akçakoca (Öztemiz, 2018).

Host plants: Demir (2009) reported this species from *Vitis vinifera*, *Rubus* sp., *Camelia sinensis*, *Ficus carica*, *Phaseolus vulgaris*, *Cucumis sativus*, *Lycopersicum esculentum* and weeds. Ak and others (2015) gave a large number of host plants - see table 1.

Table 1. Host plants of *Orosanga japonica* in Turkey. Abbreviation of province names in the table: AR: Artvin, DU: Düzce, RI: Rize, TR: Trabzon.

Family	Species	Province	Reference
Platanaceae	<i>Platanus orientalis</i> (plane)	DU	This study
Rosaceae	<i>Rubus</i> sp. (blackberry)	AR, DU, RI, TR	This study; Demir,2009; Ak et al,2015
Betulaceae	<i>Corylus avellana</i> (hazelnut)	AR, DU, RI, TR	This study; Ak et al, 2015; Öztemiz, 2018
Ranunculaceae	<i>Clematis vitalba</i>	DU	This study
Vitaceae	<i>Vitis vinifera</i> (grape)	AR, RI, TR	Demir, 2009; Ak et al, 2015
Theaceae	<i>Camelia sinensis</i> (tea)	AR, RI, TR	Demir, 2009; Ak et al, 2015
Moraceae	<i>Ficus carica</i> (fig)	AR, RI, TR	Demir, 2009; Ak et al, 2015
Fabaceae	<i>Phaseolus vulgaris</i> (beans)	RI	Demir, 2009
Cucurbitaceae	<i>Cucumis sativus</i> (cucumber)	AR, RI, TR	Demir, 2009; Ak et al, 2015
Solanaceae	<i>Lycopersicum esculentum</i> (tomato)	RI	Demir, 2009
Adoxaceae	<i>Sambucus</i> sp. (elder-berry)	AR, RI, TR	Ak et al, 2015
Grossulariaceae	<i>Actinidia deliciosa</i> (kiwifruit)	AR, RI, TR	Ak et al, 2015
Hydrangeaceae	<i>Hydrangea macrophylla</i>	AR, RI, TR	Ak et al, 2015
Betulaceae	<i>Alnus</i> sp (alder tree)	AR, RI, TR	Ak et al, 2015
Rosaceae	<i>Laurocerasus officinalis</i>	AR, RI, TR	Ak et al, 2015
Urticaceae	<i>Urtica</i> sp. (nettle)	AR, RI, TR	Ak et al, 2015
Fabaceae	<i>Robinia pseudoacacia</i>	AR, RI, TR	Ak et al, 2015
Asteraceae	<i>Artemisia absinthium</i> (wormwood)	AR, RI, TR	Ak et al, 2015
Rosaceae	<i>Eriobotrya japonica</i> (japanese plum)	AR, RI, TR	Ak et al, 2015
Lamiaceae	<i>Lavandula</i> sp. (lavender)	AR, RI, TR	Ak et al, 2015
Rutaceae	<i>Poncirus trifoliata</i>	AR, RI, TR	Ak et al, 2015
Juglandaceae	<i>Juglans regia</i> (walnut)	AR, RI, TR	Ak et al, 2015
Ebenaceae	<i>Diospyros lotus</i>	AR, RI, TR	Ak et al, 2015
Rosaceae	<i>Malus</i> sp. (apple)	AR, RI, TR	Ak et al, 2015
Rutaceae	<i>Citrus reticulata</i> (mandarin)	AR, RI, TR	Ak et al, 2015
Fagaceae	<i>Castanea sativa</i> (chestnut)	AR, RI, TR	Ak et al, 2015
Solanaceae	<i>Solanum melongena</i> (eggplant)	AR, RI, TR	Ak et al, 2015

Metcalfa pruinosa (Say, 1830)

Family: Flatidae Spinola, 1839

Material: Düzce, Akçakoca, Ceneviz Castle, 14.08.2017, 6 ♂♀; Konuralp, Bağlık Location, 2 ♂♀, Çiftepınarlar 4 ♂♀. These planthoppers were collected from the border of hazelnut and walnut gardens. On *Corylus avellana*, *Juglans regia*, *Ficus carica*, *Laurocerasus officinalis*, *Platanus orientalis*, *Rubus* sp., *Clematis vitalba*. A large number of specimens were observed on the plants (figures 7-11).

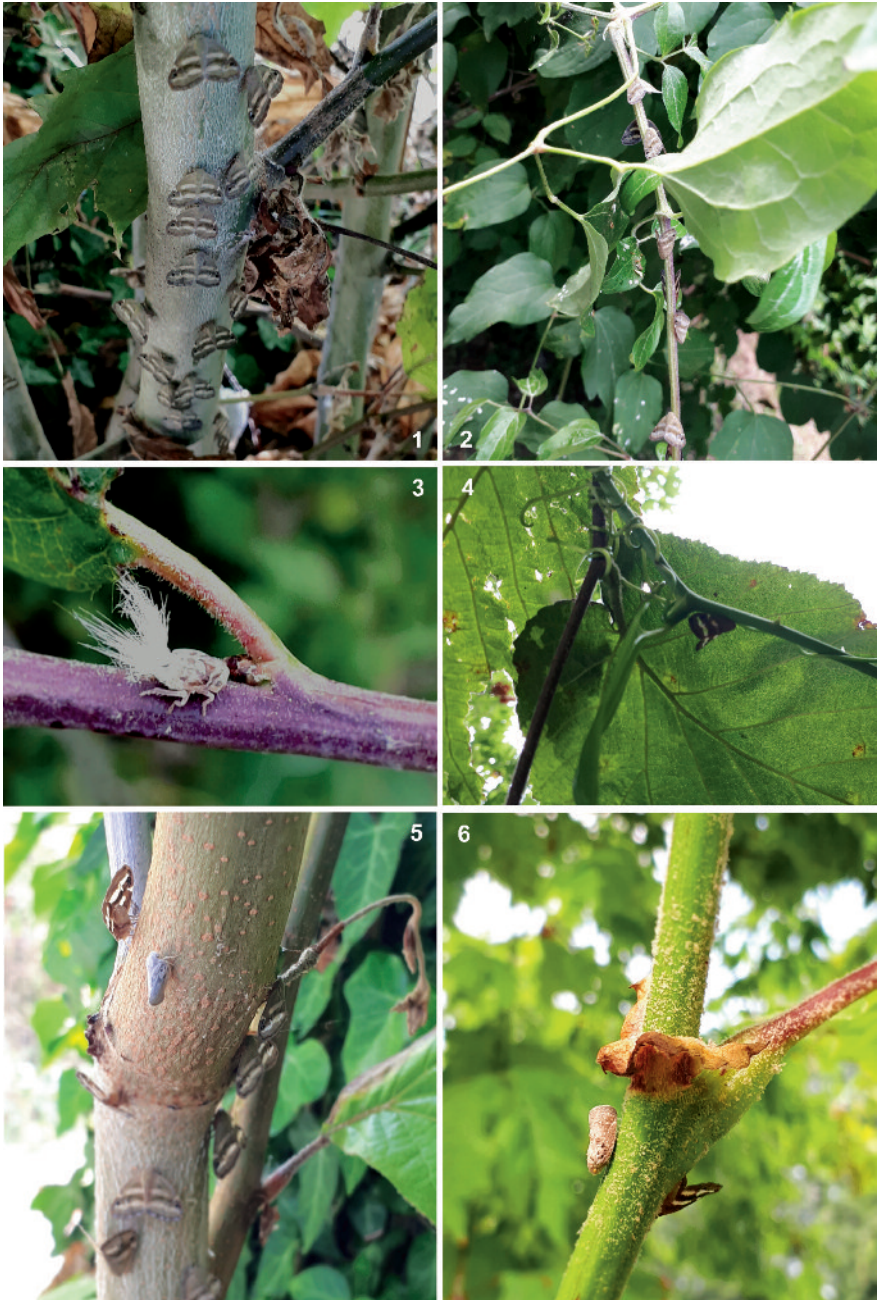


Fig. 1-6: *Orosanga japonica* on various host plants in hazelnut gardens. 1. on *Platanus orientalis*, 2., 4. on *Clematis vitalba*, 3. a nymph on *Platanus orientalis*, 5., 6. specimens of *O. japonica* and *M. pruinosa* on the same plant.

Zoogeographic range: North America inc. Cuba and Mexico. Introduced to many countries of the Mediterranean region and also Central Europe (see Hoch, 2013; Bourgoïn, 2017).

Distribution in Turkey: İzmir prov.: Balçova (Karsavuran and Güçlü, 2004); Sakarya prov.: Gevye, Yalova prov.: Center (Hantaş et al., 2014); Ordu prov.: Altınordu, Perşembe, Fatsa, Ünye (Güncan, 2014).

Host plants: According to EPPO, it is a highly polyphagous insect that can attack fruit trees, forest trees, ornamental plants and weeds. 173 host plants were recorded in Italy. Damage to citrus fruits, grapevines, fig trees, blackberries, apples, pears, olives, apricots, walnuts, plums, sunflower, soybean have been reported. Examples of species were collected in Turkey in the Aegean region mandarin trees (Karsavuran and Strong, 2004). Hantaş et al. (2014) found it in quince gardens in Sakarya and Yalova. Güncan (2014) reported that this species was the cause of the damages in the kiwi gardens in the Black Sea Region (table 2).

Table 2. Host plants of *Metcalfa pruinosa* in Turkey.

Family	Species	Province	Reference
Juglandaceae	<i>Juglans regia</i> (walnut)	Düzce	This study
Platanaceae	<i>Platanus orientalis</i> (plane)	Düzce	This study
Rosaceae	<i>Rubus</i> sp. (blackberry)	Düzce	This study
Betulaceae	<i>Corylus avallena</i> (hazelnut)	Düzce	This study
Ranunculaceae	<i>Clematis vitalba</i>	Düzce	This study
Moraceae	<i>Ficus carica</i> (fig)	Düzce	This study
Rosaceae	<i>Laurocerasus officinalis</i> (cherry laurel)	Düzce	This study
Rutaceae	<i>Citrus reticulata</i>	İzmir	Karsavuran and Güçlü, 2004
Grossulariaceae	<i>Actinidia deliciosa</i> (kiwifruit)	Ordu	Güncan, 2014

Discussion

Orosanga japonica has been recorded from Turkey first in Rize by Demir (2009). In subsequent years many *Ricania simulans* (Walker, 1851) records were given by Güçlü et al. (2010), Göktürk and Mihli (2015) and Ak et al. (2015). I think that the specimens recorded in these studies as *Ricania simulans* (Walker, 1851) are in fact *Orosanga japonica* since *R. simulans* is distributed only in China (Fujian, Jiangxi, Zhejiang), India, Japan and Taiwan (Bourgoïn, 2017).

O. japonica is distributed in the Black Sea Region in the west up to Akçakoca province (Öztemiz, 2018). It is stated that this species causes great economic problems for tea and kiwi gardens (Güçlü et al., 2010, Göktürk and Mihli, 2015, Ak et al., 2015). This study proves that it is also widespread in hazelnut gardens in the West Black Sea and distributed all over the Black Sea coast. In order to prevent a situation similar to tea gardens in hazelnut gardens, it is necessary to control the population continuously and take necessary precautions. In addition, the risk of being a vector for viral and fungal pathogens should be considered.

Metcalfa pruinosa has spread in western and northern Anatolia after recorded in İzmir Balçova by 2003 (Karsavuran and Güçlü, 2004). Also stated that it caused eco-



Fig. 7 - 11: *Metcalfa pruinosa* on various host plants in walnut and hazelnut gardens. 7. on *Junglans regia*, 8. *Corylus avellana*, 9. *M. pruinosa* secretions on walnut fruit, 10. on *Ficus carica*, 11. on leaf of plane.

onomic damages especially in the Eastern Black Sea region (Hantaş et al, 2014; Güncan, 2014; Göktürk, 2017).

M. pruinosa causes loss of nutritional value in plants, because saprophyte fungus (fumagine) grows on the sweet substance released in abundant amounts, aesthetical harm to ornamental plants and loss in market value (Della Giustina & Navarro, 1993; Lucchi & Santini, 2002). On the other hand, the species can carry disease agents such as viruses, bacteria and phytoplasmas in grapevines and other hosts. It is important to control populations of this species, which are abundantly found in Düzce especially in walnut, hazelnut, fig and cherry laurel trees.

Acknowledgements

I would like to thank Dr. Lütfi Özden who took the photos of specimens on the host plants (Düzce University, Art Design and Architecture Faculty).

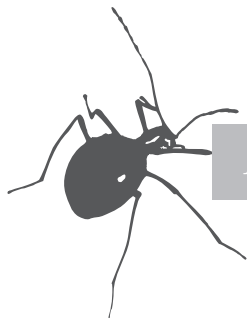
References

- Ak, K., Güçlü, Ş., Eken, C., Sekban, R.** 2015. Türkiye için yeni bir zararlı *Ricania simulans* (Walker, 1851) (Hemiptera: Ricaniidae). *Türk. Entomol. Derg.* 39(2): 179-186.
- Bourgoin, T.** 2017. FLOW (Fulgoromorpha Lists on The Web): a world knowledge base dedicated to Fulgoromorpha. Version 8, updated, last update: 06.02.2017. <http://hemiptera-databases.org/flow/>.
- Byeon, D-H., Jung, J-M., Jung, S., Lee, W-H.** 2018. Prediction of global geographic distribution of *Metcalfa pruinosa* using CLIMEX. *Entomol. Res.*, 48: 99-107.
- Camerini, G.** 2017. Spiders (Araneae) as predators of the exotic *Metcalfa pruinosa* (Say, 1830) (Homoptera: Flatidae) in the central western Po Floodplain (Northern Italy). *Indian J. Arachn.*, 6(1): 72-80.
- Chkhaidze, N.M., Lobjanidze, Mz.I., Dzmanashvili, I.I., Barjadze, Sh.Z., Maghradze, D.N.** 2016. Grapevine phytoplasma disease in Georgia. *Ann. Agrar. Sci.*, 14: 153-162.
- Ciceoi, R., Dobrin, I., Mardare, E.Ş., Dicianu, E.D., Stanica, F.** 2017. Emerging pests of *Ziziphus jujube* crop in Romania. *Sci. Papers Ser. B Hort.*, 61: 143-153.
- Čuljak, T.G., Ostojić, I., Skelin, I., Grubišić, D., Jelovčan, S.** 2007. *Metcalfa pruinosa* (Say, 1830) (Homoptera: Flatidae) potencijalno opasan štetnik u novim Područjima. *Entomol. Croat.*, 11(1-2): 75-81.
- Della Giustina, W., Navarro, E.** 1993. *Metcalfa pruinosa*, un nouvel envahisseur? *Phytoma* 451: 30-32.
- Demir, E.** 2008. Fulgoromorpha and Cicadomorpha of Turkey. Part I: Mediterranean Region (Hemiptera). *Mun. Ent. Zool.* 3: 447-522.
- Demir, E.** 2009. *Ricania* Germar, 1818 species of Western Palaearctic Region (Hemiptera: Fulgoromorpha: Ricaniidae). *Mun. Ent. Zool.* 4 (1): 271-275.

- Donati, I., Mauri, S., Buriani, G., Cellini, A., Spinelli, F.** 2017. Role of *Metcalfa pruinosa* as a Vector for *Pseudomonas syringae* pv. *actinidae*. *Plant. Pathol.*, 33(6): 554-560.
- EPPO.** 1996. *Metcalfa pruinosa*: a new pest in Europe. European and Mediterranean Plant Protection Organization Reporting Service no. 02-1996 Num.article.
- EPPO.** 2016. *Ricania japonica*: a new polyphagous insect found in the EPPO region (2016/100). European and Mediterranean Plant Protection Organization Reporting Service no.5 Paris, 2016-05-Pests, 17-18.
- EPPO.** 2017. New data on quarantine pests and pests of EPPO Alert List European and Mediterranean Plant Protection Organization Reporting Service no. 02-2017 Num.article, 2017/028.
- Gjonov, I.** 2011. *Ricania japonica* Melichar, 1898 – a representative of family Ricaniidae (Homoptera, Fulgoromorpha), new to the fauna of Bulgaria. *ZooNotes* 23: 1-3.
- Gjonov, I., Shishiniova, M.** 2014. Alien Auchenorrhyncha (Insecta, Hemiptera: Fulgoromorpha and Cicadomorpha) to Bulgaria. *Bulg. J. Agric. Sci* 20 (Suppl. 1): 151-156.
- Gnezdilov, V. M., Sugonyaev, E. S.** 2009. First record of *Metcalfa pruinosa* Homoptera: Fulgoroidea: Flatidae) from Russia. *Zoosyst. Ross.* 18(2): 260–261.
- Göktürk, T., Mihli, A.** 2015. Doğu Karadeniz sahil şeridinin önemli zararlısı *Ricania simulans* (Walker, 1851) (Hemiptera: Ricaniidae)’ın mücadelesi üzerine araştırmalar. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi.* 16(1): 89-93.
- Göktürk, T.** 2017. The Effect of Dipel and Spruzit Biopesticides on *Metcalfa pruinosa* (Say, 1830) (Homoptera: Flatidae). *International Journal of Environment Agriculture and Biotechnology* 2(3): 1387-1391.
- Grozea, I., Gogan, A., Virteiu, A.M., Grozea, A., Stef, R., Molnar, L., Carabet, A., Dinnesen, S.** 2011. *Metcalfa pruinosa* Say (Insecta: Homoptera: Flatidae): A new pest in Romania. *Afr. J. Agric. Res.*, 6(27): 5870-5877.
- Grozea, I., Vlad, M., Virteiu, A.M., Stef, R., Carabet, A., Molnar, L., Mazare, V.** 2015. Biological control of invasive species *Metcalfa pruinosa* Say (Insecta: Hemiptera: Flatidae) in ornamentals plants by using Coccinelids. *Journal of Biotechnology* Suppl. 208S112.
- Güçlü, Ş., Ak, K., Eken, C., Akyol, H., Sekban, R., Beytut, B., Yıldırım, R.** 2010. Pathogenicity of *Lecanicillium muscarium* against *Ricania simulans*. *Bull. Insectology* 63(2): 243-246.
- Güncan, A.** 2014. Türkiye kivi bahçelerinde yeni bir zararlı *Metcalfa pruinosa* (Say, 1830) (Hemiptera: Flatidae). *Akademik ziraat dergisi* 3(1): 41-44.
- Hantaş, C., Çetin, G., Akçay, M.E.** 2014. Marmara Bölgesi ayva bahçelerinde zararlı böcek ve akar türleri ile doğal düşmanlarının saptanması ve önemli zararlı türlerin populasyon değişimi. *Bit. Kor. Bült.*, 54(3): 283-302.
- Hayashi, M., Fujinuma, S.** 2016. Part Fulgoromorpha. In: Entomological Society of Japan 2016 - Catalogue of the insects of Japan. Volume 4 Paraneoptera (Psocodea, Thysanoptera, Hemiptera). 4. Editorial Committee of Catalogue of the Insects of Japan 323-355.

- Hoch, H.** 2013. Hemiptera, Fulgoromorpha Fauna Europaea. Version 2.6.2. last update 29.08.2013. <http://www.faunaeur.org>.
- Karsavuran, Y., Güçlü, Ş.** 2004. Türkiye faunası için yeni bir zararlı tür, *Metcalfa pruinosa* (Say, 1830) (Homoptera: Flatidae). *Türk. Entomol. Derg.* 28(3): 209-212.
- Lucchi, A., Santini, L.** 2002. Aspetti fisiologici e morfo-funzionali in *Metcalfa pruinosa* (Hom.: Fulgoroidea) con riferimento agli effetti prodotti sulle produzioni agricole e sulle alberature ornamentali. *Atti della Accademia Nazionale Italiana di Entomologia Rendiconti* 49: 131-147.
- Lukmazova, E.A., Selikhovkin, A.V.** 2013. Forest Pest Status of Chestnut Forests of the Abkhazia Republic. International Caucasian Forestry Symposium 24-26 October Artvin Turkey.
- Melichar, L.** 1898. Vorläufige Beschreibung neuer Ricaniiden. *Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien* 48. 384-400.
- Öztemiz, S.** 2018. *Ricania japonica* (Hemiptera: Ricaniidae): found in the western Black Sea, Turkey. *Mun. Ent. Zool.* 13(1): 326-328.
- Preda, C., Skolka, M.** 2011. Range Expansion of *Metcalfa pruinosa* (Homoptera: Fulgoroidea) in Southeastern Europe. *Ecologia Balkanica*, 3(1): 79-87.
- Strauss, G.** 2010. Pest risk analysis of *Metcalfa pruinosa* in Austria. *J. Pest Sci*, 83: 381-390.
- Wilson S.W., O'Brien L.B.** 1987. A survey of planthoppers pests of economically important plants (Homoptera: Fulgoroidea). In Proceedings of 2nd International Workshop on Leafhoppers and Planthoppers of Economic importance, Wilson, M.R. & Nault, L.R., 28th July-1st August 1986, Brigham Young University, Provo, Utah, USA, London, CAB Int. Inst. Ent., pp. 343-360.

Received / Prejeto: 16. 8. 2018

**PRISPEVEK RAZISKOVALNEGA TABORA ŠTUDENTOV BIOLOGIJE
2017 K POZNAVANJU FAVNE KAČJIH PASTIRJEV GORENJSKE**Damjan VINKO¹, Ana TRATNIKSlovensko odonatološko društvo, Verovškova 56, SI-1000 Ljubljana, Slovenija
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Izvleček – Na Raziskovalnem taboru študentov biologije 2017 – Predoslje je odonatološka skupina med 20. in 28. julijem 2017 na 65 lokalitetah na vzhodnem Gorenjskem popisala 38 vrst kačjih pastirjev. Dve vrsti, popisani vsaka na eni lokaliteti, sta novi za izbrano območje tabora: kačji potočnik (*Ophiogomphus cecilia*) in afriški minljivec (*Anax ephippiger*), ki je bil prvič zabeležen na celotnem Gorenjskem. V prispevku so zapisana nova najdišča drugih na Gorenjskem redkih ali slabo poznanih vrst kačjih pastirjev; ti so: grmiščna zverca (*Lestes barbarus*), zelena pazverca (*Chalcolestes viridis*), mali rdečeoček (*Erythromma viridulum*), višnjeva deva (*Aeshna affinis*), deviški pastir (*A. isocetes*), kovinski lesketnik (*Somatochlora metallica*), črni ploščec (*Libellula fulva*), sredozemski kamenjak (*Sympetrum meridionale*) in navadni kamenjak (*S. vulgatum*). Pomembnejši rezultati vključujejo tudi dokumentirane najdbe novih populacij velikega studenčarja (*Cordulegaster heros*), prvič tudi v Poljanski dolini. 11 zabeleženih vrst je uvrščenih na Rdeči seznam, 4 so zavarovane, 2 vrsti sta uvrščeni na Prilogi Direktive o habitatih. V manjšem obsegu smo popisali tudi vodne habitate v Parku Brdo pri Kranju, za katerega je sedaj znanih 39 vrst kačjih pastirjev, in bajer Pristava v Mengšu ter Hraški mlaki, ki glede na favno kačjih pastirjev s 43 oz. 30 vrstami spadata med vrstno najpestrejšje lokalitete v Sloveniji. Skupno je na vzhodnem Gorenjskem znanih 54 vrst kačjih pastirjev, vendar 8 vrst v daljšem obdobju ni bilo več zabeleženih, na celotnem Gorenjskem pa 63 vrst.

KLJUČNE BESEDE: kačji pastirji, Odonata, Slovenija, Gorenjska, Brdo pri Kranju, Pristava, Hraše, novi podatki

Abstract – CONTRIBUTION OF BIOLOGY RESEARCH CAMP 2017 TO THE KNOWLEDGE OF DRAGONFLY FAUNA OF THE GORENJSKA REGION

During Biology Research Camp 2017 – Predoslje 38 dragonfly species were reported from 65 localities during 20th to 28th July 2017. Geographically, research was focused on eastern part of Gorenjska region (Central-NW Slovenia). Two species are new for the area: *Ophiogomphus cecilia* and *Anax ephippiger*, each recorded on one site. *Anax ephippiger* is also new for the whole Gorenjska region. Additional records of *Lestes barbarus*, *Chalcolestes viridis*, *Erythromma viridulum*, *Aeshna affinis*, *A. isoceles*, *Somatochlora metallica*, *Libellula fulva*, *Sympetrum meridionale* and *S. vulgatum*, which are known only from few sites in the region or are considered rare are added. New populations of *Cordulegaster heros* were recorded, for the first time in the Poljanska dolina Valley. 11 recorded species are included on Slovene Red Data List, 4 are in the country protected and 2 are listed on Annexes of Habitats Directive. Also Park Brdo pri Kranju was investigated, where together with our records 39 dragonfly species were recorded, and lake Pristava in Mengeš and two ponds in Hraše, which are with 43 or 30 dragonfly species one of the richest sites in Slovenia according to dragonfly fauna. Altogether 54 dragonfly species are now mapped for eastern part of Gorenjska region although, 8 species were not recorded in recent periods and 63 for the whole region.

KEY WORDS: dragonflies, Odonata, Slovenia, Gorenjska, Brdo pri Kranju, Pristava, Hraše, new records

Uvod

Študenti biologije Univerze v Ljubljani se od leta 1988 tradicionalno zberejo na Raziskovalnem taboru študentov biologije (RTŠB), ki praviloma poteka vsakega julija na drugem območju Slovenije (Presetnik 2018). Osnovni namen tabora je študentom približati biološko terensko delo, ki je med drugim temelj za strokovno varstvo narave. V letu 2017 je Društvo študentov biologije organiziralo tabor s središčem v Predosljah. Kot običajno je na taboru delovala tudi odonatološka skupina. V prispevku so predstavljeni rezultati dela odonatološke skupine na RTŠB 2017, osredotočene na favno kačjih pastirjev vzhodnega dela Gorenjske, vzhodno od Bleda, in za dve lokaliteti na tem območju neobjavljeni podatki prvega avtorja. V podatkovni zbirki Centra za kartografijo favne in flore v sodelovanju s Slovenskim odonatološkim društvom je za to izbrano območje zbranih dobrih tisoč podatkov o pojavljanju 52 vrst kačjih pastirjev (CKFF 2017, Vinko 2010), za celotno območje Gorenjske pa je znanih 62 od 72 v Sloveniji zabeleženih vrst kačjih pastirjev (Kotarac 1997, 2015, Vinko 2017, CKFF 2017). RTŠB je na Gorenjskem že potekal leta 2003 (Planinc 2004), vendar poročilo o delu skupine za kačje pastirje ni bilo objavljeno, podatki pa tudi niso bili predani v dostopne podatkovne zbirke.

Zaradi občutljivosti na kakovost habitata, amfibijskega življenja in lahke določitve so kačji pastirji učinkoviti indikatorski organizmi za ocenjevanje okoljskih sprememb in stanja habitata, hkrati pa so uporabni kot model za oceno potencialnih sprememb v okolju (Kalkman in sod. 2018).

Metode in lokalitete

Kačje pastirje smo popisovali na širšem območju vzhodne Gorenjske (Pregl. 1) med 20. in 28. julijem 2017. Terensko delo je večinoma potekalo ob sončnem vremenu cel dan. Mesta vzorčenja smo izbirali tako, da smo zajeli čim več različnih habitatov. Posebno pozornost smo namenili večjim stoječim vodam, glinokopnim jamam, ter v preteklosti že popisanim lokalitetam. Nekaj mest vzorčenja smo izbrali za popis velikega studenčarja (*Cordulegaster heros*). Pri delu smo se posluževali klasičnih metod popisovanja kačjih pastirjev. Odrasle osebkke smo lovili z entomološkimi mrežami (metuljnicami) in jih po določitvi nepoškodovane izpustili na mestu ujetja. Nekatere odrasle osebkke smo lahko določili že brez ujetja. Na nekaj lokalitetah smo z vodno mrežo vzorčili tudi ličinke, pri pregledu vseh lokalitet pa bili pozorni tudi na leve. Dovoljenje za vznemirjanje in ujetje kačjih pastirjev je izdala Agencija RS za okolje (št. 35601-56/2015-5).

Da bi preverili uspešnost popisa na raziskovalnem taboru, smo izračunali pričakovano število vrst, ki nam posredno napove verjetnost pojavljanja v raziskavi neopazjenih vrst na izbranem območju. Za ta namen smo uporabili izračun pričakovanega števila vrst, ki pri izračunu ne upošteva števila osebkov – Chao 2 (Chao 1987). Pričakovano število vrst na območju smo izračunali ločeno enkrat samo s podatki, pridobljenimi na raziskovalnem taboru in drugič upoštevaje vse dostopne podatke za to izbrano območje.

Uporabljena okrajšava: lok – lokaliteta.

Preglednica 1: Seznam lokalitet s podatki o pojavljanju kačjih pastirjev, zbranimi na RTŠB 2017 – Predoslje.

LOKALITETA	Y	X	DATUM (2017)	N LOK
Cerklje na Gorenjskem, Šmartno: potok Smidol	463385	122313	23. 7.	31
Domžale, Rova: ribnik Plastenka	471321	115000	27. 7.	61
Golnik, Goriče: pod mostom, ki prečka potok	449567	131096	24. 7.	37
Kamnik, Tunjiška Mlaka: potok Tunjičica na J koncu vasi Tunjiška Mlaka	468546	120200	23. 7.	32
Kokrica, Bobovek: Čukova jama – J glinokop	451125	125680	20. 7.	2
Kokrica, Bobovek: Krokodilnica – S glinokop	451061	125935	20. 7.	1
Kokrica, Bobovek: kanal med obema glinokopoma	451140	125793	20. 7.	4
Kokrica, Bobovek: potok Milka ob S glinokopu	450927	126013	20. 7.	51
Kokrica, Bobovek: V glinokop v Bobovku	451215	125924	20. 7.	5
Kranj, Kranj: poplavljen JZ del glinokopa Z ob mestni četrti Stražišče	448394	121260	21. 7.	14
Kranj, Kranj: reka Sava pod jezom v Kranju	450239	122398	28. 7.	64
Kranj, Mlaka pri Kranju: mlaka v vasi Mlaka pri Kranju	450370	125963	21. 7.	13
Kranj, Orehovlje: stranski pritok reke Kokre	453992	125003	28. 7.	3
Kranj, Orehovlje: reka Kokra	453931	124871	28. 7.	47
Kranj, Predoslje: potok Bela	453062	124996	28. 7.	63
Kranj, Predoslje: Park Brdo pri Kranju, Prvo jezero	452389	125788	26. 7.	44
Kranj, Predoslje: Park Brdo pri Kranju, kamnit kanal z dvema odtočnima mlakama	452275	125871	26. 7.	45
Kranj, Predoslje: Park Brdo pri Kranju, potok pri Prvem jezeru	452315	125914	26. 7.	46
Kranj, Predoslje: Park Brdo pri Kranju, Drugo jezero	452400	125954	26. 7.	48

LOKALITETA	Y	X	DATUM (2017)	N LOK
Kranj, Predoslje: Park Brdo pri Kranju, kanal J od kamnitega kanaliziranega potoka	452297	125821	26. 7.	49
Kranj, Predoslje: Park Brdo pri Kranju, ribnik	453608	126859	21. 7.	10
Kranj, Predoslje: Park Brdo pri Kranju, močvirje nad ribnikom 5	453473	126706	21. 7.	11
Kranj, Predoslje: Park Brdo pri Kranju, potok nad ribnikom 5	453643	126758	21., 26. 7.	12
Kranj, Predoslje: Park Brdo pri Kranju, ribnik 6	453718	127094	26. 7.	43
Kranj, Predoslje: Park Brdo pri Kranju, ribnik 7	453817	127230	26. 7.	42
Kranj, Predoslje: Park Brdo pri Kranju, ribnik 10	455015	127177	21. 7.	8
Kranj, Predoslje: Park Brdo pri Kranju, ribnik 11	454830	126883	21. 7.	7
Kranj, Predoslje: Park Brdo pri Kranju, potok pod ribnikom 11	454794	126817	21. 7.	9
Kranj, Predoslje: Park Brdo pri Kranju, ribnik S od predsedniške rezidence	453274	126498	22. 7.	23
Kranj, Srednje Bitnje: mlaka na pritoku potoka Žabnica	448383	118909	23. 7.	30
Kranj, Tenetiše: V ribnik na Želinjskem potoku	448414	127284	20. 7.	6
Kranj, Tenetiše: Želinjski potok 800 m Z od deponije Tenetiše	448937	127056	22. 7.	21
Kropa, Češnjica pri Kropi: potok Plaznica, kjer ga prečka cesta	441301	126759	22. 7.	20
Log nad Škofjo Loko, Brode: Poljanska Sora pod mostom	443347	110823	23. 7.	25
Log nad Škofjo Loko, Gabrk: potok Gabrška grapa	442101	110792	23. 7.	26
Log nad Škofjo Loko, Gabrška gora: potok na travniku	439753	111309	23. 7.	27
Log nad Škofjo Loko, Volča: potok Ločivnica (do sotočja s potokom Sevnščica)	437170	110656	23. 7.	28
Medvode, Hraše: jezerci pri vasi Hraše	457399	114869	20., 26., 27. 7.	59
Medvode, Zbilje: Zbiljsko jezero	455680	112629	22. 7.	24
Mengeš, Pristava: bajer Pristava	465958	112962	27. 7.	55
Mengeš, Pristava: jarek ob cesti, 70 m V od Opekarne v Pristavi	466297	112740	27. 7.	60
Mengeš, Pristava: potok J od bajerja Pristava ob makadamu	465863	112873	27. 7.	22
Mengeš, Pristava: potok SZ od bajerja Pristava	465748	113173	27. 7.	15
Mengeš, Šinkov Turn: ribnik SV od Šinkovega Turna	464606	113647	27. 7.	53
Mengeš, Topole: reka Pšata pri obrtni coni	466608	114490	27. 7.	54
Naklo, Gobovce: potok Lesnica S ob cesti Posavec-Naklo, S od vasi Gobovce	443483	129044	22. 7.	16
Naklo, Podbrezje: luža S od betonarne Podbrezje	443608	129701	22. 7.	29
Naklo, Podbrezje: zajetje J od betonarne Podbrezje	443619	129460	22. 7.	17
Podbrezje, Podbrezje: območje ob izlivu reke Tržiška Bistrica v reko Savo	443887	126468	22. 7.	18
Podnart, Ovsiše: potok Lipnica	443169	127422	22. 7.	19
Preddvor, Preddvor: jezero Črnava	456161	128975	26. 7.	50
Spodnji Brnik, Lahovče: Ribnik Lahovče	462549	120269	23., 27. 7.	33
Spodnji Brnik, Vopovlje: reka Reka	461527	120250	27. 7.	52
Tržič, Dolina pod Košuto: ribogojnica v Jelendolu ob Tržiški Bistrici	449693	139469	22. 7.	36
Velesovo, Češnjevек: J (največji) ribnik	459753	124687	21., 27. 7.	35
Velesovo, Češnjevек: S ribnik – Virškov bajer	459689	124870	27. 7.	58
Velesovo, Češnjevек: vmesni V ribnik	459700	124808	20., 21. 7.	34
Velesovo, Češnjevек: vmesni Z ribnik	459615	124837	27. 7.	56
Velesovo, Strmol: ribnik južno pod Gradom Strmol	460278	124572	27. 7.	57
Velesovo, Strmol: potok S od ribnika pod Gradom Strmol	460130	124703	27. 7.	62
Zgornje Jezersko, Spodnje Jezersko: reka Kokrica ob kamnolomu lehnjaka	459683	139427	25. 7.	40
Zgornje Jezersko, Zgornje Jezersko: Planšarsko jezero	463175	139984	25. 7.	38
Zgornje Jezersko, Zgornje Jezersko: potok Jezernica V ob Planšarskem jezeru	463469	139896	25. 7.	39
Železniki, Torka: mlaka 100 m V od planinske kočice na Ratitovcu	430352	121819	25. 7.	65
Železniki, Torka: večja mlaka 150 m ZSZ od planinske kočice na Ratitovcu	430083	121860	25. 7.	41

Rezultati

Na skupno 65 lokalitetah (Pregl. 1) smo zbrali 284 podatkov o pojavljanju kačjih pastirjev Gorenjske in zabeležili pojavljanje 38 vrst kačjih pastirjev (Pregl. 2); 11 je uvrščenih na rdeči seznam, 4 so zavarovane in 2 uvrščeni na Prilogi II in IV Direktive o habitatih (Pregl. 2). Dve zabeleženi vrsti sta novi za območje raziskave, ena za celotno območje Gorenjske.

Preglednica 2: Seznam vrst kačjih pastirjev, zabeleženih na RTŠB 2017 – Predoslje, s pripisom zaporednih števil lokalitet (iz Pregl. 1), na katerih je bila vrsta zabeležena, in naravovarstvenim statusom vrst. Če ni zavedeno drugače, gre za najdbe odraslih osebkov. Z zvezdico sta označeni na preučevanem območju prvič popisani vrsti.

Uporabljene okrajšave: ex – lev, larv – ličinka, ten – svež osebek.

RS: Pravilnik o uvrstitvi ogroženih rastlinskih in živalskih vrst v Rdeči seznam. Uradni list RS 82/2002: E – prizadeta vrsta, V – ranljiva vrsta, R – redka vrsta.

UZ: Uredba o zavarovanih prosto živečih živalskih vrstah. Uradni list RS 46/2004 s popr. 1: zavarovane živali in njihove populacije, 2: zavarovane živali, katerih habitat se varuje.

DH: Direktiva sveta 92/43/EGS o ohranjanju naravnih habitatov ter prosto živečih živalskih in rastlinskih vrst (Direktiva o habitatih): II – priloga II, živalske in rastlinske vrste v interesu skupnosti, za ohranjanje katerih je treba določiti posebna ohranitvena območja; IV – priloga IV, živalske in rastlinske vrste v interesu skupnosti, ki jih je treba strogo varovati.

VRSTA	ZAPOREDNA ŠTEVILKA LOKALITETE IZ PREGLEDNICE 1	NV. STATUS
LESTIDAE		
<i>Lestes barbarus</i> (Fabricius 1798)	55, 59	RS: V
<i>Lestes sponsa</i> (Hansemann, 1823)	59	
<i>Chalcolestes viridis</i> (Vander Linden, 1825)	7 (+ ten), 42 (+ ex), 43 (+ ten), 44 (ex), 46 (ex), 48 (+ ex)	
CALOPTERYGIDAE		
<i>Calopteryx virgo</i> (Linnaeus 1758)	1, 2, 3, 7, 9, 10, 12, 13, 15, 16 (+ larv), 17 (larv), 18 – 20, 22, 25 (larv), 26–29, 31, 40, 43, 44 (ex), 48 (ex), 50–52, 55, 62, 63	
<i>Calopteryx splendens</i> (Harris 1782)	7, 9, 12, 15, 44 (+ ex), 45, 46 (+ ex), 47, 48 (+ex), 49, 53–55	
PLATYCNEMIDIDAE		
<i>Platycnemis pennipes</i> (Pallas 1771)	1, 2, 5, 6 (+ ten), 7, 8, 10, 11 (+ ten), 12, 13, 24, 32, 33 (+ ex, + ten), 34, 35, 43, 44 (ex), 48 (+ ex), 49 (+ ten), 51, 53, 55 (+ ten), 56–58, 61, 62	
COENAGRIONIDAE		
<i>Ischnura elegans</i> (Vander Linden 1820)	1, 2, 5–8, 13, 33, 35, 44, 48 (+ ex), 49, 53 (+ ten), 55 (+ ten), 56–59, 61, 62	
<i>Ischnura pumilio</i> (Charpentier 1825)	60 (+ ten)	
<i>Enallagma cyathigerum</i> (Charpentier 1840)	1, 2, 5, 6, 7 (+ ten), 8, 10, 13, 38, 42, 43 (+ ex), 44, 48 (+ ex), 50, 53, 55, 59	
<i>Coenagrion puella</i> (Linnaeus 1758)	1, 2, 5, 6, 7 (+ larv), 8, 38, 39, 43, 44, 48–50, 53, 56	
<i>Erythromma najas</i> (Hansemann, 1823)	44, 48	
<i>Erythromma viridulum</i> (Charpentier 1840)	1, 48	
AESHNIDAE		
<i>Aeshna affinis</i> Vander Linden 1820	5, 59	RS: V
<i>Aeshna isoceles</i> (Müller, 1767)	1	RS: V

VRSTA	ZAPOREDNA ŠTEVILKA LOKALITETE IZ PREGLEDNICE 1	NV. STATUS
<i>Aeshna cyanea</i> (Müller 1764)	6, 11, 14, 24 (larv), 30 (ex), 34 (larv, ex), 35, 36, 41 (+ larv, + ex, + ten), 42 (ex), 44 (ex), 48 (+ ex), 56, 58	
<i>Aeshna grandis</i> (Linnaeus, 1758)	1, 2, 5, 7, 9, 11, 23 (ex), 33, 35, 55, 56	RS: V
<i>Anax imperator</i> Leach 1815	1, 2, 5–9, 13, 44 (ex), 48 (+ ex), 53, 55, 56, 59, 64, 65	
<i>Anax parthenope</i> (Sélys 1839)	1, 2, 5, 48, 59	
<i>Anax ephippiger</i> (Burmeister, 1839) *	55	
GOMPHIDAE		
<i>Ophiogomphus cecilia</i> (Fourcroy, 1785) *	12	RS: V; UZ: 1, 2; DH: II, IV
CORDULEGASTRIDAE		
<i>Cordulegaster bidentata</i> Sélys 1843	3, 28 (larv)	RS: V
<i>Cordulegaster heros</i> Theischinger 1979	15, 16 (larv), 20 (+ larv), 26 (larv), 34, 37 (ex), 42 (ex)	RS: V; UZ: 1, 2; DH: II, IV
CORDULIIDAE		
<i>Cordulia aenea</i> (Linnaeus, 1758)	1, 2, 42 (+ ex)	
<i>Somatochlora metallica</i> (Vander Linden, 1825)	38	RS: E; UZ: 1, 2
<i>Somatochlora flavomaculata</i> (Vander Linden 1825)	11, 55	RS: V
<i>Somatochlora meridionalis</i> Nielsen 1935	5–7, 10, 17 (larv), 35, 42 (ex), 43, 44 (ex), 53 (+ ex), 55–58	
<i>Somatochlora</i> sp.	38	
LIBELLULIDAE		
<i>Libellula quadrimaculata</i> Linnaeus, 1758	2, 11, 55	
<i>Libellula depressa</i> Linnaeus 1758	17, 18, 21, 44, 59	
<i>Libellula fulva</i> (Müller 1764)	11, 44 (ex)	RS: V
<i>Orthetrum albistylum</i> (Sélys 1848)	2, 33 (+ ex), 53, 55, 59, 61	
<i>Orthetrum brunneum</i> (Fonscolombe 1837)	1, 17, 18, 49, 59, 60	
<i>Orthetrum cancellatum</i> (Linnaeus 1758)	1, 2, 6, 8, 9, 33, 48, 50, 53, 55	
<i>Orthetrum coerulescens</i> (Fabricius 1798)	4, 7, 11, 49 (+ ex, + ten), 55, 60	
<i>Sympetrum fonscolombii</i> (Sélys 1840)	55, 59	
<i>Sympetrum meridionale</i> (Sélys 1841)	59	RS: R; UZ: 1
<i>Sympetrum sanguineum</i> (Müller 1764)	11, 13 (larv), 34, 48, 53, 55 (+ ten), 56, 59 (+ ten)	
<i>Sympetrum striolatum</i> (Charpentier 1840)	2, 11 (+ ten), 56	
<i>Sympetrum vulgatum</i> (Linnaeus 1758)	2, 5	

Pri terenskem delu smo na RTŠB popisali tudi nekaj drugih organizmov; npr. močvirsko sklednico (*Emys orbicularis*; lok. 1), popisano sklednico (*Trachemys scripta*; lok. 2), navadno krastačo (*Bufo bufo*; lok. 6), hribskega urha (*Bombina variegata*; lok. 29), drevesno zelenko (*Tettigonia viridissima*; lok. 8).

Razprava

V devetih dneh smo popisali več kot polovico od 72 v Sloveniji zabeleženih vrst kačjih pastirjev. Po eno vrsto smo popisali na 16 lokacijah (skoraj tretjina vseh loka-

litet), na več kot polovici lokalitet (30) smo popisali tri vrste ali manj. Vsaj po eno ogroženo vrsto smo popisali na 24 lokalitetah, zavarovane vrste na 10. Kot najpogostejše vrste smo popisali: modrega bleščavca (*Calopteryx virgo*) in sinjega presličarja (*Platycnemis pennipes*) na 31 oziroma 28 lokalitetah (skoraj polovici vseh na taboru raziskanih lokalitet), na 21 modrega kresničarja (*Ischnura elegans*), 17 velikega spremljevalca (*Anax imperator*) in bleščečega zmotca (*Enallagma cyathigerum*), 15 travniškega škratca (*Coenagrion puella*) in zelenomodro devo (*Aeshna cyanea*), ki so vse v Sloveniji pogoste vrste kačjih pastirjev.

Za preučevano območje smo zabeležili dve novi vrsti: kačjega potočnika (*Ophiogomphus cecilia*) smo popisali na zanj netipičnem potoku nad ribnikom 5 na Brdu pri



Slika 1: Potok nad ribnikom 5 v Parku Brdo pri Kranju (lok. 12), kjer smo prvič na vzhodnem Gorenjskem popisali kačjega potočnika (*Ophiogomphus cecilia*), uvrščenega na Prilogi II in IV Direktive o habitatih.

Kranju (lok. 12, Sl. 1); afriškega minljivca (*Anax ephippiger*) pa na bajerju Pristava v Mengšu (lok. 55). Slednja vrsta na Gorenjskem prej še ni bila dokumentirana. Najbližje znane najdbe kačjega potočnika izvirajo iz Lukovice (Bedjanič 2008), okolice Litije (Šalamun & Kotarac 2006) in vzhodno ob Ljubljani (Šalamun & Kotarac 2010, Vinko 2017).

Na Prilogi II in IV Direktive o habitatih sta od zabeleženih vrst uvrščena kačji potočnik in veliki studenčar (*Cordulegaster heros*). Velikega studenčarja smo prvič popisali v Poljanski dolini (lok. 26) in še v potokih Lesnica pri Gobovcih (lok. 16), Plaznica v Češnjici pri Kropi (lok. 20) ter v Goričah (lok. 37).

Največ vrst smo popisali na bajerju Pristava (lok. 55) in sicer 17, po 14 smo jih popisali na Drugem jezeru v Brdu pri Kranju (lok. 48) in Čukovi jami (lok. 2), po 13 na Krokodilnici (lok. 1), v Hrašah (lok. 59) in na Prvem jezeru v Brdu pri Kranju (lok. 44). Deset ali več vrst smo popisali še na treh lokalitetah (lok. 5, 7, 53), ki se, prav tako kot skoraj vse omenjene, nahajajo na območju Mengša, Bobovka ali Brda pri Kranju.

V glinokopu Bobovek smo na taboru prvič popisali velikega rdečeokca (*Erythromma viridulum*), višnjevo devo (*Aeshna affinis*), sinjega in malega modrača (*Orthetrum brunneum*, *O. coerulescens*). Na posameznih jezerih v glinokopu (lok. 1, 2, 5) smo popisali med 10 in 14 vrst, skupaj 20. Skupaj s preteklimi podatki (Geister 1992a, Geister & Sovinc 1992, Vinko 2015, 2017, CKFF 2017) je za glinokop znanih 28 vrst.

Z lokalitet pri Gradu Strmol (lok. 57, 62) je znanih 11 vrst kačjih pastirjev (CKFF 2017, Vinko 2017). Tu smo na taboru popisali 6 vrst, ki so bile vse že poznane.

Večjo vrstno pestrost smo zabeležili še v ribnikih v opuščnem glinokopu pri vasi Češnjevek, kjer smo prvič popisali progastega kamenjaka (*Sympetrum striolatum*), ki je v Sloveniji pogosta vrsta (CKFF 2017). Na posameznih ribnikih (lok. 34, 35, 56, 58) smo popisali med 4 in 9 vrst, skupaj z našimi podatki je za ta kompleks ribnikov z bližnjimi potoki znanih 24 vrst (CKFF 2017, Vinko 2017).

Med v Sloveniji redkimi vrstami smo na RTŠB popisali še samca kovinskega lesketnika (*Somatochlora metallica*) in sicer v rahlo deževnem vremenu na Planšarskem jezeru na Zgornjem Jezerskem (lok. 38). Gre za prvi podatek vrste severno/vzhodno od gorenjske avtoceste. Edini bližnji podatki so iz Podbrezj (Geister 1992b), Volčjega potoka in Vira pri Domžalah (Kiauta 1963).

Bajer Pristava

Na bajerju Pristava smo poleg afriškega minljivca prvič popisali še grmiščno zverco (*Lestes barbarus*). Na bajerju je potekalo v preteklosti že več odonatoloških raziskav (Kotarac 1999, Vinko 2006, 2010, 2017, Pirnat 2009). 28. 5. 2005 je tam potekal prvi odonatološki teren prvega avtorja, v letu 2009 (8. 4., 31. 5., 19. 6., 20. 7., 27. 8., 8. 10.) je tam tudi popisoval (neobj., Pregl. 3). Z bajerja je skupaj s predstavljenimi rezultati znanih 43 vrst kačjih pastirjev, a je bilo 9 vrst popisanih zgolj na enem od terenskih popisov (Pregl. 3). Po številu zabeleženih vrst kačjih pastirjev se tako ta lokaliteta uvršča med vrstno najbogatejše v državi (CKFF 2017).

Preglednica 3: Seznam 43 vrst kačjih pastirjev z bajeja Pristava pri Mengšu (lok. 55), zabeleženih v različnih raziskavah.

VRSTA/POPIS	Kotarac (1999)	Šalamun & Vinko, 28.5.2005 (neobj.)	Vinko (2006)	Pirnat (2009)	Vinko, 2009 (neobj.)	Vinko (2017)	RTŠB 2017
<i>Lestes sponsa</i>				×			
<i>Lestes barbarus</i>							×
<i>Chalcolestes viridis</i>	×		×	×			
<i>Sympetma fusca</i>		×	×		×		
<i>Calopteryx virgo</i>	×	×	×	×	×	×	×
<i>Calopteryx splendens</i>			×	×			×
<i>Platycnemis pennipes</i>	×	×	×	×	×	×	×
<i>Pyrrhosoma nymphula</i>			×	×	×		
<i>Ischnura elegans</i>	×	×	×	×	×	×	×
<i>Ischnura pumilio</i>		×	×				×
<i>Enallagma cyathigerum</i>	×	×	×	×	×		×
<i>Coenagrion puella</i>	×	×	×	×	×		
<i>Erythromma najas</i>	×						
<i>Erythromma viridulum</i>	×						
<i>Erythromma lindenii</i>					×		
<i>Aeshna mixta</i>	×			×	×		
<i>Aeshna isocetes</i>	×						
<i>Aeshna cyanea</i>	×			×	×	×	
<i>Aeshna grandis</i>	×		×	×	×	×	×
<i>Anax imperator</i>	×	×	×	×	×	×	×
<i>Anax parthenope</i>	×		×	×	×		
<i>Anax ephippiger</i>							×
<i>Gomphus vulgatissimus</i>				×	×		
<i>Onychogomphus forcipatus</i>	×			×	×		
<i>Cordulegaster heros</i>				×			×
<i>Cordulia aenea</i>	×		×	×	×		
<i>Somatochlora flavomaculata</i>						×	×
<i>Somatochlora meridionalis</i>				×	×	×	×
<i>Epitheca bimaculata</i>				×			
<i>Libellula quadrimaculata</i>	×	×	×	×	×		×
<i>Libellula depressa</i>	×	×	×	×	×		
<i>Libellula fulva</i>		×	×		×		
<i>Orthetrum albistylum</i>	×	×	×	×	×	×	×
<i>Orthetrum brunneum</i>	×		×		×		×
<i>Orthetrum cancellatum</i>	×	×	×	×	×	×	×
<i>Orthetrum coerulescens</i>	×			×	×	×	×
<i>Sympetrum fonscolombii</i>	×	×	×	×	×	×	×
<i>Sympetrum sanguineum</i>				×	×	×	×
<i>Sympetrum striolatum</i>	×			×	×	×	
<i>Sympetrum vulgatum</i>	×		×	×			
<i>Sympetrum meridionale</i>					×		
<i>Sympetrum depressiusculum</i>	×						
<i>Crocothemis erythraea</i>	×	×	×	×	×		
Skupaj	27	15	23	30	29	14	20

Park Brdo pri Kranju

V Parku Brdo pri Kranju smo prvič popisali malega rdečeokca (*Erythromma najas*), črnega ploščca (*Libellula fulva*) in kačjega potočnika ter na seznam vrst parka dodali zeleno pazverco (*Chalcolestes viridis*), ki je bila poprej navedena le kot kompleks obeh v Sloveniji prisotnih vrst tega rodu (Geister 2000). V parku so bili kačji pastirji prvič popisani v raziskovalnem projektu v letih 1991–1994, 1996 in 2000 (Geister 2000), kjer je bilo v skupaj 17 terenskih dneh zabeleženih 31 vrst kačjih pastirjev, pri čemer so bili opazovani samo odrasli osebki. Potrjen razvoj je bil naveden za štiri vrste, a je v tem delu in v Jagodic (2001) zapisano, da se večina vrst na območju tudi razvija. V kasnejših popisih navaja Geister za park 32 (2004) oziroma 33 (2004, 2009a) vrst. Leta 2009 je Geister (2009a) tam popisal 23 vrst. M. Bedjanič je v enem terenskem popisu (5. 7. 1996) v parku zabeležil 11 vrst kačjih pastirjev (CKFF 2017, Pregl. 4). O favni parka je bilo izdanih več monografij (npr. Geister 2005), v Geister (2009b) je predstavljenih 24 vrst kačjih pastirjev. Na območju parka je bilo tako do sedaj popisanih 39 vrst kačjih pastirjev (Pregl. 4).

Na taboru smo v Parku, v za javnost zaprtem in odprtem delu parka, v dveh pol-dnevih popisali 27 vrst kačjih pastirjev. Ličink predvsem zaradi omejenega časa, ki nam je bil za terensko delo v parku na voljo, nismo vzorčili; smo pa bili pozorni na leve. Razvoj smo z najdbo levov ali sveže preobraženih osebkov potrdili pri 19 vrstah (Pregl. 4), odlaganje jajc pa še pri modroritem spremljevalcu (*Anax parthenope*). Največ vrst (15) smo popisali ob drugem ribniku (lok. 48), 13 na prvem (lok. 44), 12 okoli petega ribnika (lok. 11, 12) in 11 na enajstem ribniku (lok. 7). Geister (2004) največ vrst (16) navaja za območje šestega ribnika (lok. 43), ki je bilo v času raziskave tudi izpraznjeno (s tem pa so bile med drugim občutno zmanjšanje populacije plenilcev ličink – rib), kjer smo mi popisali le 6 vrst. A obenem Geister (2009a) navaja seznam vrst popisa, ko je bilo na posameznem ribniku v enem terenskem obisku (14. 7. 2009) popisanih od 1 do 6 vrst.

Z izjemo prvega in drugega ribnika so preostali ribniki večinoma brez plavajoče vegetacije, bregovi so bili v času RTŠB večinoma pokošeni, posumili pa smo na prevelike ribje populacije, ki bi lahko bile vzrok tako za odsotnost plavajoče vegetacije kot tudi prisotnost manjšega števila vrst od sprva pričakovanega. Zaradi majhnega obsega terenskega dela resnih zaključkov o območju sicer ne moremo podati, naši rezultati pa sicer nakazujejo na za varstvo kačjih pastirjev slabše upravljanje ribnikov.

Preglednica 4: Seznam 39 vrst kačjih pastirjev Parka Brdo pri Kranju, zabeleženih v različnih raziskavah z objavljenim seznamom vrst ali v preglednem delu Geister (2009b). Z zvezdico so označene vrste za katere smo na RTŠB 2017 potrdili razvoj v parku.

VRSTA/POPIS	Geister (2000)	Bedjanič M. (CKFF, 2017)	Geister (2009a)	Geister (2009b)	RTŠB 2017
<i>Lestes sponsa</i>	×				
<i>Chalcolestes viridis</i>					×
<i>Chalcolestes</i> sp. *	×				×
<i>Calopteryx virgo</i> *	×	×	×	×	×
<i>Calopteryx splendens</i> *	×		×	×	×

VRSTA/POPIS	Geister (2000)	Bedjanič M. (CKFF, 2017)	Geister (2009a)	Geister (2009b)	RTŠB 2017
<i>Platycnemis pennipes</i> *	×	×	×	×	×
<i>Pyrrhosoma nymphula</i>	×	×	×	×	
<i>Ischnura elegans</i> *	×	×	×	×	×
<i>Ischnura pumilio</i>	×				
<i>Enallagma cyathigerum</i> *	×		×	×	×
<i>Coenagrion puella</i> *	×	×	×		×
<i>Erythromma najas</i>					×
<i>Erythromma viridulum</i>			×		×
<i>Erythromma najas/viridulum</i> *					×
<i>Erythromma lindenii</i>	×			×	
<i>Aeshna mixta</i>	×		×	×	
<i>Aeshna isocetes</i>				×	
<i>Aeshna cyanea</i> *	×	×	×	×	×
<i>Aeshna grandis</i> *	×		×	×	×
<i>Anax imperator</i> *	×		×	×	×
<i>Anax parthenope</i>	×	×	×	×	×
<i>Gomphus vulgatissimus</i>	×		×	×	
<i>Ophiogomphus cecilia</i>					×
<i>Onychogomphus forcipatus</i>			×	×	
<i>Cordulegaster heros</i> *	×		×	×	×
<i>Cordulia aenea</i> *	×		×	×	×
<i>Somatochlora flavomaculata</i> *	×	×	×	×	×
<i>Somatochlora meridionalis</i> *	×	×			×
<i>Libellula quadrimaculata</i> *	×			×	×
<i>Libellula depressa</i>	×		×	×	×
<i>Libellula fulva</i> *					×
<i>Orthetrum albistylum</i>	×				
<i>Orthetrum brunneum</i>	×		×	×	×
<i>Orthetrum cancellatum</i>	×			×	×
<i>Orthetrum coerulescens</i> *			×		×
<i>Sympetrum fonscolombii</i>	×				
<i>Sympetrum sanguineum</i>		×			×
<i>Sympetrum striolatum</i> *	×		×	×	×
<i>Sympetrum vulgatum</i>	×		×		
<i>Sympetrum danae</i>	×				
<i>Crocothemis erythraea</i>	×			×	×
Skupaj	31	11	23	24	27

Opomba: pri rodovih *Chalcolestes* in *Erythromma* je zapisana določitev leva do kompleksa, saj zanesljiva določitev do vrste ni možna.

Hraški mlaki

Na dveh mlakah v Hrašah (lok. 59) smo prvič popisali grmiščno zverco, sinjega modrača, malinovordečega in sredozemskega kamenjaka (*Sympetrum fonscolombii*, *S. meridionale*). Na taboru smo na območju popisali 13 vrst. Grmiščna zverca, višnjeva deva, modroriti spremljevalec in sredozemski kamenjak so v tem delu Slovenije redke vrste kačjih pastirjev (CKFF 2017). Sredozemski kamenjak je bil z območja znan le iz bajerja Pristava (Bedjanič in sod. 2010), višnjeva deva pa iz Češenika pri Domžalah in

iz Nomnja pri Bohinjski Bistrici (CKFF 2017). V Hrašah sta Erbida (2009a) in Turk (2018) opravili časovno kratki študentski deli, ki nista bili strokovno pregledani, je pa bila večina določitev preverjenih s strani prvega avtorja tega prispevka. M. Sameja je 2. 7. 1996 na območju zabeležil travniškega škratca (CKFF 2017), D. Vinko pa 19. 8. 2009 sinjega presličarja, obe vrsti bleščavcev in kresničarjev (*Calopteryx* spp., *Ischnura* spp.), bleščечеge zmotca, bledo in rjavo devo (*Aeshna mixta*, *A. grandis*), velikega in modroritega spremljevalca, lesketnika (*Somatochlora* sp.), temnega modrača (*Orthetrum albistylum*), modrega ploščca (*Libellula depressa*) in krvavordečega kamenjaka (*Sympetrum sanguineum*) (neobj., v delu Vinko povzeto po Erbida 2009b), 20. 8. 2018 pa od popisanih 16 vrst kačjih pastirjev tudi nove za lokaliteto (neobj., Pregl. 5), Trebar (2005) fotodokumentira modrega ploščca. Na hraških mlakah je bilo tako brez resne favnistične raziskave skupaj popisanih 30 vrst kačjih pastirjev (Pregl. 5).

Preglednica 5: Seznam 30 vrst kačjih pastirjev, zabeleženih na dveh Hraških mlakah (lok. 59) v različnih popisih.

VRSTA/POPIS	Erbida (2009a)	Vinko, 19.8.2009 (neobj.)	Vinko (2017)	Turk (2018)	Vinko, 20.8.2018 (neobj.)	RTŠB 2017
<i>Lestes sponsa</i>			×			×
<i>Lestes barbarus</i>					×	×
<i>Chalcolestes viridis</i>					×	
<i>Sympecma fusca</i>					×	
<i>Calopteryx virgo</i>		×		×	×	
<i>Calopteryx splendens</i>		×			×	
<i>Platycnemis pennipes</i>	×	×	×	×	×	
<i>Ischnura elegans</i>	×	×	×	×	×	×
<i>Ischnura pumilio</i>	×	×		×		
<i>Enallagma cyathigerum</i>	×	×	×	×	×	×
<i>Coenagrion puella</i>	×			×		
<i>Erythromma viridulum</i>					×	
<i>Erythromma lindenii</i>			×			
<i>Aeshna mixta</i>		×			×	
<i>Aeshna affinis</i>			×	×		×
<i>Aeshna cyanea</i>					×	
<i>Aeshna grandis</i>		×				
<i>Anax imperator</i>	×	×	×	×	×	×
<i>Cordulia aenea</i>				×		
<i>Somatochlora meridionalis</i>					×	
<i>Somatochlora</i> sp.		×				
<i>Libellula depressa</i>	×	×	×	×		×
<i>Orthetrum albistylum</i>	×	×	×	×	×	×
<i>Orthetrum brunneum</i>			×			×
<i>Orthetrum cancellatum</i>	×		×	×	×	
<i>Sympetrum fonscolombii</i>						×
<i>Sympetrum sanguineum</i>	×	×	×	×		×
<i>Sympetrum striolatum</i>					×	
<i>Sympetrum vulgatum</i>			×			
<i>Sympetrum meridionale</i>						×
Skupaj	11	14	14	13	16	13

Izračun pričakovanega števila vrst

Pri izračunu pričakovanega števila vrst (Chao 2) za območje raziskave s podatki samo iz tokratnega popisa je rezultat 40 vrst, dve več od zabeleženih vrst. S tem smo potrdili, da je bil popis zadovoljiv. Vključeval je zadostno število obiskov in mest vzorčenj ter podal realen prikaz prisotnosti vrst kačjih pastirjev območja. Sedem vrst (*Lestes sponsa*, *Ischnura pumilio*, *Aeshna isocles*, *Anax ephippiger*, *Ophiogomphus cecilia*, *Somatochlora metallica*, *Sympetrum meridionale*) smo na območju zabeležili le na eni lokaliteti, kar je vplivalo na izračun pričakovanega števila vrst. Zaradi premalo intenzivnega vzorčenja ličink smo sicer zagotovo vrste tudi spregledali, npr. preostale porečnike (Gomphidae).

Pri izračunu pričakovanega števila vrst, kjer smo uporabili na RTŠB zbrane podatke in pretekle favnistične podatke za območje raziskave (Kiauta 1963, 1965, Kotarac 1999, Geister 2000, 2004, 2009a, Vinko 2006, 2010, 2015, 2017, neobj., Pirnat 2009, Erbida 2009a, CKFF 2017, Turk 2018), je rezultat 59 vrst, kar je pet več od dejansko popisanih vrst na celotnem območju vzhodne Gorenjske. Razlog za večjo razliko med dejansko zabeleženim in pričakovanim številom vrst je šest vrst, popisanih le enkrat (*L. virens*, *L. dryas*, *A. ephippiger*, *O. cecilia*, *S. depressiusculum*, *S. flaveolum*) in dve le dvakrat (*S. depressiusculum*, *S. meridionale*). Kar osem vrst v daljšem obdobju na vzhodnem Gorenjskem ni bilo več opaženih – več kot 50 let loška in obrežna zverca (*Lestes virens*, *L. dryas*), rumeni kamenjak (*Sympetrum flaveolum*) (Kiauta 1965), barjanska deva (*Aeshna juncea*) (Kiauta 1963, 1965), – nazadnje v 90. letih prejšnjega stoletja: črni kamenjak (*S. danae*) (Geister 1992c), nosna jezerka (*Epitheca bimaculata*) (CKFF 2017), stasiti kamenjak (*S. depressiusculum*) in dristavični spreletavec (*Leucorrhinia pectoralis*) (Kotarac 1999).

Zaključek

Z zabeleženimi 54 vrstami kačjih pastirjev je območje vzhodne Gorenjske med vrstno bogatejšimi območji Slovenije, vendar pa kar 8 vrst v daljšem obdobju ni bilo več zabeleženih. Na območju najdemo z vidika favne kačjih pastirjev vrstno najbogatejše lokalitete v Sloveniji. Za celotno območje Gorenjske je skupaj z našimi rezultati znanih 63 vrst kačjih pastirjev. Veliko vrstno pestrost dosega jo še npr. porečje reke Mure s 57 vrstami (Šalamun in sod. 2015), Vipavska dolina s 53 (Vinko 2016) in Bela krajina s 50 (Šalamun in sod. 2012), ki pa so vsa od Gorenjske mnogo manjša območja. Želiva si, da bo prispevek prispeval k nadaljnjemu delu pri ugotavljanju stanja kačjih pastirjev Slovenije in posledično v Sloveniji manjkajočega varstva.

Zahvale

Hvala udeležencem skupine za kačje pastirje na RTŠB 2017 (Katja Mazinjanin, Rudi Kraševac, Ana Janovič, Danijel Kablar), ki so sodelovali pri zbiranju predstavljenih podatkov, in Iztoku Geistru (Zavod za favnistiko Koper), Aliju Šalamunu, Marijanu Govediču (Center za kartografijo favne in flore) in Matjažu Bedjaniču (Slovensko odonatološko društvo) za pomoč pri literaturi in zbirki podatkov. Aliju Šala-

munu najlepša hvala tudi za izboljšanje besedila in strokovni pregled. Delo odonatološke skupine na RTŠB 2017 je sofinancirala Območna enota Kranj Zavoda RS za varstvo narave.

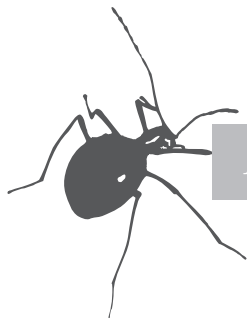
Literatura

- Bedjanič M.**, 2008: Favna kačjih pastirjev občine Dol pri Ljubljani (Insecta: Odonata). *V: Iz dežele Jurija Vege* (zbornik občine Dol pri Ljubljani), 1(1): 261–278.
- Bedjanič M., Klenovšek D., Polak S., Šalamun A., Vinko D.**, 2010: Novi podatki in pregled pojavljanja sredozemskega kamenjaka *Sympetrum meridionale* v Sloveniji. *Erjavecija*, 25: 5–14.
- CKFF**, 2017: *Podatkovna zbirka Centra za kartografijo favne in flore v sodelovanju s Slovenskim odonatološkim društvom*, Miklavž na Dravskem polju. [14. julij 2017]
- Chao A.**, 1987: Estimating the population size for capture-recapture data with unequal catchability. *Biometrics*, 43(4): 783–791.
- Erbida N.**, 2009a: *Terensko delo iz botanike in zoologije: Poročilo o samostojnem terenskem delu*. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za biologijo, 3 str.
- Erbida N.**, 2009b: Individualni terenski dan - Hraše. *Erjavecija*, 24: 16–18.
- Jagodic F.**, 2001: *Popis živalstva na Brdu v letu 2000*. Servis za protokolarne storitve, Brdo 5(9): 13–14.
- Geister I.**, 1992a: Bobovek, zavarovan in znova ogrožen. *Gea*, 2(2): 8–12.
- Geister I.**, 1992b: Drugotni vodni biotopi kot prebivališča kačjih pastirjev. *Proteus*, 54(9): 323–329.
- Geister I.**, 1992c: Photographic records of some new or little known Anisoptera in the fauna of Slovenia (Gomphidae, Libellulidae). *Notulae odonatologicae*, 3(9): 151–152.
- Geister I.**, 2000: *Kačji pastirji (Odonata) z Brda pri Kranju. Popis favne na Brdu pri Kranju*. Zavod za favnistiko Koper, Sveti Anton, 18 str. [Naročnik: Servis za protokolarne storitve Brdo.]
- Geister I.**, 2004: Popis rastlin in živali na Brdu pri Kranju. *Kronika*, 2: 273–284.
- Geister I.**, 2005: *Brdo pri Kranju, nadzorovano območje naravnih vrednot*. MOP, Agencija Republike Slovenije za okolje & JGZ Brdo protokolarne storitve RS. 43 str.
- Geister I.**, 2009a: *Kačji pastirji (Odonata) z Brda pri Kranju. Popis favne in flore na Brdu pri Kranju, 2009/IX del*. Zavod za favnistiko Koper, Kranj/Sveti Anton, 5 str., Pril. [Naročnik: JGZ Brdo, Protokolarne storitve RS.]
- Geister I.**, 2009b: *Naravoslovni sprehodi na Brdu pri Kranju*. Zavod za favnistiko Koper, Sveti Anton, 96 str.
- Geister I., Sovinc A.**, 1992: *Sympetrum fonscolombi* (Selys) in Slovenia (Odonata: Libellulidae). *Opuscula zoologica fluminensia*, 86: 1–5.

- Kalkman V. J., Boudot J.-P., Bernard R., De Knijf G., Suhling F., Termatt T.,** 2018: Diversity and conservation of European dragonflies and damselflies (Odonata). *Hydrobiologia* (2018). <https://doi.org/10.1007/s10750-017-3495-6>
- Kiauta B.,** 1963: Odonatna favna v porečju Kamniške Bistrice. *Kamniški zbornik*, 9: 137–153.
- Kiauta B.,** 1965: On the odonate fauna of Warmbad Villach in Southern Carinthia. *Beaufortia*, 13(152): 35–46.
- Kotarac M.,** 1997: *Atlas kačjih pastirjev (Odonata) Slovenije z Rdečim seznamom: projekt slovenskega odonatološkega društva*. Center za kartografijo favne in flore, Miklavž na Dravskem polju, 205 str.
- Kotarac M.,** 1999: *Popis kačjih pastirjev v glinokopih Rova in Mengeš. Poročilo za MOP – Upravo RS za varstvo narave*. Center za kartografijo favne in flore, Miklavž na Dravskem polju, 21 str.
- Kotarac M.,** 2015: Country accounts: Slovenia. *V: Atlas of the European dragonflies and damselflies*. Boudot J.-P., Kalkman V. J. (ur.). The Netherlands, KNNV Publishing: 48.
- Pirnat A.,** 2009: Inventarizacija kačjih pastirjev v glinokopu Pristava pri Mengšu. *V: T. Gregorc T. & I. Nekrep (ured.), Inventarizacija habitatnih tipov, kačjih pastirjev (Odonata), dvoživk (Amphibia), plazilcev (Reptilia) in ptic (Aves) na območju Jezera v Pristavi ter predlog naravovarstveno pomembnih delov na območju raziskav, Lutra - Inštitut za ohranjanje naravne dediščine, Ljubljana*. 9 str.
- Planinc G. (ur.),** 2004: *Raziskovalni tabor študentov biologije, Žirovnica 2003*. Društvo študentov biologije, Ljubljana, 72 str.
- Presetnik P. (ur.),** 2018: *Raziskovalni tabor študentov biologije Dragatuš 2015*. Društvo študentov biologije, Ljubljana: 3–4.
- Šalamun A., Kotarac M.,** 2006: Drobtinice in ocvirki: Zanimive nove najdbe kačjega potočnika *Ophiogomphus cecilia* v reki Savi. *Erjavecija*, 21: 20–21.
- Šalamun A., Kotarac M.,** 2010: *Dopolnitev predloga območij za vključitev v omrežje Natura 2000. Kačji pastirji (Odonata): kačji potočnik (Ophiogomphus cecilia)*. Center za kartografijo favne in flore, Miklavž na Dravskem polju, 36 str.
- Šalamun A., Pirnat A., Vinko D.,** 2012: Dragonfly fauna of Bela krajina, SE Slovenia. *V: ECOO2012, The Second European Congress on Odonatology, Book of abstracts, Belgrade, Serbia, July 2–6, 2012*. Jović M., Anđus L., Bedjanič M., Marinov M. (ur.) Belgrade, Natural History Museum in Belgrade & Entomological Society of Serbia: 44–45.
- Šalamun A., Podgorelec M., Kotarac M.,** 2015: Inventarizacija kačjih pastirjev (Odonata) in njihovih habitatov ob reki Muri. *V: Inventarizacija favne območja reke Mure (končno poročilo)*. Govedič M., Lešnik A., Kotarac M. (ur.). Miklavž na Dravskem polju, Center za kartografijo favne in flore: 150–190.
- Trebar T.,** 2005: Hraške mlake. *Svet ptic*, 11(3/4): 46–47.
- Turk T.,** 2018: *Kačji pastirji na Hraških mlakah*. Individualna naloga pri predmetu Ekologija živali. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za biologijo, 15 str.

- Vinko D.**, 2006. *Popis kačjih pastirjev (Odonata) v Mengšu in okolici*. Individualna naloga pri predmetu Sistematska zoologija nevretenčarjev, Oddelek za biologijo, Univerza v Ljubljani, Ljubljana, 13 str.
- Vinko D.**, 2010: Terenjenje ob Pristavi, domovanju 40 vrst kačjih pastirjev. *Erjavecia*, 25: 30–34.
- Vinko D.**, 2015: SODovanje 2015: Terenski vikend na Gorenjskem z mahovno devo *Aeshna subarctica elisabethae*. *Erjavecia*, 30: 50–57.
- Vinko D.**, 2016: *Favna kačjih pastirjev (Odonata) Vipavske doline*. Diplomsko delo, univerzitetni študij, Oddelek za biologijo, Biotehniška fakulteta, Univerza v Ljubljani, Ljubljana. XI + 86 str. + pril. A–F.
- Vinko D.**, 2017: BOOM 2017: 7th Balkan Odonatological Meeting – 7. Mednarodno srečanje odonatologov Balkana. Slovenija, 4.–11. avgust 2017. *Erjavecia*, 32: 29–40.

Received / Prejeto: 1. 5. 2018



FAVNISTIČNI ZAPISKI / FAUNISTICAL NOTES

***CRIORHINA RANUNCULI* (PANZER) (DIPTERA: SYRPHIDAE), A NEW HOVERFLY SPECIES FOR SLOVENIA**

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Abstract - A new hoverfly species is recorded for Slovenia, *Criorhina ranunculi* (Panzer, 1805). This species was found on the Mrzlica Mt. on the 26th of May 2018. We propose its Slovenian name »čmrljelika trepetavka«.

KEY WORDS: Diptera, Syrphidae, fauna, Slovenia

Izvleček - *CRIORHINA RANUNCULI* (PANZER) (DIPTERA: SYRPHIDAE), ZA SLOVENIJO NOVA VRSTA TREPETAVKE

Nova vrsta muhe trepetavke je zabeležena v Sloveniji: *Criorhina ranunculi* (Panzer, 1805). Vrsta je bila najdena pod samim vrhom hriba Mrzlica, dne 26. 5. 2018. Predlagano slovensko ime za to vrsto je čmrljelika trepetavka.

KLJUČNE BESEDE: Diptera, Syrphidae, fauna, Slovenia

Hoverflies are very diverse in species and larvae have different niches (Rotheray & Gilbert, 2011). Larvae of many species are predating on aphids, feeding on plants or micro-organisms. Several species are known as saproxylic species which are good indicators of the status of the forest (Speight, 1989; Reemer, 2005; Rotheray & Gilbert, 2011). 309 hoverfly species are known for Slovenia so far (De Groot & Govedič, 2008; De Groot et al., 2010; Van Steenis et al., 2013). One of the genera of which the species have saproxylic larvae is the genus *Criorhina* (Reemer et al., 2009). *Criorhina* species are middle sized to large hoverflies and resemble bumblebees or

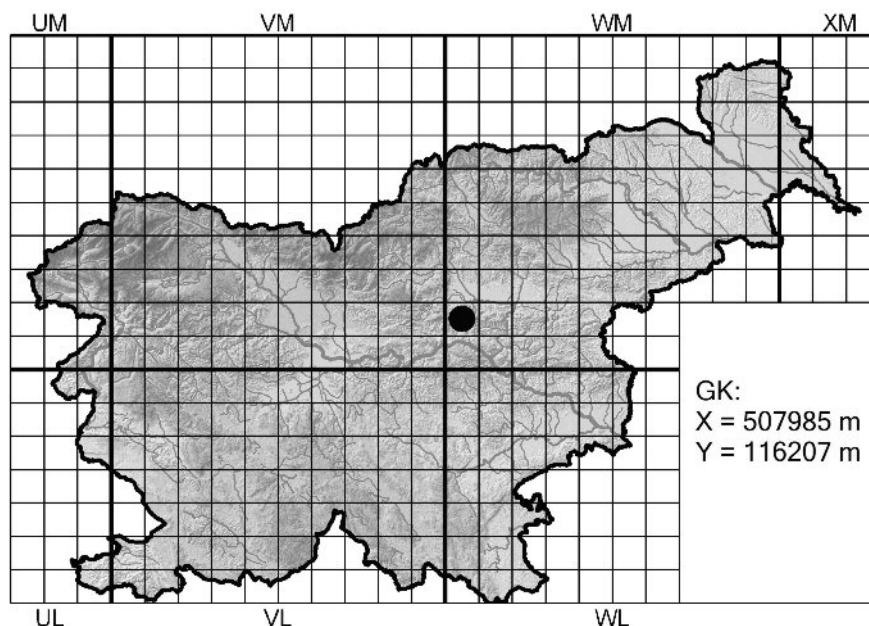


Fig. 1: Distribution of *Criorhina ranunculi* in Slovenia.

bees (Reemer et al., 2009; Speight, 2017). They are often found near old trees where their larvae live in rotting heartwood of various tree species, particularly in *Fagus* (Rotheray, 1993; Reemer et al., 2009). They also occur deep in the root system and in rot holes (Rotheray, 1993). In total there are six species found in Europe: *Criorhina asilica* (Fallen, 1816), *C. berberina* (Fabricius, 1805), *C. brevipila* Loew, 1871, *C. floccosa* (Meigen, 1822), *C. pachymera* (Egger, 1858) and *C. ranunculi* (Panzer, 1804) (Speight, 2017). Except for *C. brevipila*, the other species are observed in the Balkan peninsula (Vujic & Milankov, 1999). Till now four species of the genus *Criorhina* were found in Slovenia: *Criorhina asilica*, *C. berberina*, *C. floccosa* and *C. pachymera* (De Groot & Govedič, 2008). In this paper the fifth species of *Criorhina* in Slovenia, *C. ranunculi*, is presented.

Fieldwork for this study took place in the Mrzlica Mountain, central Slovenia. The species was identified with the key of van Veen (Van Veen, 2004).

***Criorhina ranunculi* (Panzer, 1805)**

Material examined (Figs 2a, b). Slovenia, Mrzlica Mt. (GKX: 507985, GKY: 116207, Fig 1), 26.05.2018, 1020 m a.s.l., 1♀, leg. D. Janević.

Criorhina ranunculi is a bumblebee lookalike (Van Veen, 2004). It is the only species in the genus with black hairs on the mesonotum and tergite 2 (Vujic & Milankov, 1999). The species is known to visit flowers of different tree and shrub species like *Cornus sanguinea* and *Prunus cerasus*, but also feed on herbs like *Car-*

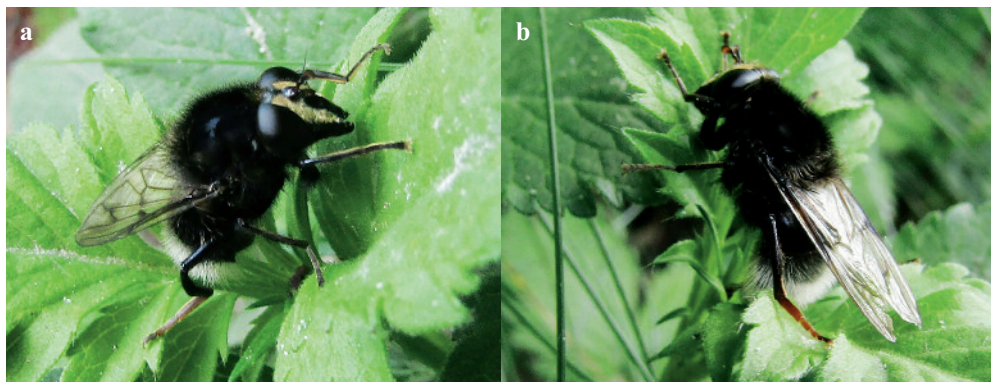


Fig. 2: *Criorhina ranunculi* (Panzer, 1805), ♀. Photo: D. Janević: a) habitus in antero-lateral view, b) habitus in lateral view.

damine pratensis (Speight, 2017). The flight period is from the beginning of March to mid May and on higher altitudes to the end of June. The larvae live in the base of tree trunks, in fungus-infested, wet-rot cavities of several deciduous tree species. The species occurs across Europe from north to south and west to east (Speight, 2017). Therefore, it was to be expected in Slovenia. Although some hoverfly species in Slovenia have Slovenian names, most of the species, including *C. ranunculi*, haven't got one yet. Therefore, we propose that this species is called “čmrljelika trepetavka” (in English: bumblebee-like hoverfly), which indicates that the species is a bumblebee lookalike. *Volucella bombylans* (Linnaeus, 1758) has the Slovenian name “čmrljasta gozdna trepetavka” and therefore the name “čmrljelika trepetavka” is still available.

Acknowledgments

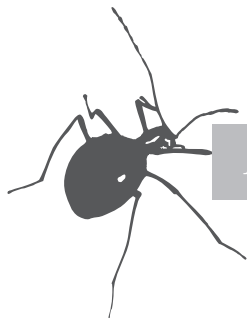
We would like to thank Tim Faasen and an anonymous reviewer for comments on a previous version of the manuscript.

References

- De Groot M., Govedič M.,** 2008: Checklist of the hoverflies (Diptera: Syrphidae) of Slovenia. *Acta Entomologica Slovenica*, 16, 1: 67-87.
- De Groot M., Luštrik R., Faasen T., Fekonja D.,** 2010: Additions and omissions to the list of hoverfly fauna (Diptera: Syrphidae) of Slovenia. *Acta Entomologica Slovenica*, 18, 2: 77-86.
- Reemer M.** 2005: Saproxylic hoverflies benefit by modern forest management (Diptera: Syrphidae). *Journal of Insect Conservation*, 9: 49-59.
- Reemer M., Renema W., van Steenis W., Zeegers T., Barendregt A., Smit J.T., Van Veen M.P., van Steenis J., van der Leij L.J.J.M.,** 2009: De Nederlandse zweefvliegen (Diptera: Syrphidae). Leiden, Natuurhistorisch Museum Naturalis, KNNV uitgeverij, European Invertebrate Survey - Nederland: 442 pp.

- Rotheray G.**, 1993: Guide to Hoverfly Larvae (Diptera, Syrphidae). *Dipterist digest*, 9: 1-155.
- Rotheray G., Gilbert F.**, 2011: The natural history of hoverflies. Ceredigion, Forrest texts: 333 str.
- Speight M.C.D.**, 1989: Saproxylic invertebrates and their conservation. Strasbourg, Council of Europe: 79 pp.
- Speight M.C.D.**, 2017: Species accounts of European Syrphidae (Diptera). Dublin, Syrph the Net publications: 296 pp.
- Van Steenis W., de Groot M., Van Steenis J.**, 2013: New data on the hoverflies (Diptera: Syrphidae) of Slovenia. *Acta Entomologica Slovenica*, 21, 2: 131-162.
- Van Veen M.**, 2004: Hoverflies of Northwest Europe, Identification keys to the Syrphidae. Utrecht, KNNV Publishing 247 pp.
- Vujic A., Milankov V.**, 1999: New data for the tribes Milesiini and Xylotini (Diptera, Syrphidae) on the Balkan Peninsula. *Dipteron*, 2, 6: 113-132.

Received / Prejeto: 5. 6. 2018

**ANDRENA DANUVIA STOECKHERT AND HOPLITIS PEREZI (FERTON)
IN SLOVENIA (HYMENOPTERA: ANDRENIDAE AND MEGACHILIDAE)**

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Abstract – Two bee species are recorded for the first time for Slovenia: *Andrena (Melandrena) danuvia* Stoeckhert and *Hoplitis (Anthocopa) perezi* (Ferton). They were both found on the Karst plateau at the border between Slovenia and Italy. Additionally, the specimens in the E. Jaeger collection, identified as *Andrena cineraria* (Linnaeus), were proved to be *Andrena danuvia*.

KEY WORDS: Hymenoptera, Andrenidae, Megachilidae, fauna, Slovenia, Italy

**Izveček – ANDRENA DANUVIA STOECKHERT IN HOPLITIS PEREZI (FERTON)
V SLOVENIJI (HYMENOPTERA: ANDRENIDAE IN MEGACHILIDAE)**

Dve vrsti čebel sta prvič zabeleženi za Slovenijo: *Andrena (Melandrena) danuvia* Stoeckhert in *Hoplitis (Anthocopa) perezi* (Ferton). Obe sta bili najdeni na Krasu ob meji med Slovenijo in Italijo. Poleg tega primerki iz zbirke E. Jaegra, določeni kot *Andrena cineraria* (Linnaeus), v resnici pripadajo vrsti *Andrena danuvia*.

KLJUČNE BESEDE: Hymenoptera, Andrenidae, Megachilidae, favna, Slovenija, Italija

In 2018 I visited several times the border area between Slovenia and Italy on the western edge of the Karst plateau between the villages Sela na Krasu in Slovenia and Iamiano/Jamlje in Italy with the highest points Kremenjak and Špik. From these places there is a nice view on the valley of Brestovica near Komen, Monfalcone/Tržič on the coast, intermittent lake at Doberdo/Doberdob and the Friulan plain to the west. Here I found two bee species for the first time, *Andrena danuvia* E. Stoeckhert and *Hoplitis perezi* (Ferton). The first is still poorly known species, for a long time confused with related species, and the find is the first in the Karst. The other was al-



Fig. 1: *Andrena danuvia* female from Kremenjak, Kras/Carso.



Fig. 2: *Andrena danuvia* female from Trobevnik near Podčetrtek, collected by E. Jaeger.

ready known from the surroundings of Trieste, while it has not yet been found in Slovenia. I found its nests just above the walls of the karst edge.

Andrena danuvia E. Stoeckhert, 1950

Slovenia, Styria: Podčetrtek, UTM: WM41, 23. 4. 1932, 1♀, 27. 4. 1932, 1♂, 12. 5. 1932, 1♀, 10. 4. 1933, 2♀2♂, 28. 4. 1934, 1♀, E. Jaeger leg.

Podčetrtek, TRO - Olimje, Trobevnik, 20. 5. 1933, 1♀, E. Jaeger leg. (Fig. 2)

Italy/Slovenia: Sela na Krasu, Kremenjak, UL97, 1. 5. 2018, 1♀ on *Cotinus coggygria*, A. Gogala leg. (Fig. 1)

I found one female of the *Andrena (Melandrena) cineraria* group on the flowers of *Cotinus coggygria* on the Italian side of the border between Italy and Slovenia on the south-western slope of Kremenjak, which is not a mountain, only a high point at the edge of the Karst plateau. It turned out it is a specimen of *Andrena danuvia*, described from Vienna where it is very numerous, nesting under the trees along avenues (Fraberger 2005). It has dark apical half of the front wings while *A. cineraria* (Linnaeus, 1758) has only a dark apical border. This character is similar in *A. barbareae* Panzer, 1805, but this species has much shorter third antennal segment. In *A. danuvia* it is almost three times as long as wide, while it is less than two times as long as wide in *A. barbareae* (Pittioni & Stöckhert 1950). *A. danuvia* is also characterized by more evident blue luster of the abdomen and less evident black stripe on the thorax.

Andrena danuvia is already known from Italy (Scheuchl & Willner 2016), but is not listed by Zandigiacoimo et al. (2013) among the *Andrena* species of Friuli Venezia Giulia. So the record from Kremenjak is new for the Karst (Kras/Carso) and this Italian region. After this find I checked the specimens identified as *A. cineraria* in the E. Jaeger collection, kept in the Slovenian Museum of Natural History. All specimens collected by E. Jaeger in Podčetrtek and its surroundings, proved to be *A. danuvia*. The records of *Andrena cineraria* by Gogala (1994) are thus wrong and probably also the record by Vogrin (1955) as it is also based on the specimens collected in Podčetrtek by Jaeger. This finding is in accordance with observations by Scheuchl and Willner (2016) that all checked specimens of the *A. cineraria* group from Greece and Turkey turned out to be *A. danuvia*, which is thus an East Mediterranean species. We could omit *A. cineraria* from the list of Slovenian species. An unresolved question remains the identity of *Apis atra*, described by Scopoli (1763). Scopoli found it in Gorjuše between Bled and Bohinj in 1761. As his collection is not preserved, we cannot check its identity.

Hoplitis perezii (Ferton, 1895)

Sela na Krasu, Špik, 219 m, UL97, 12. 5. 2018, 1♀, A. Gogala leg.

Hoplitis (Anthocopa) perezii is a Mediterranean and Central Asian species nesting in the soil and collecting pollen from *Convolvulus* flowers. It also cuts pieces out of *Convolvulus* petals to make cells in the burrow (Ducke 1900, Müller 2018). Ferton described it from France, but Ducke (1900) described it again as a form of *Osmia pa-*



Fig. 3: *Hoplitis perezi* female in front of her burrow.



Fig. 4: The place on Špik near Sela na Krasu, where *Hoplitis perezi* nests were found.

paveris, *O. p. convolvuli*. He found it in Contovello near Trieste and stated it is not rare there. Contovello is situated at the coast with milder climate than the Slovenian part of the Karst in the interior, probably the reason the species was not recorded before in Slovenia. I found at least three nests just above the walls of the karst edge on Špik near Sela na Krasu. Females were entering the burrows and were also seen visiting *Convolvulus cantabrica* flowers nearby. Some flowers were missing pieces cut out by the bees. The burrows were dug in shallow soil on top of the limestone and one female was seen closing the burrow with anything around it, like small pieces of twigs and leaves. The place with the nests has direct climatic influence from the sea, which is seen below and is oriented towards the sun. *Convolvulus cantabrica* is very numerous there. The border between Slovenia and Italy is just a few meters away and *Hoplitis perezii* specimens were seen also on the Italian side.

Acknowledgement

I dedicate this paper to my father Matija, my first teacher of entomology, at his 80th birthday.

References

- Ducke, A.**, 1900: Die Bienengattung *Osmia* Panz. *Ber. naturw.-med. Ver. Innsbruck*, 25: 1-323.
- Fraberger, R. J.**, 2005: Bionomie der Sandbiene *Andrena danuvia* Stöckert 1950 (Hymenoptera, Andrenidae) und aktuelle Vorkommen in Wien. *Linzer biol. Beitr.*, 37 (2): 1481-1499.
- Gogala, A.**, 1994: Contribution to the Knowledge of the Bee Fauna of Slovenia II. (Hymenoptera: Apidae). *Scopolia*, 31: 1-40.
- Müller, A.**, 2018: Palaearctic Osmiine Bees. ETH Zürich, <http://blogs.ethz.ch/osmiini>
- Pittioni, B., E. Stöckert**, 1950: Über einige neue und verkannte *Andrena*-Arten (Hymenoptera, Andrenidae). Beiträge zu Kenntnis paläarktischer Apiden III. *Ann. Naturhist. Mus. Wien*, 57: 284-295.
- Scopoli, I. A.**, 1763: Entomologia carniolica exhibens insecta Carnioliae indigena et distributa in ordines, genera, species, varietates. Methodo Linnaeana. Trattner, Vindobonae.
- Scheuchl, E., W. Willner**, 2016: Taschenlexikon der Wildbienen Mitteleuropas. Alle Arten im Porträt. Quelle & Meyer Verlag Wiebelsheim, 917 pp.
- Vogrin, V.**, 1955: Prilog fauni Hymenoptera-Aculeata Jugoslavije. *Zaštita bilja* (Beograd), 31: Dodatak.
- Zandigiacomo, P., L. Fortunato, R. Barbattini, F. Frilli, G. Pagliano, M. Quaranta**, 2013: Apoidea del Friuli Venezia Giulia e di territori confinanti. III. Andrenidae. *Gortania. Botanica, Zoologia*, 34: 101-136.

Received / Prejeto: 9. 10. 2018