ACTA BIOLOGICA SLOVENICA

VOL. 54 ŠT. 1 LJUBLJANA 2011

prej/formerly BIOLOŠKI VESTNIK

ISSN 1408-3671
UDK 57(497.4)

izdajatelj/publisher
Društvo biologov Slovenije

ABS ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 1–84

Acta Biologica Slovenica
Glasilo Društva biologov Slovenije – Journal of Biological Society of Slovenia

Izdaja – Published by
Društvo biologov Slovenije – Biological Society of Slovenia

Naslov uredništva – Adress of Editorial Office
Acta Biologica Slovenica, Večna pot 111, SI-1001 Ljubljana, Slovenija
http://bijh.zrc-sazu.si/abs/

Oblikovanje – Design
Žare Vrezec

ISSN 1408-3671 UDK 57(497.4)

Natisnjeno – Printed on: 2011
Tisk – Print: Tiskarna Pleško d.o.o., Ljubljana
Naklada: 400 izvodov

Cena letnika (dve številki): 15 € za posameznike, 42 € za ustanove

Številka poslovnega računa pri Ljubljanski banki: 02083-142508/30

Publikacijo je sofinancirala Agencija za Raziskovalno dejavnost Republike Slovenije.

Acta Biologica Slovenica je indeksirana v – is indexed in: Biological Abstracts, Zoological records.

ABS ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 3–13

Mentorju, akademiku in profesorju, dr. Zvonimirju Devidéju – ob 90. obletnici rojstva in 64. letnici dela v znanosti in izobraževanju

To my tutor, academician and professor Zvonimir Devidéju, on the occasion of his 90th birthday and the 64th year of work in science and education

Božidar Krajnčič, zaslužni professor (professor emeritus)

Univerza v Mariboru, Kamniška ulica 52, 2000 Maribor
University of Maribor, Kamniška ulica 52, 2000 Maribor

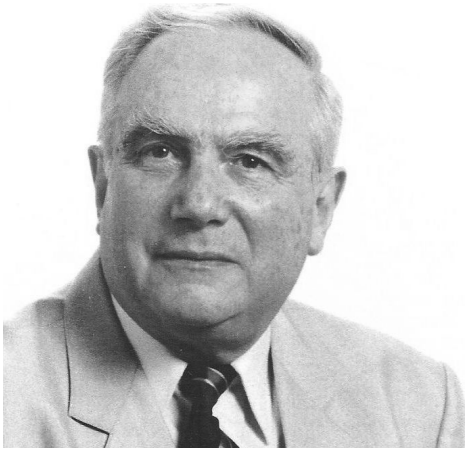
Running title
Krajnčič: Prof. dr. Zvonimir Devidé

Izvleček: Prispevek je namenjen mojemu vodniku in mentorju, profesorju dr. Zvonimirju Devidéju, priznanemu biologu in botaniku, članu Hrvaške akademije znanosti in umetnosti, profesorju na Naravoslovno – matematični fakulteti Univerze v Zagrebu, ob 90. obletnici rojstva in 64. letnici dela v znanosti in izobraževanju.

Ključne besede: citologija, fiziologija, rastline, Slovenija, Hrvaška, raziskave, izobraževanje

Abstract: This paper is dedicated to my first guide and mentor, professor Zvonimir Devidé, distinguished biologist and botanist, member of the Croatian Academy of Sciences and Arts, professor at the Faculty of Natural Sciences and Mathematics of the University of Zagreb, on the occasion of his 90th birthday and the 64th year of work in science and education.

Key words: cytology, physiology, plants, Slovenia, Croatia, research, education



Prof. dr. Zvonimir Devidé

Prof. dr. Zvonimirja Devidéja sem spoznal na podiplomskem študiju Naravoslovno – matematične fakultete Univerze v Zagrebu leta 1968. Na podiplomskem študiju biologije, morfološko-fiziološki smeri botanike, nam je prof. Devidé v šolskem letu 1968/69 vzorno predaval tri predmete: 1. Izbrana poglavja iz citologije – osnovna plazma, 2. Submikroskopska zgradba kloroplastov, 3. Metodika in tehnika znanstvenega dela v biologiji. V drugem letniku (šolsko leto 1969/70) pa je prof. Devidé v okviru seminarja Izdelava magistrskega dela vodil izdelavo mojega podiplomskega dela, za katerega naslov sva se soglasno dogovorila: Fotoperiodične reakcije lemnacej severovzhodne Slovenije. Predloženo raziskovalno delo sem opravil v prostorih I. Gimnazije v Mariboru, kjer sem si v kleti z lastnimi sredstvi uredil skromen

rastlinsko-biološki laboratorij z dvema termostatiranima rastlinjakoma, ki sem ju kasneje preselil v prostor genske banke Botaničnega vrta Univerze v Mariboru, katerega ustanovitev in izgradnjo (8 ha) sem vodil od leta 1994–2008.

V okviru magistrske naloge sem na terenskih raziskavah severovzhodne Slovenije odkril rastišča vseh petih vrst lemnacej, ki rastejo v Sloveniji: *Lemna minor, Lemna gibba, Lemna trisulca, Spirodela polyrrhiza* in *Wolffia arrhiza,* vzgojil njihove aksenične kulture in raziskal fotoperiodične reakcije vrst *Lemna minor, Lemna gibba* in *Spirodela polyrrhiza*. Magistrska naloga je bila opravljena leta 1972. Ker je bila magistrska naloga (106 strani + 2 prilogi) zelo dobro ocenjena, je moj mentor prof. Devidé predlagal, da nadaljujem še z doktorsko disertacijo z naslovom: Mehanizmi indukcije cvetenja lemnacej Slovenije, ki sem jo prav tako opravil (192 strani) pod mentorstvom prof. Devidéja, kateremu se najlepše zahvaljujem za načrtno vodenje in vsestransko pomoč, saj mi je vsa leta mojega raziskovalnega dela pomagal z uspešnimi nasveti, me vzpodbujal k vztrajnemu in natančnemu delu in mi pošiljal literaturo.

Izdelavo doktorske disertacije sem zaključil z zagovorom 3. junija 1976 pred mednarodno komisijo: dr. Zvonimir Devidé, redni profesor Naravoslovno-matematične fakultete v Zagrebu (predsednik), dr. Riklef Kandeler, redni profesor dunajske Universität für Bodenkultur in dr. Miran Vardjan, redni profesor Biotehniške fakultete v Ljubljani. Diploma o doktoratu bioloških znanosti je bila izdana 12. novembra 1976. V okviru doktorata sem raziskoval učinke aminokislin v različnih koncentracijah in različnih fotoperiodah ter učinke mikroelementov cinka, mangana, bakra in molibdena pri cvetni indukciji. Razpravo Vpliv aminokislin na cvetno indukcijo vrst *Lemna minor* in *Spirodela polyrrhiza* sva objavila v Biološkem vestniku: Krajnčič, Božidar in Devidé, Zvonimir: Vpliv aminokislin na cvetno indukcijo vrst *Lemna minor* in *Spirodela polyrrhiza*, Biološki vestnik 30, str. 85–104 (1982).

Ker je bilo iz literature vidno, da so bili vsi do takrat izvršeni eksperimenti za dosego cvetenja pri vrsti *Wolffia arrhiza* neuspešni, mi je moj mentor prof. Devidé priporočil naj v okvirju doktorske disertacije še poizkusim pripraviti tudi to vrsto do cvetenja. Takrat te naloge nikakor nisem bil vesel. Vendar sem imel neverjetno srečo, da sem volfijo v prvem eksperimentu pripravil do cvetenja. Ker volfija ni cvetela v dolgodnevnih in kratkodnevnih pogojih, sem pravilno zaključil: če morda rastline cvetijo v jeseni, potem verjetno potrebujejo najprej dolgodnevno osvetlitev in nato zacvetijo v kratkodnevnih pogojih, kar sem dosegel tako, da sem rastline posadil v dolgodnevne pogoje in jih po 3 tednih prenesel v kratkodnevne pogoje in rastline so zacvetele, kolikor je znano, prvič na svetu v laboratorijskih pogojih. S tem je pri Lemnacejah odkrit nov fotoperiodični tip rastlin dolgo-kratkodnevnice. O tem sem se tudi v naravi prepričal, saj sem v Istri v oktobru našel cvetoče rastline v Vižinadi, Markovičih in Višnjanu.

Prof. dr. Zvonimir Devidé je eden od ustanoviteljev Jugoslovanskega društva za fiziologijo rastlin skupaj s profesorjem dr. Miranom Vardjanom iz Ljubljane, prof. dr. Milojem Sarićem iz Novega Sada in prof. dr. Mirjano Nešković iz Beograda. Omenjeno društvo je z organizacijo znanstvenih simpozijev, kongresov, seminarjev in izdajo knjig pomembno vplivalo na razvoj fiziologije rastlin. Tako npr. je leta 1983 izdalo knjigo ¨Prirodni i sintetički regulatori rastenja biljaka¨ iz predavanj na III. Seminarju Jugoslovenskog društva za fiziologiju biljaka v Beogradu (262 strani). V tej knjigi so natisnjena predavanja priznanih raziskovalcev iz področja regulatorjev rasti iz celotne Jugoslavije. Od slovenskih raziskovalcev so sodelovali s svojimi prispevki:

– Nada Gogala: Rastne substance mikoriznih gliv in njihov vpliv na višje rastline (strani 112–120),
– L. Eleršek, M. Hočevar in D. Jurc: Razmnoževanje smreke in metasekvoje s podtaknjenci (strani 137–140),
– Mihaela Černe in Miran Vardjan: Uporaba avksinov pri vegetativnem razmnoževanju zelja (stran 140),
– Dušan Modic: Primena regulatora rastenja u voćarskoj praksi – proredjivanje, sazrevanje i opadanje plodova (strani 141–170),
– Božidar Krajnčič: Vloga giberelinov in citokininov v cvetni indukciji in razvoju cvetov -evokaciji in diferenciaciji – Uloga giberelina i citokinina u cvetnoj indukciji i razviću cvetova – evokaciji i diferenciaciji (strani 172–207).

Profesor Devidé se je rodil 6. avgusta 1921 v Sv. Lenartu v Slovenskih goricah v Sloveniji. Po končani srednji šoli v Mariboru, je študiral

naravoslovje na Univerzi v Zagrebu. Zaradi vojnih dogodkov je študij nadaljeval na Dunaju, kjer je leta 1944 diplomiral iz biologije, fizike in kemije, kmalu nato pa je bil povabljen v laboratorij profesorja L. Geitlerja, na Biološki postaji Lunz am See, da pridobi izkušnje na področju citologije. Po vrnitvi v rodno deželo in odsluženem vojaškem roku, se je na povabilo profesorja V. Vouka preselil v Zagreb, sprva kot pripravnik (1947), pozneje (tj. leta 1948) pa kot asistent v Botaničnem zavodu Naravoslovno-matematične fakultete. Leta 1953 je prejel štipendijo Britanskega sveta, ki mu je omogočila šestmesečno bivanje v Angliji pod mentorstvom profesorja C. D. Darlington-a v John Innes Horticultural Institution Bayfordbury na Oddelku za citologijo.

Po vrnitvi iz Anglije je v izredno skromnih razmerah nadaljeval raziskave na področju citologije brezbarvnih kemosintetičnih žveplenih bakterij, ki jih je obravnaval tudi v svoji doktorski disertaciji leta 1954.

Leta 1960 se je habilitiral na Naravoslovno-matematični fakulteti na temo: Strukture in optične značilnosti svetlo pegastih zelenih listov (Devidé 1959/1960). Kmalu zatem se je sicer prijavil za mesto docenta na Botaničnem zavodu Naravoslovno-matematične fakultete, vendar ga je fakultetni svet te ustanove predložil in izbral za izrednega profesorja. Leta 1970 je napredoval v rednega profesorja. Predstojnik Botaničnega zavoda in Botaničnega vrta je postal leta 1981 in to funkcijo opravljal vse do upokojitve leta 1986.

Znanstveni opus profesorja Devidéja sega vse od biologije celic in fiziologije rastlin do splošnih bioloških tem, kot so varstvo narave in naravnih virov.

V začetku kariere se je posvetil predvsem raziskovanju kromosomov (Devidé in Geitler 1947). Številke v oklepaju so zaporedne številke iz seznama znanstvenih publikacij. V nadaljevanju pa je iskal načine, da pojasni mikroskopsko zgradbo celic velikih brezbarvnih kemoavtotrofnih žveplovih bakterij (*Leucothiobacteria*) v Jadranu, ki z oksidacijo hidrogen sulfida vežejo energijo in jo sproščajo v obliki, primerni za njihov metabolizem (Devidé 1949). Profesorjev prispevek k taksonomiji teh mikroorganizmov je pomemben (Devidé 1949, Devidé 1952, Devidé 1953 a,b, Devidé 1954, Devidé 1956a), obenem pa je razvil nove metode za njihovo kultiviranje.

Med raziskovanjem kariologije migetalkarjev je uspel dokazati obstoj posameznih kromosomov v procesu meioze in njihovo pretvorbo v kromosomske agregate med oblikovanjem mikronukleusa v ločenih konjugantih ter tako pojasnil do tedaj ne dovolj raziskano mitozo in še neznano strukturo kromosomov v mikronukleusu migetalkarja. S tem je bil storjen pomemben korak v razumevanju struktur mikronukleusov in poliploidnih makronukleusov ter vloge endomitoze in njenega formiranja (Devidé in Geitler 1947, Devidé 1950, Devidé 1951).

Spodbudo za raziskave, ki jih je profesor Devidé opravil z mlajšimi kolegi (Sibilo Jelasko, Draženo Papeš, Branko Kolevsko-Pletikapić in Biserko Jelenčić) na področju rasti in diferenciacije v rastlinskih tkivih in kulturi celice, gre iskati predvsem v njegovem zanimanju za spremljajoče kariološke spremembe, kljub temu, da je bilo pred tem potrebno opraviti mnogo raziskav na področju optimiziranja rastnega medija in izvora vcepkov. S pomočjo Giemsove C-progavostne tehnike je bilo sedaj mogoče identificirati celo posamezne dele prelomljenih kromosomov. Z uporabo te metode v in-vitro-kulturah boba (*Vicia faba*) je bilo mogoče v klicah, ki so se razvile iz osnovnih vcepkov, opaziti tako precejšnji delež triploidnih celic z izrazitimi ekstrakromosomi kot tudi strukturne mutacije. Zanimivo je dejstvo, da je v subkultiviranem tkivu stopnja poliploidnosti narastla v korist diploidnih celic z normalnim kariotipom (Jelaska in Devidé 1977, Papeš in sod.1978, Jelaska in Devidé 1983, Pavalek in sod. 1980, Jelaska in sod. 1981).

Profesor Devidé je na Inštitutu »Ruđer Bošković« uvedel novost, namreč uporabo elektronskega mikroskopa v biologiji. Ob tej priliki so odkrite tudi nove metode dela (Devidé in Wrischer 1960 a,b), s katerimi je bilo pozneje lažje raziskovati vpliv ionizirajočega sevanja in drugih zunanjih dejavnikov na razvoj plastidov. S svojo sodelavko Mercedes Wrischer sta ugotovila, da izpostavljenost sevanju rentgenskim žarkom, ki še ni smrtno, ne vpliva na pretvorbo prolamelarnih telesc v ozelenečih etioliranih listih. Upočasnjen razvoj tilakoidov in formiranje granumov pa dokazujeta, da odvisnost od velikosti sevanja do neke mere vendarle obstaja (Wrischer in Devidé 1964 c,d, Wrischer in Devidé 1967 a,b, Devidé 1967, Devidé 1969 a,b). Dobljeni rezultati so še

spodbudili njegovo že nekaj časa trajajoče zanimanje za plastidno metamorfozo. Pri sadežih, kot so pomaranče in kultivirane vrste buč (*Cucurbita pepo* L. var. *ovifera*), mu je s kolegom Nikolo Ljubešićem uspelo dokazati, da lahko kromoplasti v določenih okoliščinah ponovno ozelenijo, pri čemer se pretvorijo v funkcionalne kloroplaste. Rezultati tega dela so dokončno ovrgli Frey-Wysslingovo hipotezo o monotropnem razvoju plastidov (Devidé 1970 a,b, Devidé in Ljubešić 1972, Devidé in Ljubešić 1974), ki pravi, da kromoplasti predstavljajo zadnjo fazo v razvoju plastidov in da se ne morejo ponovno razviti v kloroplaste. Toda koreni rdečega korenja na svetlobi ozelenijo. Drugo obliko reverzibilne plastidne transformacije predstavljajo aurea mutacije, ki so raziskane v vrstah *Acer negundo* var. *odessanum*, *Fraxinus excelsior* var. *aurea* in *Ligustrum ovalifolium* var. *aureum*. V vseh treh primerih močna svetloba preprečuje ozelenitev – akumulacijo klorofila. Vtis je, kot da bi bile posledice napake v biosintezi karotenoidov in drugih zaščitnikov pred prekomernim sevanjem sonca (triplet karotenoidov in epoksidni cikli), pri čemer je kolorofil subjekt foto-oksidacije. Morfometrični podatki za aureo varietete so pokazali, da vsebujejo plastidi rumenih listov, ki so izpostavljeni soncu, le okrog 10 % mase grana tilakoidov, ki jo običajno najdemo v senčni legah rastočih zelenih listih. Kljub vsemu je bila fotosinteza pri rumenih aurea listih mnogo učinkovitejša, kot bi pričakovali, glede na nizko vsebnost klorofila; to je ugotovitev, na osnovi katere lahko sklepamo, da je v tem slučaju velikost fotosintetične enote manjša (Wrischer in sod. 1975 a,b, Wrischer in sod. 1976).

Z Mercedes Wrischer je prof. Devidé raziskoval tudi ultrastrukturne spremembe, ki nastanejo zaradi delovanja inhibicijskih dejavnikov na proces celične respiracije. Eden od učinkov, ki so bili predmet raziskave, je bilo značilno povečanje velikosti mitohondrijev; takšnega doslej še nismo poznali (Wrischer in Devidé 1964 a,b, Devidé in Wrischer 1964, Devidé in Wrischer 1965, Devidé in Wrischer 1967).

Znanstveni interes prof. Devidéja je tudi fiziologija cvetenja. Skupaj z menoj (B. Krajnčičem) sva objavila 5 znanstvenih člankov (Krajnčič in Devidé 1979, Krajnčič in Devidé 1980, Krajnčič in Devidé 1982 a,b,c), v katerih sva raziskovala embrionalni razvoj cvetov pri vrsti *Spirodela polyrrhiza (Lemnaceae)* (Krajnčič in Devidé 1979), fotoperiodizem pri vrstah lemnacej s področja Slovenije in severne Hrvaške (Krajnčič in Devidé 1980, Krajnčič in Devidé 1982b) in pri tem ugotovila, da je vrsta *Lemna minor* kvalitativna dolgodnevnica, *Lemna gibba* kvantitativna dolgodnevnica, *Spirodela polyrrhiza* večinoma fotoperiodično nevtralna rastlina, *Wolffia arrhiza* pa dolgo-kratkodnevnica. Z raziskavami vpliva 20 aminokislin na cvetno indukcijo vrst *Lemna minor* in *Spirodela polyrrhiza* (Krajnčič in Devidé 1982a) sva ugotovila naslednje.

Pri pH 4,8 in koncentraciji 10^{-6} M, ki je za večino aminokislin optimalna, so najmočneje pospešile indukcijo cvetenja v primerjavi s kontrolo.

(1) Pri dolgodnevnih klonih *Lemna minor* na dolgem dnevu: serin za 27 %, glutaminova kislina za 26 %.

(2) Pri dnevno nevtralnih klonih vrste *Spirodela polyrrhiza,* na dolgem dnevu: glutaminova kislina za 38 %, leucin za 28 %, serin za 21 %, na kratkem dnevu: valin za 45 %, tirozin za 36 %.

Pri terenskih raziskavah lemnacej na področju severne Hrvaške (Krajnčič in Devidé 1982c) sva odkrila večje število še neobjavljenih rastišč lemnacej, od tega 14 rastišč vrste *Spirodela polyrrhiza*, 17 rastišč splošno razširjene vrste *Lemna minor*, tri rastišča vrste *Lemna gibba*, 11 rastišč vrste *Lemna trisulca* in 7 rastišč vrste *Wolffia arrhiza*. Najpomembnejša novoodkrita rastišča lemnacej so opisana in vrisana v geografski karti priloženi na koncu objavljenega članka.

Pri raziskavah fotoperiodičnih reakcij lemnacej s področja severne Hrvaške (Krajnčič in Devidé 1982b) sva ugotovila, da so izmed petih klonov vrste *Spirodela polyrrhiza* (Đelekovec, D. Miholjac, Slavonski Brod, Bijelo brdo in Vinkovci) prvi štirje kloni fotoperiodično nevtralne rastline, klon iz Vinkovcev pa je kvantitativna dolgodnevnica, kar je pri vrsti *Spirodela polyrrhiza* prvič ugotovljeno. Oba raziskovana klona vrste *Lemna gibba* (Bročice in Stupna) sta kvalitativni dolgodnevnici. Izmed šestih klonov vrste *Wolffia arrhiza* je uspela cvetna indukcija samo pri klonu iz Zagrebškega botaničnega vrta, ki je dolgo-kratkodnevnica.

Profesor Devidé je tako citolog kot fiziolog, zato kaže veliko zanimanje za biokemične raziskave. Tako se je začelo sodelovanje z radioizo-

topnim (sledilnim) laboratorijem Instituta »Ruđer Bošković«, katerega predstojnica je bila dr. Dina Keglević (Ladešić in sod. 1962). Da bi mogli razviti podobne raziskave tudi v njegovi univerzitetni enoti, je svojemu asistentu, Ivanu Reguli, omogočil usposabljanje v tem laboratoriju z namenom, da se ta priuči potrebnih metod dela. Začeli so raziskovati biogenični amin, tj. serotonin, ki so ga nedavno tega odkrili v živalskih in človeških tkivih in je postal izziv številnim fiziologom in farmakologom. V laboratoriju profesorja Devidéja je I. Regula potrdil njegovo prisotnost, na primer, v žgalnih laskih koprive, v spodnji listni povrhnjici oljčice (*Elaeagnus*), v mezokarpnem tkivu paradižnika ter v semenih lešnikov (tukaj v povezavi s triptofanom). Serotonin se tvori po šikimatskih poteh prek triptofana in triptamina. Z akumuliranjem v semenih naj bi tvoril mehanizem za razstrupljanje amoniaka (in/ali rezerve za kasnejšo uporabo). Poleg tega serotonin spodbuja podaljševanje celic v koreninah/korenih/korenikah in ovsenih (*Avena sativa*) koleoptilah (Regula in Devidé 1979, Regula in Devidé 1980).

Znanje optike je profesorju Devidéju omogočilo, da je analiziral optične značilnosti modrega sija pri plodovih vrste *Viburnum tinus* (Devidé 1986). Z Marijano Krsnik-Rasol sta začela z raziskavami na področju rastlinskih tumorjev. Objavil je tudi številne članke o domačem rastlinstvu (Domac in Devidé 1954, Devidé 1956 a,b,c,d, Devidé 1957, Krajnčič in Devidé 1982) in s svojimi lastnimi izkušnjami prispeval k skupnim raziskavam s kolegi z najrazličnejših področij (Tunki in Devidé 1957, Deželič in sod. 1960, Mamula in sod. 1966).

Naj na tem mestu omenim še članek o makroevolucijskih teorijah in njihovih citogenetskih osnovah (Kochansky in Devidé 1985), ki ga je napisal skupaj s soprogo Vando Kochansky-Devidé, paleontologinjo s pronicljivim poznavanjem biologije. V glavnem pa je ostal pri elektronski mikroskopiji in plastidnih ultrastrukturah s poudarkom na razvoju kromoplastov in njihovih kompartimentov, v katerih se nahajajo karotenoidi (Devidé in Ljubešić 1989, Ljubešić in sod. 1996, Wrischer in sod. 1992, Ljubešić in sod. 1995, Ljubešić in sod. 1996, Wrischer in sod. 1998, Ljubešić in sod.1999, Wrischer in sod.2000, Ljubešić in sod. 2005).

Profesor Devidé je rezultate svojega dela predstavil na 75 znanstvenih konferencah doma in po svetu, na dvanajst od teh je nastopil kot plenarni predavatelj. Pomen njegovega znanstvenega dela je viden v odzivu, ki ga je sprožil v mednarodni znanstveni skupnosti. Njegove rezultate so citirali v več kot 40 mednarodnih znanstvenih časopisih in jih vključevali v univerzitetne učbenike kot študijsko gradivo.

V času, ko je bil prof. Devidé član Botaničnega zavoda, ga je obiskalo več kot štirideset tujih znanstvenikov, med njimi M. Bopp, M. Bukovac, J. Greilhuber, W. Haupt (po zaslugi katerega je Botanični inštitut Univerze v Erlangen Nuernbergu prispeval številne volumne Priročnika rastlinske fiziologije in še mnogo pomembnih znanstvenih publikacij, knjig, učbenikov in priročnikov), K. Jones, R. Kandeler, E. Landolt, M. Nešković, J. Reinhert, E. Schnepf, P. Sitte, M Vardjan, H. Ziegler in I. Zelich. Mnogi izmed naštetih kolegov so bili člani komisij za zagovor doktorskih disertacij.

Profesor Devidé je bil glavni organizator več pomembnih znanstvenih konferenc, med katerimi velja še posebej omeniti Evropski fotobiološki simpozij na Hvaru leta 1967, simpozij Jugoslovanskega društva za rastlinsko fiziologijo v Stubiških toplicah leta 1975 ter 5. jugoslovanski simpozij iz elektronske mikroskopije v Plitvicah leta 1986. Ob tem je sodeloval še v organizacijskih odborih mnogih drugih domačih konferenc.

Napisal je recenzije za več kot 34 knjig, univerzitetnih učbenikov in drugih znanstvenih del ter 14 preglednih in poljudno znanstvenih člankov v revijah Priroda in Proteus. Ob tem ne smemo pozabiti njegovega prispevka v splošnih, medicinskih in gozdarskih enciklopedijah. Pisal je o najrazličnejših temah, vse od zgodovine naravoslovnih znanosti do vprašanja etike v biologiji. Posebnega pomena je poglavje, ki ga je prispeval v knjigi Mikroskop, avtorja B. Varićaka, kjer je razložil teoretska izhodišča mikroskopije, načine priprave vzorca in uporabo elektronskega mikroskopa v biologiji. Nič manj pomembno ni profesorjevo sodelovanje pri prevajanju 31. izdaje Strassburgerjevega učbenika botanike za univerzitetne namene (Školska knjiga, Zagreb, 1982, ki je doživela v kratkem času 3 izdaje).

Profesor Devidé je bil izjemen predavatelj. Predstavljene primere je ponazoril z nadvse

razumljivimi risbami in koristnimi ilustracijami, s pomočjo katerih je bilo moč razumeti kompleksne pojme iz biologije, vse od delovanja kompliciranih naprav do strukture in delovanja rastlinskih celic. Svoje trditve je po možnosti vselej podkrepil z zanimivimi eksperimenti.

Veliko časa in napora je vložil v izboljšanje obstoječih ter uvajanju novih dodiplomskih študijskih programov (osnove citologije, celična biologija, znanstvena mikroskopija, splošne metode in orodja znanstvenega raziskovanja, še posebej pa velja omeniti sodobno fiziologijo rastlin). Bil je mentor pri številnih diplomskih nalogah na dodiplomski in podiplomski stopnji.

Profesor Devidé je bil voditelj Podiplomskega študija iz Botanike in Eksperimentalne biologije na Naravoslovno-matematični fakulteti (1960–1970) in, po reorganizaciji Podiplomskega študija voditelj za Biologijo Podiplomskega študija Univerze v Zagrebu (1970–1983). Vodil je naslednje dodiplomske predmete: Biomembrane, Principi in metode znanstvene mikroskopije ter specialne predmete s področja ultrastrukture in funkcije mitohondrijev ter ultrastruktur in delovanja fotosintetičnega aparata in submikroskopske organizacije celic. Pod njegovim vodstvom je nastala prenekatera magistrska in doktorska naloga.

S kolegi je spodbujal raziskovanje področij kot so biologija celic in rastlinskih tumorjev (Marijana Krsnik-Rasol), citogenetika (Dražena Papeš), submikroskopska zgradba celic in elektronska mikroskopija (Mercedes Wrischer, Nikola Ljubešić), kulture rastlinskih tkiv (Sibila Jelaska, El Khalifa El Mamoun iz Kartuma, Sudan, Branka Kolevska-Pletikapić, Branka Pevalek-Kozlina), fiziologija cvetenja (Božo Krajnčič, Maribor), biokemična fiziologija rastlin (Ivan Regula) ter kultura in fiziologija alg (Elena Marčenko).

Zaradi svojih zaslug je bil profesor Devidé leta 1973 izbran za izrednega člana in leta 1991 in za rednega člana poprej Jugoslovanske, sedaj Hrvaške akademije znanosti in umetnosti.

Od leta 1974 je veliko časa in energije usmeril v poučevanje o nujnih potrebah ohranjanja narave in zdravega okolja, sodeloval je v mnogih komisijah in podobnih telesih (gl. Scientia Yugoslavica, Zagreb, 1987).

Profesor Devidé je v svoji akademski karieri zavzemal pomembne položaje v številnih raziskovalnih in izobraževalnih ustanovah. Na Naravoslovno-matematični fakulteti je bil voditelj Podiplomskega študija Botanike in Eksperimentalne biologije (1960 – 1970) in po reorganizaciji voditelj Podiplomskega študija Univerze iz stroke Biologija (1970 – 1983) ter predstojnik Botaničnega zavoda in Botaničnega vrta (1981–1986). Bil je tudi predsednik Sveta za varovanje narave na akademiji, Prometno ekološkega odseka znanstvenega sveta za promet na Akademiji, član Medakademske komisije za varstvo narave in okolja, delegat v Svetu jugoslovanskih Akademij in v okoljski komisiji OECD (1986) ter v Komisiji za varovanje in razvoj okolja v jugoslovanskem parlamentu (1986). Bil je predstojnik Odseka za biologijo v Hrvaškem prirodoslovnem društvu (1974–1976), predsednik Hrvaškega društva za fiziologijo rastlin (1972–1974), predstojnik Sekcije za elektronsko mikroskopijo pri Hrvatskem prirodoslovnem društvu (1984–1989), član upravnega odbora Hrvaškega združenja genetikov ter mednarodnih društev kot so Federacija evropskih društev za fiziologijo rastlin, Mednarodne zveze za fiziologijo rastlin in mednarodne zveze za kulturo rastlinskih tkiv. Je član uredniških odborov znanstvenih revij Periodicum Biologorum (1973–1976), Acta Botanica Croatica (od 1967) in Acta Biologica ASAC (1987–2002).

Nenazadnje velja, poleg zgoraj omenjenih oblik javnega priznanja profesorjevih dosežkov v znanosti, omeniti tudi odlikovanja in javna priznanja, ki jih je bil prof. Devidé deležen. Leta 1976 je prejel priznanje za svojo znanstveno dejavnost republiško nagrado »Ruđer Bošković«. Leta 1985 je bil odlikovan z Ordenom dela z zlatim vencem za posebne zasluge in dosežene uspehe v delu, pomembne za napredek domovine. Leta 1988 pa je sprejel republiško Nagrado za življenjsko delo. Leta 1980 je Znanstveni svet Instituta »Ruđer Bošković« profesorja Devidéja izvolil v naziv častnega znanstvenega svetnika Instituta »Ruđer Bošković«, leta 1981 je postal častni član Hrvaškega biološkega društva, leta 1990 Hrvaškega prirodoslovnega društva, leta 1998 Hrvaškega genetičnega društva, leta 1999 Hrvaškega društva za fiziologijo rastlin, leta 2000 mu je Hrvaško biološko društvo podelilo Plaketo Zdravka Lorkovića v priznanje kot ustanovitelju tega društva, leta 2010 pa zahvalnico Hrvaškega prirodoslovnega društva kot svojemu častnemu članu za dolgoletno prizadevnost uresničiti cilj HPD-ja.

Ob 80. in 85. obletnici rojstva prof. Devidéja sem svojemu mentorju posvetil dva znanstvena članka, ki sem ju objavil v mednarodnih znanstvenih časopisih: Mechanisms of EDDHA effects on the promotion of floral induction in the long day plant *Lemna minor (L.)* Journal of Plant Physiology 160, 143–151 (2003) (Članek je posvečen 80. obletnici rojstva prof. Devidéja) in Possible role of jasmonic acid in the regulation of floral induction, evocation and floral differentiation in *Lemna minor (L.)* Plant Physiology and Biochemistry 44, 752–758 (2006) (Članek je posvečen 85. obletnici rojstva prof. Devidéja).

Profesor Devidé je znan po svoji prijaznosti, dostopnosti in pripravljenosti sodelovanja. Dobro poznavanje petih jezikov (hrvaščine, slovenščine, nemščine, francoščine in angleščine) mu je zelo olajšalo vzpostavljanje zvez z inozemstvom in inozemnimi kolegi, kar je pospešilo znanstvene stike in osebna poznanstva v stroki.

Devidéjevo navdušenje za poučevanje in raziskovanje na področju biologije ter obsežno znanje pridobljeno na Dunaju in v Angliji sta našla dober odziv v Botaničnem zavodu in biološkem oddelku novoustanovljenega Inštituta »Ruđer Bošković« v Zagrebu, kamor je bil povabljen, da razvije elektronsko mikroskopijo.

Profesor Devidé je navdušil za znanost številne mlade ljudi. Trije njegovi sodelavci so člani Hrvaške akademije znanosti in umetnosti, eden je zaslužni profesor, številni njegovi študentje in študenti njegovih sodelavcev pa so se izkazali po svetu v uglednih laboratorijih. Do študentov je bil izredno razumevajoč, naklonjen, hkrati pa je, glede na sloves Univerze, kakršna je zagrebška, ohranil strogo objektivnost glede kriterijev ocenjevanja.

V letih visoke starosti, ki jo je dosegel, je seveda moral zmanjšati svojo dejavnost. Od leta 1994 do danes je voditelj Zavoda za ornitologijo Hrvaške akademije znanosti in umetnosti, kjer se, poleg s tekočimi zadevami, ukvarja zlasti s problemi hrvaške ornitološke terminologije in nomenklature. Kot član uredniškega odbora mednarodnega časopisa Acta Botanica Croatica se z glavnim urednikom prof. dr. Damirjem Viličićem trudi, kako v kriznih časih zagotoviti časopisu varnejšo bodočnost. Objavlja še krajše članke, večinoma kritične razprave o važnih znanstvenih knjigah in zlasti učbenikih, važnejših obletnicah in podobno.

Profesor Devidé je imel kljub širini svojih dejavnosti tudi željo imeti svoje »konjičke«, za kar pa seveda ni bilo nikoli dovolj časa. Bil je velik ljubitelj opazovanja neba, za kar si je sam izdeloval in prilagajal opazovalne naprave. Njegov najljubši konjiček pa je bila komorna glasba, o čemer je treba nekoliko več povedati.

V 9. letu starosti ga je njegov oče, mr. ph. Bogdan Devidé, lekarnar, učil igrati violino. V Mariboru ga je v letih 1930/31 do 1938/39 v igranju violine dalje poučeval upokojeni koroški učitelj in priznani violinist Franjo Serajnik, ki je leta 1932/33 ustanovil mladinski godalni kvartet v sestavi Zvonimir Devidé, Dora Močivnik, Fran Brglez in Mladen Devidé, s katerim je prirejal nastope na šolskih proslavah v Mariboru in samostojne koncerte v mariborski okolici (Sv. Lenartu, Ormožu, Ptuju) na katerih je Z. Devidé nastopal tudi kot solist, zadnjič v Kazinski dvorani v Mariboru 1939. O teh prireditvah sta redno poročala časnika Jutro in Večernik. Ob takih okoliščinah je bil maturant Devidé v težki dilemi, ali naj se posveti študiju biologije, ali glasbi. Po opravljenem sprejemnem izpitu na Glasbeni akademiji v Zagrebu je bil dve leti učenec prof. Ladislava Miranova, vendar je zaradi vojnih dogodkov moral svoj glasbeni študij opustiti in se zadovoljiti z igranjem violinskih sonat v domačem krogu. Leta 1954 pa je postal po naključju član Društvenega orkestra Hrvaškega glasbenega zavoda, v katerem je redno sodeloval do leta 1993/94, najprej kot violinist, pozneje pa kot violist. Posebno rad se je ukvarjal z violo d´amore. Nekajkrat je tudi nastopil z Društvenim orkestrom kot solist, zlasti na violi in violi d´amore. Zadnja koncerta, na katerih je sodeloval, sta bila koncerta v Nemčiji leta 1993 v Düsseldorfu in Bonnu.

Ker prof. Devidé smatra Slovenijo kot svojo »rojstno domovino«, Hrvaško pa kot svojo »očetnjavsko domovino« sem se odločil, da ob 90. obletnici rojstva svojega mentorja pošljem obširnejši spominski prispevek v Acta Biologica Slovenica v znak prisrčne hvaležnosti za njegova prizadevanja v mojem znanstvenem napredku na področju fiziologije rastlin. Naj se izpolni tudi moja srčna želja, da bi moj spoštovani in dragi mentor prof. dr. Zvonimir Devidé doživel še mnogo zdravih in srečnih let. Enako mu želijo tudi vsi njegovi učenci in sodelavci.

Seznam znanstvenih publikacij

Devidé, Z., 1949. Izvještaj o citološkim istraživanjima leukotiobakterija. Ljetopis JAZU 55, 77–85.

Devidé, Z., 1950. Hromosomi cilijata (eucilijata i opalinida). Rad JAZU 280, 179–217.

Devidé, Z., 1951. Chromosomes in Ciliates (Euciliata and Opalinidae). Bull. Intern. Acad. Yugosl. N.s. 3, 75–114.

Devidé, Z., 1952. Zwei neue farblose Schwetelbakterien. *Thiogloea ruttneri* n. gen. N. sp. Ind *Thiogloea ragusina* n. sp. Schweiz. Z. Hydrologie. 14. 446–455.

Devidé, Z., 1953. Godišnji izvještaj o istraživanju citologije leukobakterija. Ljetopis JAZU 58, 174–176.

Devidé, Z., 1953. Izvještaj o citološkim istraživanjima na leukobakteriama. Ljetopis JAZU 58, 169–173.

Devidé, Z., 1954. Istraživanja o stanici bezbojnih sumpornih bakterija. Acta Pharm. Jug. 4, 147–176.

Devidé, Z., 1956. *Branchiura sowerbyi* Beddard v ribniku botaničnega vrta v Zagrebu. Biol. Vestn. (Ljubljana) 5, 76–78.

Devidé, Z., 1956. Does Thiosiphon exist? Acta Bot. (Zagreb) 14/15, 181–183.

Devidé, Z., 1956. *Echinocystis lobata* (Michx.) Torr. I Gray. Acta Bot. (Zagreb) 14/15, 186–187.

Devidé, Z., 1956. Novo nalazište volfije (*Wolffia arrhiza* /L./ Wimm.) u Hrvatskoj. Acta Bot. (Zagreb) 14/15, 184–186.

Devidé, Z., 1957. O nalazištu bezbojnih bakterija kod Ulcinja. Acta Pharm. Jug. 7, 129–135.

Devidé, Z., 1959/1960. Beiträge zur Kenntnis des Baues hellgefleckter Laubblätter. Acta Bot. Croat. 18/19, 107–166.

Devidé, Z., 1967. The effect of ionizing radiation and ultraviolet light on developing plastids in primary leaves of etiolated bean seedings. Proc. Abstr. Eur. Photobiol. Symp. Hvar. 9–12.

Devidé, Z., 1969. Helical arrangement of ribosomes in the leaf cells of etiolated bean seedings after UV-irradiation. Acta Bot. Croat. 28, 55–57.

Devidé, Z., 1969. Veränderungen im Chloroplasten-Feinbau nach Röntgenbenstrahlung etiolierter Bohnenblätter. Österr. Bot. Z. 116, 444–453.

Devidé, Z., 1970. Changes in fine structure of plastids in ripe fruits of *Cucurbita pepo* cv. *ovifera*. Proc. 7. Congr. Int. Microsc. Electron., Grenoble, C. R., 201–202.

Devidé, Z., 1970. Ultrastructural changes of plastids in ripe fruits of *Cucurbita pepo* cv. *ovifera*. Acta Bot. Croat. 29, 57–62.

Devidé, Z., 1986. Über die Ursache des Blauglanzes der Früchte von *Viburnum tinus* L. Acta Bot. Croat. 45, 97–100.

Devidé, Z., Geitler, L., 1947. Die Chromosomen der Ciliaten. Chromosoma 3, 110–136.

Devidé, Z., Ljubešić, N., 1972. Plastid transformations in pumpkin fruits. Natur-wissenschaften 59, 39–40.

Devidé, Z., Ljubešić, N., 1974. The reversion of chromoplasts to chloroplasts in pumpkin fruits. Z. Pflanzenphysiol. 73, 296–306.

Devidé, Z., Ljubešić, N., 1989. Plastid transformation in greening scales of the onion bulb (*Allium cepa, Alliaceae*). Plant Syst. Evol. 165, 85–89.

Devidé, Z., Wrischer, M., 1960. Eineinfaches Verfahren zur Herstellung von Glasmessern für Ultramikrotomie. Mikroskopie (Wien) 15, 9–11.

Devidé, Z., Wrischer, M., 1960. Versuche über gasblasenfreie Plexiglas-Einbettung von pflanzlichen Objekten für Ultramikrotomie. Mikroskopie (Wien) 14, 337–342.

Devidé, Z., Wrischer, M., 1964. The ultrastructure of developing plastids in the leaves of etiolated bean seedings at disturbed respiration. Electron Mocroscopy. B. Proc. 3. Europ. Conf. ČSAV, Praha, 151–152.

Deželič, Gj., Wrischer, M., Devidé, Z., Kratohvil, P., 1960. Electron microscopy of ludox colloidal silica. Kolloid-Z. 171, 42–45.

Domac, R., Devidé, Z., 1954. Novo nalazište paprati *Phyllitis hybrida* (Milde) Christensen na Jadranu. Acta Pharm. Jug. 4, 184–187.

Jelaska, S., Devidé, Z., 1977. Primjena kulture biljnih stanica i tkiva u suvremenoj genetici. Genetika 9, 85–94.

Jelaska, S., Devidé, Z., 1983. Primjena kulture stanica i organa u hortikulturi. Proc. Symp. Robert Visiani, Šibenik, 331–335.

Jelaska, S., Pevalek, B., Papeš, D., Devidé, Z., 1981. Developmental aspects of long-term callus cultures of *Vicia faba* L. Protoplasma 105, 285–292

Kochansky-Devidé, V., Devidé, Z., 1985. Makroevolucijske teorije in njihova citigenetska osnova. Rasprave SAZU 26, 329–340.

Krajnčič, B., Devidé, Z., 1979. Flower development in *Spirodela polyrhiza* (*Lemnaceae*). Plant Syst. Evol. 132, 305–312.

Krajnčič, B., Devidé, Z., 1980. Report on photoperiodic responses in *Lemnaceae* from Slovenia. Ber. Geobot. Inst. ETH. Stiftung Rübel, Zürich. 47, 75–86.

Krajnčič, B., Devidé, Z., 1982. Photoperiodic responses of *Lemnaceae* from northern Croatia. Acta Bot. Croat. 41, 57–63.

Krajnčič, B., Devidé, Z., 1982. Rasprostranjenost vodnih leća (*Lemnaceae*) u sjevernoj Hrvatskoj. Acta Bot. Croat. 41, 175–180.

Krajnčič, B., Devidé, Z., 1982. Vpliv aminokislin na cvetno indukcijo vrst *Lemna minor* in *Spirodela polyrrhiza*. Biol. Vestn. (Ljubljana) 30, 105–120.

Ladešić, B., Devidé, Z., Pravdić, N., Keglević, D., 1962. Biochemical studies in tobacco plants. I. The relative utilization of the optical isomers of alpha- and beta-methionine through transmethylation on *Nicotiana rustica* . Arch. Biochem. Biophys. 97, 556–561.

Ljubešić, N., Prebeg, T., Devidé, Z., Regula-Bevilacqua, Lj., 1999. Chromoplasts in the sepals of *Physalis alkekengi*: The effect of norflurazon on chromoplast differentiation. Acta Bot. Croat. 58, 79–86.

Ljubešić, N., Wrischer, M., Devidé, Z., 1991. Chromoplasts – the last stages in plastid development. Int. J. Dev. Biol. 35, 251–258.

Ljubešić, N., Wrischer, M., Devidé, Z., 1995. Development of chromoplast tubules in *Hypericum* flowers. Period. Biol. 97, 333–336.

Ljubešić, N., Wrischer, M., Devidé, Z., 1996. Chromoplast structures in *Thumbergia* flowers. Protoplasma 193, 174–180.

Ljubešić, N., Wrischer, M., Prebeg, T., Devidé, Z., 2005. Structural changes in leaves of the moss *Polytrichum formosum* Hedw. during winter freezing and thawing processes, Acta Bot. Croat. 64, 219–226.

Mamula, Đ., Juretić, N., Wrischer, M., Devidé, Z., Miljčić, D., 1966. Novi podaci o virusima krucifera u Jugoslaviji. Agron. Glasnik 11/12, 845–861.

Papeš, D., Jelaska, S., Tomaseo, M., Devidé, Z., 1978. Triplody in callus culture of *Vicia faba* investigated by the Giemsa C-banding technique. Experientia 34, 1016–1017.

Pevalek, B., Jelaska, S., Papeš, D., Devidé, Z., 1980. Growth regulators requirement for the initiation of *Vicia faba* callus tissue. Acta Bot. Croat. 39, 51–57.

Regula, J., Devidé, Z., 1979. Occurence of some indoles in *Shenopherdia ergentea* (Pursh.) Nitt. Acta Bot Croat. 38, 41–44.

Regula, J., Devidé, Z., 1980. The presence of serotonin in some species of genus *Urtica*. Acta Bot. Croat. 39, 47–50.

Tunkl, M., Devidé, Z., 1957. Über Sklerotienbildung bei *Pyronema domesticum* (Sow.) Sacc. Phytopathol. Z. 29, 295–298.

Wrischer, M., Devidé, Z., 1964. Elektromikroskopische Beobachtungen an Mitochondrien pflanzlicher Zellen bei Störung von Atmungsprozessen. Mikroskopie (Wien) 19, 43.

Wrischer, M., Devidé, Z., 1964. On the changes of mitochondria in plant cells with disturbed respiration. Proc. Yugosl. Conf. Radiobiol. Ljubljana. 86.
Wrischer, M., Devidé, Z., 1964. The effect of gamma radiation on the development of the chloroplasts in etiolated bean seedings. Proc. 5. Yugosl. Conf. Radiobiol.. Ljubljana. 85.
Wrischer, M., Devidé, Z., 1964. The effect of gamma rays on the fine structure of developing plastids in the leaves of etiolated bean seedings. Electron Microscopy. B. Proc. 3. Europ. Conf. ČSAV, Praha, 271–272.
Wrischer, M., Devidé, Z., 1965. Mitochondrien-Veränderungen pflanzlicher Zellen bei Störung von Atmungsprozessen. Z. Naturforsch. 20b, 260–263.
Wrischer, M., Devidé, Z., 1967. Über den Einfluss von Atmungsstörungen auf die Differenzierung der Plastiden im Blattgewebe etiolierter Bohnenkeimlinge. Z. Naturforsch. 22b, 447–450.
Wrischer, M., Devidé, Z., 1967. Über den Einfluss von Vorbelichtung auf die Plastidenentwicklung in den Primärblättern gamma-bestrahlter etiolierter Bohnenkeimlinge. Planta (Berl.) 73, 319–323.
Wrischer, M., Devidé, Z., 1967. Über die Wirkung von Gammastrahlen auf die Entwicklung der Plastiden etiolierter Bohnenkeimlinge. Z. Naturfosch. 20b, 260–263.
Wrischer, M., Ljubešić N., Magnus, V., Devidé, Z., 2000. Structural and functional characteristics of overwintering blackberry leaves. Acta Bot. Croat. 59, 5–16.
Wrischer, M., Ljubešić, N., Devidé, Z., 1975. Transformation of plastids in the leafes of *Acer negundo* L. var *odessanum* (H. Rothe). J.Cell Sci. 18, 509–518.
Wrischer, M., Ljubešić, N., Devidé, Z., 1975. Ultrastructural studies of plastids in leaves of *Fraxinus exelsior* L. var. *aurea* (Wild.). J. Microsc. Biol. Cell. 23, 105–112.
Wrischer, M., Ljubešić, N., Devidé, Z., 1976. Ultrastructural and functional characteristics of plastids in the leaves of *Ligustrum ovalifolium* Hassk. var. *aureum*. Acta Bot. Croat. 35,057–64.
Wrischer, M., Ljubešić, N., Devidé, Z., 1992. Ultrastructural studies of degradational processes in amitrole-damaged photosyntetic membranes. J. Struct. Biol. 108, 1–5.
Wrischer, M., Ljubešić, N., Devidé, Z., 1998. The influence of norflurazon on the formation of chromoplst tubules in *Hypericum perfoliatum* flowers. Acta Bot. Croat. 57, 11–18.

Viri podatkov

Bezić, N., 2009. Društveni orkestar Hrvatskoga glazbenog zavoda (uz 55. godišnjicu njegove obnove (1954–2009)). Hrvatski glazbeni zavod, Zagreb: 45, 49, 53, 57, 66, 67, 82, 84–86, 90, 99, 107–108, 114, 128, 166.
Forstnerič Hajnšek, M., 2007. Zagrebački Slovenci 2005 – 2007. Vijeće slovenske nacionalne manjine grada Zagreba. Prolog Šime Ivanjko, Milan Orožen Adamič; prijevod Koraljka Čeh, Maribor, samozal.: 237–248.
Grlić, Lj., 1993. Devidé Zvonimir, v: Hrvatski biografski leksikon, sv. 3, Zagreb, Leksikografski zavod »Miroslav Krleža«: 355–356.
Ljubešić, N., 2003. 50 years of modern plant biology in Croatia. Period. Biol. 105 (3): 357–358.
Magnus, V., 2003. Professor Zvonimir Devidé. Period. Biol. 105 (3): 357–358.
Papeš, D., Jelaska, S., 1986. Prof. dr. Zvonimir Devidé prigodom 65. godišnjice života. Acta Bot. Croat. 45: 155–165.
Regula, I., 1992. Akademik Zvonimir Devidé prigodom 70. godišnjice života. Period Biol. 94: 43–45.
Regula, I., 1992. Akademik Zvonimir Devidé prigodom 70. godišnjice života. Priroda 82 (3–5): 43–45.
Regula, I., 2001. Professor Zvonimir Devidé – to mark his eightieth birthday. Acta Bot. Croat. 60 (2): 155–165.

Sveučilište u Zagrebu, Zagreb 1974. Spomenica Prirodoslovno-matematičkog fakulteta 1874–1974, Zagreb: 13,15, 122–123, 131, 132, 136, 155, 203.
Sveučilište u Zagrebu, Zagreb 1996. Prirodoslovno-matematički fakultet: 120 godina nastave Prirodoslovlja i matematike na Sveučilištu u Zagrebu. Spomenica PMF: 214–216, 232, 236, 244–245, 390, 392, 397, 420.

ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 15–38

Diversity and ecology of epiphytic and terricolous lichen mycota in Gorski kotar and Kvarner littoral (Croatia)

Raznolikost in ekologija epifitskih in talnih lišajskih gliv na območju Gorskega Kotarja in Kvarnerja (Hrvaška)

Siniša Ozimec*

University of J. J. Strossmayer in Osijek, Faculty of Agriculture, Trg Sv. Trojstva 3, HR-31000 Osijek, Croatia
*correspondence: sinisa.ozimec@pfos.hr

Running title
Ozimec: Lichen mycota of Gorski kotar and Kvarner

Abstract: This paper lists a total of 264 taxa of lichenized and non-lichenized fungi recorded for Gorski kotar and Kvarner littoral; specifically, 184 for Gorski kotar and 170 for Kvarner littoral. Nine taxa are new to Croatia. The list is based on literature records and field work carried out in periods 2000–2002, and 2009–2010. Taxonomic analyses as well as ecological and phytogeographical analyses are presented. The ecological characterization of the lichen flora was determined by assessing the indicator values, and comparing them to values determined for adjacent areas in Slovenia and Italy. Due to particularities in relief and climate, percentage of lichens of oceanic/suboceanic distribution is higher along the eastern Adriatic coast, in relation to the west Adriatic coast.

Key words: lichen, diversity, ecology, Gorski kotar, Kvarner, Croatia

Izvleček: Prispevek navaja 264 taxonov lišajotvornih in drugih gliv z območja Gorskega kotarja in Kvarnerja; 184 z območja Gorskega kotarja in 170 z območja Kvarnerja. Devet taksonov je novih za Hrvaško. Seznam je narejen na podlagi literaturnih podatkv in terenskih raziskav v obdobjih 2000–2002 in 2009–2010. Podani so rezultati taksonomskih, ekoloških in fitogeografskih analiz. Ekološka karakterizacija lišajske flore temelji na oceni indikatorskih vrednosti ter primerjave z vrednostmi določenimi na območju Slovenije in Italije. Zaradi posebnosti v reliefu in klimi, je delež lišajev oceanske/suboceanske razširjenosti večji na vzhodni obali Jadrana v primerjavi z zahodno

Ključne beside: lišaj, raznolikost, ekologija, Gorski kotar, Kvarner, Hrvaška

Introduction

In the first paper on lichen mycota of Kvarner littoral, Friedrich Wilhelm Noè reported 56 lichens in the area of city of Rijeka (Noè 1858), but without any stated localities. Paolo Matković reported on results of his researches into cryptogamic flora of Rijeka and its surrounding (Matković 1879), and recorded 58 lichen species, some of which are collected for the first time in Gorski kotar. Hungarian lichenologist Frigyes Hazslinszky listed 80 lichen taxa from Rijeka and Lokve in Gorski kotar, according to data from various collectors (Hazslinszky 1884). First Croatian botanists who mentioned lichens in the floristic papers is Dragutin Hirc. In the publication „Vegetation of Gorski kotar“ (Hirc, 1896) he recorded *Cetraria islandica* on Velika Viševica and Suhi vrh. A major

contribution to the knowledge of lichen mycota of Rijeka and Gorski kotar was made by Johann Schuler, who provided a list of 329 taxa with associated localities (Schuler 1902). According to actual administrative division of that time, localities have been grouped in four parts: area of Rijeka, Istria, Carniola and Croatia. The lichen material collected by Schuler were discussed by the outstanding world lichenologist, Alexander Zahlbruckner, whose important contribution is description of several new lichen species (Zahlbruckner 1905, 1906, 1909). Hungarian lichenologist Ödön Szatala (Szatala 1927,1929) listed lichens from Gorski kotar. During research into the vegetation of the massifs of Risnjak and Snježnik in Gorski kotar, Ivo Horvat recorded the presence of lichens in composition of the grassland alliance *Seslerion tenuifoliae* (Horvat 1962). The most distinguished Croatian lichenologist Fran Kušan recorded lichens on Bijele stijene (Kušan 1933) in Gorski kotar, and in Sušak near Rijeka (Kušan 1953).

There is a record of *Dimerella lutea* from Risnjak, collected in 1968 by Czech lichenologist Antonín Vězda (Vězda 1969). Danish lichenologists Steen N. Christensen and Eric Steen Hansen reported on lichens collected on few localities in Gorski kotar and Kvarner littoral (Christensen 1987, Christensen and Hansen 1994). Alebić-Juretić and Arko-Pijevac (1989, 2005) used lichen thalli as bioindicators for the assessment of air pollution in Rijeka and its surrounding. Five new lichens to Croatia, collected in Gorski kotar, were reported by Ozimec (2000), while the list of 80 taxa recorded for the Risnjak National Park has been published recently by Ozimec et al. (2010). These researches are complementary with those of the Austrian and Slovenian lichenologists in adjacent Dinaric parts of Slovenia.

Material and methods

Study area

Gorski kotar and Kvarner littoral are situated in western Croatia, administratively in Primorsko-Goranska County with a seat in City of Rijeka (Fig. 1). Both regions belong to the western Karst Dinarides, stretching in NW-SE direction. North and NW border of Gorski kotar is also the state border between Croatia and Slovenia, while the west and SW border to Kvarner stretches along the mountains range of Obruč and Kamenjak in Rijeka hinterland, Tuhobić, Medviđak and Viševica. The highest peaks of Gorski kotar are Risnjak (1,528 m a.s.l.) and Snježnik (1,506 m) in the westerm part, and Bjelolasica (1,534 m) and Viševica (1,428 m) in the SE part (Munić et al. 1996). Towards the NW, there is a lowland area along the Dobra and Kupa river valleys. The Karst Dinarides are made up of pure Jurassic carbonates (Bucković 2006), and typical karst relief with its specific morphology is developed in the area.

The Kvarner littoral represents a semi closed part of the northern Adriatic Sea, lying between eastern part of the Istrian peninsula and the Vinodol-Velebit coastlines. It is divided by the island chains of Cres-Lošinj and Krk-Rab-Pag into the Rijeka Bay, the Kvarner Bay, the Kvarnerić and the Velebit-Vinodol Channel (Benac et al. 2006).

Two climate types, defined under the Köppen's climatic classification, are present

in Gorski kotar: moderately warm and humid climate with warm summers (Cfsbx"), and wet boreal climate (Dfsbx") in the altitudinal zone above 1,200 m. Climate in Kvarner littoral is classified into Cfsax" type, characterised as moderately warm and humid climate with hot summer. In both areas, dry period occur during the warm half of the year, while the maximum precipitation is recorded in late autumn. The amount of precipitation increases abruptly with altitude on the windward side, from the coast to the Risnjak and Snježnik massifs, while going further inland, the amount of precipitation decreases. Gorski kotar is region with the highest annual precipitation in Croatia: Lividraga (3,728 mm), Risnjak (3,449 mm), Snježnik (3,302 mm). Based on data from Parg (863 m) meteorological station (1971-2000), mean air temperature is 7.2 °C, annual precipitation is 1,841 mm, and air humidity is 80%. Mean air temperature is lowest at high altitudes: 2.4 °C at 1,400 m, and only 1.4 °C above 1,500 m (Horvat 1962). Although some characteristics of Mediterranean climate are present in Kvarner littoral, the impact of vicinity of the coastal mountain range is pronounced in relatively low temperatures during the winter, increased precipitation, occasionally with snow cover, and cold windbreaks. At Rijeka (120 m)

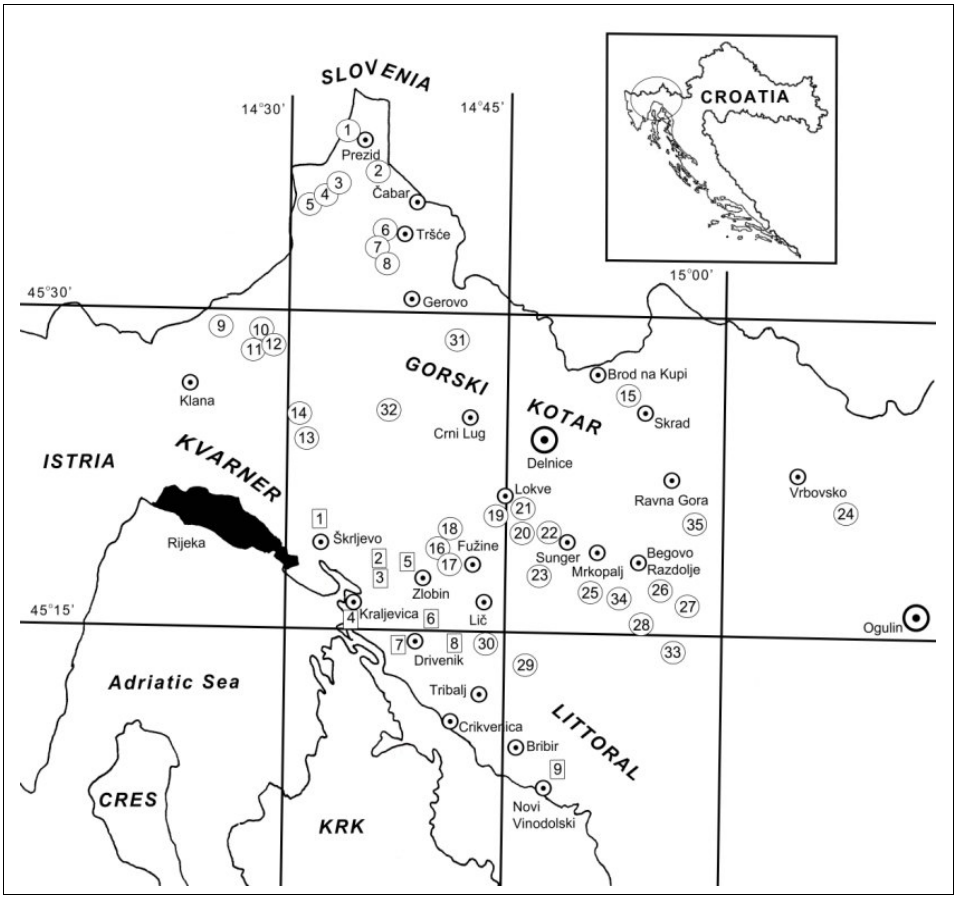


Figure 1: Map of the study area with indicated collection sites.
Slika 1: Zemljevid območja z označenimi lokacijami vzorčevanja.

meteorological station (1971–2000), mean annual temperature is 13.8 °C, annual precipitation is 1,552 mm, and air humidity is 63% (Zaninović et al. 2008).

Regarding the phytogeographical division of Croatia, the most of the Gorski kotar area belongs to the Illyrian province of the Eurosiberian-North American region, while the most exposed and highest mountain peaks exhibit influences from Alpine-Nordic region, but without zonal belt (Topić and Šegulja 2005). The largest part of Gorski kotar situated between 600 and 1,100 m altitude is covered by mixed Dinaric beech and fir forests (*Omphalodo-Fagetum*). In management sense, these forests have permanent and ongoing regeneration, so their sustainability is in no way threatened (Vukelić et al. 2008). Subalpine beech forest (*Ranunculo platanifolii-Fagetum*) cover large areas made up of limestone rock at 1,200–1,400 m altitude. The highest zonal vegetation belt above 1,350 m consists of the special Dinaric stands of mountain pine (*Lonicero borbasianae-Pinetum mugi*). The highest mountain peaks are covered by alpine grasslands of the order *Seslerietalia tenuifoliae*. Steep and warmer limestone blocks at 950–1,350 m covers fir forests (*Calamagrosti-Abietetum*). The subalpine spruce forest (*Listero-Piceetum abietis*) grows in wet and cold locations in the shallow depressions, and on the edge of dolines. Acidophilous fir forest

(*Blechno-Abietetum*) grows on acid soil at 650–950 m. The warmer climatic influence of the Kupa valley favours the occurrence of thermophilous forest associations such as hop hornbeam forests (*Erico-Ostryetum* and *Ostryo-Fagetum)*. Pure Illyrian beech forests (*Lamio orvalae-Fagetum*) grow on heights between 350 and 600 m. Littoral beech forest (*Seslerio autumnalis-Fagetum*) is developed on skeletal carbonate soils on the southern slopes of the Dinarids, mostly above 700 m. It is a bordering forest community between Gorski kotar and Kvarner littoral, as well as between two phytogeographical regions in Croatia.

Some parts of the forests in Gorski kotar remained as primeval due to their inaccessibility and are being protected at national level, such as: Bijele and Samarske Stijene Strict Nature Reserve and Risnjak National Park.

Kvarner littoral belongs to the Adriatic province of the Mediterranean region. Relatively cold winters cause the absence of the evergreen forest vegetation of the *Quercion ilicis* alliance, typical for the Eumediterranean zone (Topić and Šegulja 2005). Lower belt of the sub-Mediterranean zone up to 300–400 m altitude is characterized by deciduous forest and scrub of pubescent oak and oriental hornbeam (*Querco-Carpinetum orientalis*). Horizontal continuation of this belt in the direction of hinterland is mixed forest and scrub of pubescent oak and hop hornbeam (*Ostryo-Quercetum pubescens*) in Mediterranean-montane belt at 400–950 m altitude.

Lichenological survey

Epiphytic lichens were collected on trees and shrubs, while terricolous lichens were collected on soil, some being together with the mosses. The lichen material was collected in the period 2000–2002 and 2009–2010 at 35 different sites across Gorski kotar (Tab. 1), and 9 in Kvarner littoral (Tab. 2).

Identification of the collected material

Identification in the field was made with a hand lens, and in the laboratory using a dissecting microscope, a light microscope and the usual spot tests, according to the reference books: Clerc (1998), Purvis et al. (1992), Vitikainen (1994) and Wirth (1995). Some specimens were analysed by thin-layer chromatography following Orange et al. (2001). The lichen collections from the herbaria: ZA, ZAHO, GZU and W have been studied. Nomenclature follows Suppan et al. (2000), Santesson et al. (2004), Knežević and Mayrhofer (2009), and modern treatments. Vauchers are kept in the Herbarium Croaticum (ZA) of Botanical Institute, Faculty of Science in Zagreb.

Floristic and ecological analyses

The comprehensive list of lichen mycota is given in alphabetical order. Non-lichenized fungi are marked with a plus sign (+). New records to Croatia are marked with (*HR), to Gorski kotar with (*GK), and to Kvarner littoral with (*KL).

The indicator values with relation to distinct environmental factors are given in range of 5-class ordinal scale for each taxon, according to Nimis and Martellos (2008), as follows:

Substrate reaction (R): 1 = on very acid substrata; 2 = on acid substrata; 3 = on subacid to subneutral substrata; 4 = on slightly basic substrata; 5 = on basic substrata

Light (L): 1 = in very shaded situations; 2 = in shaded situations; 3 = in sites with plenty of diffuse light; 4 = in sun-exposed sites; 5 = in sites with very high direct solar irradiation

Moisture (F): 1 = hygrophytic; 2 = rather hygrophytic; 3 = mesophytic; 4 = xerophytic, 5 = very xerophytic

Eutrophication (N): 1 = no eutrophication; 2 = very weak eutrophication; 3 = weak eutrophication; 4 = rather high eutrophication; 5 = very high eutrophication

Altitudinal range (A): 1 = eu-Mediterranean belt with evergreen *Quercus ilex* forest; 2 = submediterranean belt with deciduous *Quercus* and *Carpinus* forests; 3 = montane belt with *Fagus* forests; 4 = oroboreal belt of the Alps; 5 = above treeline, both Alpine and oromediterranean).

Phytoclimatic range in Europe: oc = restricted to oceanic areas; suboc = in suboceanic areas

Table 1

Site	Description	MTB	Date
GK1	Prezid (765 m) and Vražji vrtec (904 m), near the road border crossing to Slovenia	0353/3	27 Sep. 2001
GK2	Kozji vrh (916 m) near Prezid	0353/4	27 Sep. 2001
GK3	Surrounding of forest house Milanov vrh (1,011 m)	0353/3	27 Sep. 2001
GK4	Forest area Ivica (1,000 m), 2 km from Milanov vrh to Jarmovac	0453/1	29 Apr. 2002
GK5	Forest area Jarmovac (1,000 m), 4 km from Milanov vrh	0453/1	29 Apr. 2002
GK6	Surrounding of Frbežari (824 m) near Tršće	0453/2	4 Nov. 2000
GK7	Rudnik (1,052 m) above Frbežari	0453/2	4 Nov. 2000
GK8	Surrounding of Sokoli (733 m) near Tršće	0453/2	4 Nov. 2000
GK9	Trstenik bog (960 m)	0552/2	8 Jun. 2001
GK10	Rečičko (c. 1,140 m), near the forest road Platak–Trstenik	0553/1	8 Jun. 2001
GK11	Rečice (c. 950 m), near the forest house Suho, 13 km from Platak	0553/1	8 Jun. 2001
GK12	Donji Medvejci (1,395 m)	0553/1	19 Sep. 2001
GK13	Kripanjski path, Mala Peša (c. 900 m)	0553/3	28 Sep. 2001
GK14	Kripanjski path, near the forest house Crni Vrh (1,087 m), and Primorski Klek (1,210 m)	0553/3	28 Sep. 2001
GK15	Zeleni vir area near Skrad (345 m)	0555/3	22 Jun. 2001
GK16	Path from Benkovac Fužinski (880 m) to the summit of Tuhobić (1,106 m),	0653/4	7 Nov. 2000
GK17	Path from Zlobinsko Brdo to the summit of Jelenčić (1,106 m)	0654/3	30 Sep. 2001
GK18	Surrounding of Fužine, near the forest road along the Lepenice Lake (c. 730 m)	0654/3	6 Sep. 2000
GK19	Sljeme, chappel by the road to Fužine, near the extension to Slavica (c. 700 m)	0654/4	29 Sep. 2001
GK20	Fajeri above Brestova Draga (c. 1,050 m)	0654/4	22 Jun. 2001
GK21	Park-forest "Golubinjak" (c. 800 m)	0654/2	9 Jun. 2001
GK22	Surrounding of Sunger (804 m), forest „Sungerski lug", chappel by the Sopač–Mrkopalj road	0654/4	9 Jun. 2001 29 Sep. 2001
GK23	Path above Brestova Draga to the summit of Bitoraj (1,385 m)	0654/4 0754/2	1 May 2002
GK24	Surrounding of Vrbovsko, by the road to Ogulin (c. 450 m)	0656/2	3 May 2002
GK25	Southern surrounding of Mrkopalj (c. 950 m)	0755/1	18 Aug. 2001
GK26	By the forest road from Begovo Razdolje to Vrbovska poljana (c. 1,150 m)	0755/2	3 May 2002
GK27	Path from Vrbovska poljana to the summit of Bjelolasica (1,534 m)	0755/2	3 May 2002
GK28	Path from Ratkovo sklonište (1,184 m) to the summit of Samarske stijene (1,302 m)	0755/4	22 Jun. 2001
GK29	By the road Lič–Lukovo–Novi Vinodolski, near the extension to the forest house Marin vjetar (c. 840 m)	0754/4	1 May 2002
GK30	By the road between Drivenik railway station and Lukovo, near the foresthouse Bukova Draga (c. 920 m)	0754/3	1 May 2002
GK31	National Park „Risnjak", Razloge village (c. 500 m)	0554/1	3 Aug. 2010
GK32	National Park "Risnjak", path from Južni Mali Risnjak to the mountain hut (c. 1,400 m)	0553/4	12 Jun. 2009
GK33	Path from the road Mrkopalj-Plana-Jasenak to the summit of Bijele Stijene (1,335 m)	0755/4	11 Jun. 2009
GK34	Calcareous grassland in the vicinity of Tuk (c. 880 m)	0755/1	11 June 2009
GK35	Southeastern surrounding of Ravna Gora (c. 900 m)	0655/4	5 Oct. 2010

Table 1: List of collection sites in Gorski kotar area and their description.
Tabela 1: Seznam mest vzorčevanja v Gorskem kotarju in njihov opis.

Table 2

Site	Description	MTB	Date
KL1	By the path from Škrljevo railway station (263 m) to Trebestin (542 m)	0653/3	9 Nov. 2000
KL2	Satničko area (704 m), at crossroad of paths from Zlobin and Plase towards Tuhobić	0653/4	28 Apr. 2002
KL3	Surrounding of Meja railway station (445 m), by the path to Satničko	0653/4	28 Apr. 2002
KL4	Surrounding of hotel "Uvala Scott" near the Krk bridge (c. 50 m)	0753/1	15 Sep. 2001
KL5	Surrounding of Zlobin railway station, Draževo area by the path to Satničko (c. 750 m)	0753/2	28 Apr. 2002
KL6	Lipove šume area (c. 700 m), by the road from Plase, above the Vinodol	0753/2	20 Sep. 2001
KL7	Old fortress Drivenik (182 m)	0753/4	23 Jun. 2001
KL8	Medviđak (1,027 m)	0754/1	20 Sep. 2002
KL9	Above Novi Vinodolski, Gusta Draga area (c. 350 m), near the extension to Bribir	0854/2	20 Sep. 2002

Table 2: List of collection sites in Kvarner littoral area and their description.
Tabela 2: Seznam mest vzorčevanja v Kvarnerju in njihov opis.

Results

List of taxa

Acrocordia gemmata (Ach.) A. Massal.
Gorski kotar: Schuler (1902):141; GK23
Kvarner littoral: Schuler (1902):140
Amandinea punctata (Hoffm.) Coppins & Scheid.
Kvarner littoral: Schuler (1902):151 as *Buellia punctiformis*
Anaptychia ciliaris (L.) Körb
Gorski kotar: Schuler (1902):227 as *Physcia ciliaris*; GK1, GK30
Kvarner littoral: Matković (1879):37; Schuler (1902):227 as *Physcia ciliaris*
*GK *Aplotomma turgida* (A. Massal.) A. Massal.
Gorski kotar: GK14, GK20
Arthonia caesia (Flot.) Arnold;
Kvarner littoral: Schuler (1902):142
+ *Arthonia punctiformis* Ach.
Kvarner littoral: Schuler (1902):142 as *Arthonia punctiformis, Arthopyrenia atomaria*
Arthonia radiata (Pers.) Ach.
Gorski kotar: Kušan (1953):111; Christensen and Hansen (1994):104; Ozimec at al. (2010): 22
Kvarner littoral: Schuler (1902):142 as *Arthonia astroidea*
*GK *Arthonia spadicea* Leight.
Gorski kotar: GK8
Arthopyrenia analepta (Ach.) A.Massal.
Kvarner littoral: Schuler (1902):143 as *Arthopyrenia fallax*; Zahlbruckner (1907): 108.
Arthopyrenia cerasi (Schrad.) A. Massal.
Kvarner littoral: Matković (1879):41; Schuler (1902):143
Arthopyrenia cinereopruinosa (Schaer.) A. Massal.
Kvarner littoral: Schuler (1902):143
+ *Arthopyrenia platypyrenia* (Nyl.) Arnold
Kvarner littoral: Zahlbruckner (1906):218
Arthothelium ruanum (A. Massal.) Körb.
Gorski kotar: Schuler (1902):144
Bacidia arceutina (Ach.) Arnold
Kvarner littoral: Schuler (1902):144
Bacidia fiumensis Zahlbr.
Kvarner littoral: Zahlbruckner (1909b):474; Printzen (1995):239
Bacidia laurocerasi (Duby) Zahlbr.
Kvarner littoral: Schuler (1902):145 as *Bacidia endoleuca*
Bacidia rubella (Hoffm.) A. Massal.
Gorski kotar: Schuler (1902):145 as *Bacidia rubella*; GK27
Kvarner littoral: Schuler (1902):145 as *Bacidia rubella*
Bacidia subincompta (Nyl.) Arnold
Gorski kotar: Schuler (1902):144 as *Bacidia atrosanguinea*
Kvarner littoral: Schuler (1902):144 as *Bacidia atrosanguinea*
Bacidina phacodes (Körb.) Vězda
Gorski kotar: Schuler (1902):144 as *Bacidia albescens*
Kvarner littoral: Schuler (1902):144 as *Bacidia albescens, Bilimbia chlorotica*

*GK *Baeomyces rufus* (Huds.) Rebent.
Gorski kotar: GK8; GK18
Kvarner littoral: Schuler (1902):239 as *Sphyridium byssoides*.
Bilimbia sabuletorum (Schreb.) Arnold
Gorski kotar: Schuler (1902):147 as *Bilimbia hypnophila*; Kušan (1933):110 as *Bacidia sabuletorum*; GK27
Kvarner littoral: Schuler (1902):147 as *Bilimbia hypnophila*
+ *Blastodesmia nitida* A.Massal.
Kvarner littoral: Schuler (1902):150
Bryoria capillaris (Ach.) Brodo & D.Hawksw.
Gorski kotar: Schuler (1902):141 as *Alectoria cana*
Bryoria fuscecsens (Gyeln.) Brodo & D. Hawksw.
Gorski kotar: Schuler (1902):141 as *Alectoria jubata*
*HR; *GK *Bryoria implexa* (Hoffm.) Brodo & D. Hawksw.
Gorski kotar: GK6
Buellia disciformis (Fr.) Mudd
Gorski kotar: Schuler (1902):150 as *Buellia parasema*
Kvarner littoral: Matković (1879):38 as *Buellia parasema*; Schuler (1902):150 as *Buellia parasema*
*HR; *GK *Calicium glaucellum* Ach.
Gorski kotar: GK14
Caloplaca cerina (Hedw.) Th.Fr. var. *cerina*
Gorski kotar: Schuler (1902):153; Ozimec et al. (2010):22
Kvarner littoral: Schuler (1902):153
Caloplaca cerinella (Nyl.) Flagey
Kvarner littoral: Schuler (1902):154
Caloplaca ferruginea (Huds.) Th. Fr
Gorski kotar: Schuler (1902):154
Kvarner littoral: Schuler (1902):154; Christensen and Hansen (1994):105
Caloplaca flavorubescens (Huds.) J. R. Laundon
Kvarner littoral: Zahlbruckner (1923):40 as *Caloplaca salicina*
Caloplaca haematites (St.-Amans) Zwackh
Kvarner littoral: Schuler (1902):155; Zahlbruckner (1913):274.
Caloplaca herbidella (Hue) H. Magn.
Gorski kotar: Ozimec et al. (2010):22; GK10; GK14; GK17
Caloplaca luteoalba (Turner) Th. Fr.
Kvarner littoral: Matković (1879):40 as *Callopisma luteo album*
Caloplaca obscurella (Körb.) Th. Fr.
Kvarner littoral: Schuler (1902):156 as *Caloplaca sarcopidoides*
Caloplaca pollinii (A.Massal.) Jatta
Kvarner littoral: Schuler (1902):149 as *Blastenia pollinii*; Christensen and Hansen (1994): 105
Caloplaca pyracea (Ach.) Th. Fr.
Kvarner littoral: Schuler (1902):155
Caloplaca sinapisperma (Lam. & DC.) Maheu & A.Gillet
Gorski kotar: Schuler (1902):148 as *Blastenia leucoraea*
Caloplaca stilicidiorum (Vahl.) Lynge
Gorski kotar: Kušan (1933):115 as *Caloplaca cerina* var. *stillicidiorum*
*GK *Candelaria concolor* (Dicks.) Stein
Gorski kotar: GK1; GK2
Kvarner littoral: Zahlbruckner (1901):85; Schuler (1902):248 as *Xanthoria concolor*; Christensen and Hansen (1994):105; KL4; KL5; KL9
Candelariella reflexa (Nyl.) Lettau
Gorski kotar: Ozimec (2000):135; Ozimec et al. (2010):22
Candelariella vitellina (Hoffm.) Müll. Arg.
Kvarner littoral: Schuler (1902):160 as *Caloplaca vitellina*
Candelariella xanthostigma (Ach.) Lettau
Kvarner littoral: Christensen and Hansen (1994): 106
Catapyrenium cinereum (Pers.) Körb.
Gorski kotar: Kušan (1933):106 as *Dermatocarpon hepaticum*
Kvarner littoral: Schuler (1902):173 as *Dermatocarpon hepaticum*
Catillaria croatica Zahlbr.
Gorski kotar: Zahlbruckner (1906b):487; Printzen (1995):168
Catillaria erysiboides (Nyl.) Th. Fr.
Gorski kotar: Schuler (1902):162
Catillaria nigroclavata (Nyl.) Schuler
Kvarner littoral: Schuler (1902):163
Catinaria atropurpurea (Schaer.) Vězda & Poelt
Kvarner littoral: Schuler (1902):162 as *Catillaria atropurpurea*
Cetraria aculeata (Schreb.) Fr.
Gorski kotar: Schuler (1902):165
Kvarner littoral: Schuler (1902):165
Cetraria islandica (L.) Ach.

Gorski kotar: Schuler (1902):166; Horvat (1930):24; Kušan (1933):114; GK23; GK27
Cetraria sepincola (Ehrh.) Ach.
Gorski kotar: Schuler (1902):166
Cetrelia cetrarioides (Duby) W.L.Culb. & C. F. Culb.
Gorski kotar: GK5; GK26
Cetrelia olivetorum (Nyl.) W.L.Culb. & C. F. Culb.
Gorski kotar: Ozimec et al. (2010):22; GK2; GK4; GK16
Chaenotheca brachypoda (Ach.) Tibell
Kvarner littoral: Hazslinszky (1884):242 as *Coniocybe furfuracea* γ) *sulphurella*
Chaenotheca brunneola (Ach.) Müll. Arg.
Gorski kotar: Ozimec (2000):135; GK8
Chaenotheca furfuracea (L.) Tibell
Kvarner littoral: Matković (1879):41 as *Coniocybe furfuracea*
+ *Chaenothecopsis pusilla* (Ach.) A. F. W. Schmidt
Kvarner littoral: Matković (1879):41 as *Calicium pusillum*
Cladonia cariosa (Ach.) Spreng.
Gorski kotar: Schuler (1902):166
Kvarner littoral: Schuler (1902):166
Cladonia ciliata Stirt.
Gorski kotar: Schuler (1902) as *Cladonia pycnoclada*
Cladonia coniocraea (Flörke) Spreng.
Gorski kotar: Schuler (1902):167 as *Cladonia fimbriata* var. *apolepta*; Kušan (1933):111; Ozimec et al. (2010):22; GK11; GK12; GK14; GK17; GK18; GK22
Cladonia convoluta (Lam.) Anders
Gorski kotar: Schuler (1902):167
Kvarner littoral: Matković (1879):37 as *Cladonia endiviaefolia*; Schuler (1902):167; Kušan (1953); KL1
Cladonia deformis (L.) Hoffm.
Gorski kotar: Kušan (1933):111
Cladonia digitata (L.) Hoffm.
Gorski kotar: Schuler (1902):167
Cladonia fimbriata (L.) Fr.
Gorski kotar: Matković (1879):37; Kušan (1933): 111; Ozimec at al. (2010):23; GK8; GK16
Kvarner littoral: Schuler (1902):167
Cladonia foliacea (Huds.) Willd.
Kvarner littoral: Matković (1879):37 as *Cladonia alcicornis*; Schuler (1902):167; KL4
Cladonia furcata (Huds.) Schrad. subsp. *furcata*
Gorski kotar: Hazslinszky (1884):41; Schuler (1902):168; Kušan (1933):111, Kušan (1953): 296 as *Cladonia furcata* var. *pinnata* f. *foliolosa*; Ozimec et al. (2010):23
Kvarner littoral: Matković (1879):37; Schuler (1902):168
Cladonia gracilis (L.) Willd.
Gorski kotar: Kušan (1933):111 as *Cladonia gracilis* var. *elongata*
Cladonia macilenta Hoffm. subsp. *macilenta*
Gorski kotar: Schuler (1902):166 as *Cladonia bacillaris*
Cladonia macilenta Hoffm. subsp. *floerkeana* (Fr.) V.Wirth
Gorski kotar: Kušan (1933):111 as *Cladonia floerkeana*; Ozimec et al. (2010):23; GK22
Cladonia pocillum (Ach.) O.J.Rich.
Gorski kotar: Schuler (1902):169 as *Cladonia pyxidata* subsp. *pocillum*; Kušan (1933):111 as *Cladonia pyxidata* var. *pocillum*; Kušan (1953):306 as *Cladonia pyxidata* subsp. *pocillum*
Kvarner littoral: Schuler (1902):169 as *Cladonia pyxidata* subsp. *pocillum*
Cladonia polycarpoides Nyl.
Kvarner littoral: Schuler (1902):171 as *Cladonia subcariosa*
Cladonia pyxidata (L.) Hoffm.
Gorski kotar: Matković (1879):37; Schuler (1902):169; Kušan (1933):111 as *Cladonia pyxidata* var. *neglecta*; Kušan (1953):306; Ozimec et al. (2010):23; GK1; GK4; GK6; GK8; GK12; GK14; GK15; GK18; GK17; GK21; GK22; GK26; GK27
Kvarner littoral: Matković (1879):37; Schuler (1902):169; Kušan (1953):306; KL8
Cladonia ramulosa (With.) J.R.Laundon
Gorski kotar: Schuler (1902):169 as *Cladonia pityrea*
Cladonia rangiferina (L.) F.H.Wigg.
Gorski kotar: Matković (1879):37; Hazslinszky (1884):42; Schuler (1902):179; Kušan (1933):111; Ozimec et al. (2010):23; GK6
Cladonia rangiformis Hoffm.
Gorski kotar: Schuler (1902):170
Kvarner littoral: Matković (1879):37 as *Cladonia pungens*; Schuler (1902):170; Kušan (1953):297
*KL *Cladonia squamosa* Hoffm.

Gorski kotar: Schuler (1902):170; GK1; GK27
Kvarner littoral: KL3
Cladonia subulata (L.) F.H.Wigg.
Gorski kotar: Schuler (1902):167 as *Cladonia fimbriata* var. *cornutoradiata*
Kvarner littoral: Schuler (1902):167 as *Cladonia fimbriata* var. *cornutoradiata*
Collema auriforme (With.) Coppins & J. R. Laundon
Gorski kotar: Hazslinszky (1884):290 as *Collema granosum*; Szatala (1929):890 as *Collema auriculatum* f. *membranaceum*; Kušan (1933): 108 as *Collema auriculatum*; Ozimec et al. (2010):23; GK15; GK21
Kvarner littoral: Schuler (1902):171 as *Collema granosum*; KL7
Collema crispum (Huds.) F.H.Wigg.
Kvarner littoral: Matković (1879):42 as *Collema cheileum* α *verum*; Schuler (1902):171 as *Collema cheileum*
Collema cristatum (L.) F.H.Wigg.
Gorski kotar: Kušan (1933):108 as *Collema multifidum*; Ozimec et al. (2010):23
Collema fasciculare (L.) F.H.Wigg.
Kvarner littoral: Schuler (1902):240 as *Synechoblastus conglomeratus*
Collema flaccidum (Ach.) Ach.
Gorski kotar: Hazslinszky (1884):292 as *Synechoblastus flaccidus*; Schuler (1902):240 as *Synechoblastus flaccidus*; Szatala (1929): 887 as *Collema rupestre*; Kušan (1933):109 as *Collema rupestre*; GK27
Kvarner littoral: Schuler (1902):240 as *Synechoblastus flaccidus*
Collema fragrans (Sm.) Ach.
Kvarner littoral: Schuler (1902):172 as *Collema microphyllum*
Collema nigrescens (Hudson) DC.
Gorski kotar: Hazslinszky (1884):293 as *Synechoblastus vespertilio*; Schuler (1902):241 as *Synechoblastus nigrescens*
Kvarner littoral: Matković (1879):42 as *Collema nigrescens* α *vespertilio*; Schuler (1902):241 as *Synechoblastus nigrescens*
Collema occultatum Bagl.
Gorski kotar: Schuler (1902):172 as *Collema quadratum*
Collema subflaccidum Degel.
Gorski kotar: Ozimec et al. (2010):23
Kvarner littoral: Christensen and Hansen (1994): 107
Collema tenax (Sw.) Ach.
Gorski kotar: Kušan (1933):108 as *Collema pulposum*
Kvarner littoral: Schuler (1902):172 as *Collema pulposum*
Degelia plumbea (Lightf.) P. M.Jørg & P. James
Gorski kotar: Schuler (1902):212 as *Pannaria plumbea*; Ozimec et al. (2010):23; GK3; GK4; GK5; GK7; GK18
Kvarner littoral: Hazslinszky (1884):81 as *Pannaria plumbea*; Beck and Zahlbruckner (1898):462 as *Parmeliella plumbea* var. *myriocarpa*; Schuler (1902):212 as *Pannaria plumbea*
Dibaeis baeomyces (L. fil.) Rambold & Hertel
Gorski kotar: Schuler (1902):146 as *Baeomyces roseus*
Kvarner littoral: Schuler (1902):146 as *Baeomyces roseus*
Dimerella lutea (Dicks.) Trevisan
Gorski kotar: Vězda (1969) in Lich. Sel. Exs. 730
Dimerella pineti (Ach.) Vězda
Kvarner littoral: Schuler (1902):174
Diploschistes muscorum (Scop.) R.Sant.
Gorski kotar: Hazslinszky (1884):136 as *Urceolaria scruposus c) bryophila*; Kušan (1933):107 as *Diploschistes bryophilus*
Kvarner littoral: Schuler (1902):175 as *Diploschistes scruposus* var. *bryophilus*
Diplotomma alboatrum (Hoffm.) Flot.
Kvarner littoral: Matković (1879):40
Endocarpon pallidum Ach.
Kvarner littoral: Schuler (1902):176
Endocarpon pusillum Hedw.
Kvarner littoral: Schuler (1902):176
Evernia divaricata (L.) Ach.
Gorski kotar: Schuler (1902):176; GK22
Evernia illyrica (Zahlbr.) Zahlbr.
Gorski kotar: Schuler (1902); Kušan (1933):115; GK22
Evernia prunastri (L.) Ach.
Gorski kotar: Schuler (1902):177; Ozimec et al. (2010):23; GK1; GK6; GK7; GK8; GK17; GK18
Kvarner littoral: Schuler (1902):177; KL4; KL5
*HR; *GK *Fellhanera bouteillei* (Desm.) Vězda
Gorski kotar: GK15
Flavoparmelia caperata (L.) Hale

Gorski kotar: Schuler (1902):214 as *Parmelia caperata*; Ozimec et al. (2010):23; GK2; GK6; GK16; GK17; GK18

Kvarner littoral: Matković (1879):38 as *Imbricaria caperata;* Schuler (1902):214 as *Parmelia caperata*; Zahlbruckner (1913):270 as *Parmelia caperata*; Christensen and Hansen (1994): 109 as *Parmelia caperata*; KL1; KL3; KL4; KL5; KL7

Fulgensia fulgida (Nyl.) Szatala

Kvarner littoral: Schuler (1902):191 as *Lecanora fulgidum*; Zahlbruckner (1912):177 as *Caloplaca fulgida*

Fuscidea stiriaca (A. Massal.) Hafellner

Gorski kotar: Schuler (1902):197 as *Lecidea rivulosa*; Ozimec et al. (2010):23; GK2

*GK *Fuscopannaria ignobilis* (Anzi) P. M. Jørg.

Gorski kotar: GK8; GK31

Fuscopannaria olivacea (P.M.Jørg.) P. M. Jørg.

Kvarner littoral: Schuler (1902):211 as *Pannaria leucosticta*

Graphis scripta (L.) Ach.

Gorski kotar: Schuler (1902):178; Zahlbruckner (1909a):224; Szatala (1929):859; Christensen (1987): 163 as *Graphis scripta* var. *serpentina*; Ozimec et al. (2010):23; GK4; GK10; GK11; GK12; GK14; GK16; GK17; GK16; GK17; GK26.

Kvarner littoral: Schuler (1902):178

Gyalecta derivata (Nyl.) H.Olivier

Gorski kotar: Zahlbruckner (1905b):5 as *Gyalecta croatica*

Gylecta truncigena (Ach.) Hepp

Kvarner littoral: Schuler (1902):178

Gyalecta ulmi (Swartz) Zalhbr.

Gorski kotar: Kušan (1933):108

Heppia lutosa (Ach.) Nyl.

Kvarner littoral: Schuler (1902):179 as *Heppia virescens*

Hyperphyscia adglutinata (Flörke) H.Mayrhofer & Poelt

Kvarner littoral: Schuler (1902):226 as *Physcia adglutinata*

Hypocenomyce scalaris (Ach.) M. Choisy

Gorski kotar: Matković (1879):40 as *Psora ostreata*

Hypogymnia physodes (L.) Nyl.

Gorski kotar: Schuler (1902):218 as *Parmelia physodes*; Kušan (1933):114 as *Parmelia physodes*; Ozimec et al. (2010):23; GK1; GK4; GK6; GK8; GK9; GK10; GK11; GK12; GK14;GK16; GK17; GK18; GK21; GK22; GK27

Kvarner littoral: Matković (1879):38 as *Imbricaria physodes;* Schuler (1902):218 as *Parmelia physodes*; KL4; KL6

Hypogymnia tubulosa (Schaer.) Hav.

Gorski kotar: Ozimec et al. (2010):23; GK17; GK22

Hypogymnia vittata (Ach.) Parrique

Gorski kotar: Schuler (1902):218 as *Parmelia physodes* var. *vittata*

Icmadophila ericetorum (L.) Zahlbr.

Gorski kotar: Hazslinszky (1884):123 as *Icmadophila aeruginosa*; Schuler (1902):179; Kušan (1933):113

+ *Julella lactea* (A.Massal.) M.E.Barr

Kvarner littoral: Schuler (1902):231 as *Polyblastia lactea*

Koerberia biformis A.Massal.

Kvarner littoral: Beck and Zahlbruckner (1898): 467; Schuler (1902):179

Lecania cyrtella (Ach.) Th.Fr.

Gorski kotar: Ozimec et al. (2010):23

Lecania naegelii (Hepp) Diederich & van den Boom

Kvarner littoral: Schuler (1902):148 as *Bilimbia naegelii*

Lecanographa amylacea (Pers.) Egea & Torrente

Gorski kotar: Matković (1879):41 as *Lecanactis illecebrosa*

Lecanora albella (Pers.) Ach.

Gorski kotar: Schuler (1902):188 as *Lecanora pallida*

Kvarner littoral: Matković (1879):40 as *Lecanora scrupulosa*; Schuler (1902):188 as *Lecanora pallida*

Lecanora argentata (Ach.) Malme

Gorski kotar: Christensen (1987):166; Ozimec et al. (2010):23; GK6

Kvarner littoral: Matković (1879):40 as *Lecanora subfusca* var. *argentea*

Lecanora carpinea (L.) Vain.

Gorski kotar: Schuler (1902):185 as *Lecanora angulosa*; Ozimec et al. (2010):23; GK1; GK8; GK11

Kvarner littoral: Schuler (1902):185 as *Lecanora angulosa*; KL5

Lecanora chlarotera Nyl.

Gorski kotar: Schuler (1902):190 as *Lecanora subfusca* f. *rugosa*; Ozimec et al. (2010):24; GK1; GK4; GK27
Kvarner littoral: Schuler (1902):190 as *Lecanora subfusca* f. *rugosa*
Lecanora expallens Ach.
Kvarner littoral: Schuler (1902):186 as *Lecanora conizaea*
Lecanora glabrata (Ach.) Malme
Gorski kotar: Schuler (1902):190 as *Lecanora subfusca* f. *glabrata*
Lecanora hagenii var. *fallax* Hepp
Kvarner littoral: Schuler (1902):187 as *Lecanora hageni*
Lecanora intumescens (Rebent.) Rabenh.
Gorski kotar: Schuler (1902):187
Lecanora pulicaris (Pers.) Ach.
Gorski kotar: Christensen (1987): 163; GK10
Kvarner littoral: Schuler (1902):189
Lecanora sambuci (Pers.) Nyl.
Kvarner littoral: Schuler (1902):188
Lecanora subcarpinea Szatala
Gorski kotar: Ozimec et al. (2010):24
Lecanora symmicta (Ach.) Ach.
Kvarner littoral: Zahlbruckner (1914):145 as *Lecanora symmictera*
Lecidea exigua Chaub.
Kvarner littoral: Schuler (1902):195
Lecidella elaeochroma (Ach.) M.Choisy
Gorski kotar: Schuler (1902):201 as *Lecidea olivacea*,202 as *Lecidea parasema*; Christensen (1987):163 as *Lecidella euphorea*; Ozimec et al. (2010):24; GK1; GK5; GK17; GK27
Kvarner littoral: Schuler (1902):201 as *Lecidea olivacea*, 202 as *Lecidea parasema*; Christensen and Hansen (1994):108 as *Lecidella achristotera*
*HR; *GK *Lepraria eburnea* J. R. Laundon
Gorski kotar: GK14
Lepraria incana (L.) Ach.
Gorski kotar: Christensen (1987):167; Ozimec et al. (2010):24
*HR; *GK *Lepraria rigidula* (de Lesd.) Tønsberg
Gorski kotar: GK10; GK22
Leptogium cyanescens (Rabenh.) Körb.
Kvarner littoral: Christensen and Hansen (1994): 108
Leptogium gelatinosum (With.) J. R. Laundon
Kvarner littoral: Schuler (1902):205 as *Leptogium sinuatum*
Leptogium lichenoides (L.) Zahlbr.
Gorski kotar: Szatala (1929):899; Kušan (1933): 109; Ozimec et al. (2010):24
Kvarner littoral: Hazslinszky (1884):294 as *Leptogium lacerum* c) *lophaeum*; Schuler (1902): 205 as *Leptogium atrocoeruleum.*
Leptogium saturninum (Dicks.) Nyl.
Gorski kotar: Hazslinszky (1884):296 as *Mallotium saturninum*; Schuler (1902):207 as *Mallotium saturninum*
Lobaria amplissima (Scop.) Forssell
Gorski kotar: Hazslinszky (1884):61 as *Sticta amplissima*; Schuler (1902):206; Zahlbruckner (1914):145 as *Lobaria laciniata*; Szatala (1929):914; Ozimec et al. (2010):24; GK1; GK23; GK29
Lobaria pulmonaria (L.) Hoffm.
Gorski kotar: Schuler (1902):206 as *Lobaria pulmonacea*; Szatala (1929):916; Kušan (1933):109; Ozimec et al. (2010):24; GK3; GK4; GK5; GK7; GK8; GK10; GK11; GK12; GK15; GK16; GK17; GK20; GK23; GK24; GK25; GK26; GK27; GK28; GK29; GK30; GK33; GK35
Kvarner littoral: Matković (1879):38 as *Sticta pulmonaria*; Schuler (1902):206 as *Lobaria pulmonacea*.
*HR; *GK *Lobaria virens* (With.) J.R.Laundon
Gorski kotar: GK29
Lobarina scrobiculata (Scop.) Nyl.
Gorski kotar: Hazslinszky (1884):60 as *Sticta scrobiculata*; Schuler (1902):240 as *Sticta scrobiculata*; Ozimec et al. (2010):24
Kvarner littoral: Schuler (1902):240 as *Sticta scrobiculata*
Lopadium disciforme (Flot.) Kullh.
Gorski kotar: Schuler (1902):206 as *Lopadium pezizoideum*
Maronea constans (Nyl.) Hepp
Gorski kotar: Schuler (1902):207
Kvarner littoral: Schuler (1902):207 as *Maronea berica*
Megalaria laureri (Th.Fr.) Hafellner
Gorski kotar: Schuler (1902):165 as *Catillaria laurerei*; Ozimec et al. (2010):24
Megaspora verrucosa (Ach.) Hafellner & V. Wirth
Gorski kotar: Schuler (1902):184 as *Lecanora verrucosa*

Melanelixia fuliginosa (Duby) O. Blanco et al. subsp. *fuliginosa*
Gorski kotar: Schuler (1902):216 as *Parmelia fuliginosa*
Kvarner littoral: Schuler (1902):216 as *Parmelia fuliginosa*
Melanelixia fuliginosa (Duby) O. Blanco et al. subsp. *glabratula* (Lamy) J. R. Laundon
Gorski kotar: Schuler (1902):216 as *Parmelia fuliginosa* var. *laetevirens*; 217: as *Parmelia glabratula;* Christensen (1987):163 as *Parmelia glabratula*; Ozimec et al. (2010): 24; GK11; GK14; GK16; GK18; GK27; GK28; GK33
Kvarner littoral: Schuler (1902):216 as *Parmelia fuliginosa* var. *laetevirens*; Christensen and Hansen (1994):109 as *Parmelia glabratula* subsp. *glabratula*
Melanelixia glabra (Schaer.) O.Blanco et al.
Gorski kotar: Schuler (1902) as *Parmelia glabra*
Kvarner littoral: Schuler (1902) as *Parmelia glabra*
Melanelixia subaurifera (Nyl.) O. Blanco et al.
Kvarner littoral: Schuler (1902) as *Parmelia subaurifera*; Christensen and Hansen (1994): 109 as *Parmelia subaurifera*
Melanohalea exasperata (De Not.) O. Blanco et al.
Gorski kotar: Schuler (1902):216 as *Parmelia exasperata*; GK26
Kvarner littoral: Schuler (1902):216 as *Parmelia exasperata*; Christensen and Hansen (1994):109 as *Parmelia exasperata*
Melaspilea urceolata (Fr.) Almb.
Kvarner littoral: Schuler (1902):207 as *Melaspilea arthonioides*
Menegazzia terebrata (Hoffm.) A.Massal.
Gorski kotar: Schuler (1902):218 as *Parmelia pertusa*; Ozimec et al. (2010):24
Micarea lignaria (Ach.) Hedl.
Gorski kotar: Hazslinszky (1884):175 as *Bilimbia milliaria*; Schuler (1902):148 as *Bilimbia lignaria.*
Micarea prasina Fr.
Gorski kotar: Schuler (1902):164 as *Catillaria prasina*
Kvarner littoral: Schuler (1902):164 as *Catillaria prasina*
Moelleropsis nebulosa (Hoffm.) Gyeln.
Kvarner littoral: Schuler (1902):212 as *Pannaria nebulosa*
Mycobilimbia berengeriana (A. Massal.) Hafellner & V.Wirth
Gorski kotar: Kušan (1933):110 as *Lecidea berengeriana*
Mycobilimbia hypnorum (Lib.) Kalb & Hafellner
Gorski kotar: Schuler (1902):195 as *Lecidea fusca*
Kvarner littoral: Schuler (1902):195 as *Lecidea fusca*
Mycobilimbia pilularis (Körb.) Hafellner & Türk
Kvarner littoral: Schuler (1902):164 as *Catillaria sphaeroides*.
*HR; *GK *Mycobilimbia sanguineoatra* auct.
Gorski kotar: GK27
Mycobilimbia tetramera (De Not) Hafellner & Türk
Gorski kotar: Schuler (1902):148 as *Bilimbia obscurata*
*GK *Mycoblastus sanguinarius* (L.) Norman
Gorski kotar: GK22
Nephroma laevigatum Ach.
Gorski kotar: Schuler (1902):208 as *Nephromium lusitanicum*; Kušan (1933):109 as *Nephroma lusitanicum*; GK5; GK29
Kvarner littoral: Schuler (1902):208 as *Nephromium lusitanicum*
Nephroma parile (Ach.) Ach.
Gorski kotar: Schuler (1902):208 as *Nephromium laevigatum* var. *parile*; Ozimec et al. (2010):24; GK13; GK17; GK27
Kvarner littoral: Schuler (1902):208 as *Nephromium laevigatum* var. *parile*
Nephroma resupinatum (L.) Ach.
Gorski kotar: Hazslinszky (1884):54 as *Nephroma tomentosum*; Schuler (1902):209 as *Nephromium resupinatum*; Kušan (1933):110; GK17; GK23; GK29; GK30
Normandina pulchella (Borrer) Nyl.
Gorski kotar: Hazslinszky (1884):79; Schuler (1902):209; Ozimec et al. (2010):24; GK8; GK17; GK29
Kvarner littoral: Schuler (1902):209; Zahlbruckner (1911):239; KL7
*GK *Ochrolechia androgyna* (Hoffm.) Arnold
Gorski kotar: Ozimec et al. (2010):24; GK10; GK17; GK27
*GK *Ochrolechia turneri* (Sm.) Hasselrot

Gorski kotar: GK17
Opegrapha atra Pers.
Gorski kotar: Hazslinszky (1884):222; Szatala (1929):843; Christensen (1987):163
Kvarner littoral: Matković (1879):41; Schuler (1902):209; Zahlbruckner (1907):109.
Opegrapha rufescens Pers.
Kvarner littoral: Schuler (1902):210
Opegrapha varia Pers.
Kvarner littoral: Schuler (1902):210
Opegrapha viridis (Ach.) Behlen & Desberger
Gorski kotar: Schuler (1902):210
Pannaria conoplea (Ach.) Bory
Gorski kotar: Schuler (1902):211 as *Pannaria coeruleobadia*; Ozimec et al. (2010):24; GK8
Kvarner littoral: Schuler (1902):211 as *Pannaria coeruleobadia*
Pannaria rubiginosa (Ach.) Bory
Kvarner littoral: Schuler (1902):213
Parmelia saxatilis (L.) Ach.
Gorski kotar: Matković (1879):38 as *Imbricaria saxatilis;* Schuler (1902):219; Ozimec et al. (2010):24; GK1; GK5; GK6; GK9; GK10; GK11; GK12; GK14; GK16; GK20; GK22; GK26; GK27, GK29
Kvarner littoral: Matković (1879):38 as *Imbricaria saxatilis;* Schuler (1902); Alebić-Juretić and Arko-Pijevac (1989):30; Christensen and Hansen (1994):109; KL5
Parmelia submontana Hale
Gorski kotar: Ozimec et al. (2010):24; GK15; GK22; GK26
Parmelia sulcata Taylor
Gorski kotar: Ozimec et al. (2010):24; GK1; GK2; GK4; GK6; GK7; GK8; GK11; GK14; GK16; GK17; GK20; GK22; GK27; GK29
Kvarner littoral: Hazszlinszky (1884):63 as *Imbricaria saxatilis* a) *leucochroa*; Christensen and Hansen (1994):109; KL2; KL3; KL
Parmeliella triptophylla (Ach.) Müll.Arg.
Gorski kotar: Hazszlinszky (1884):83 as *Pannaria triptophylla*; Schuler (1902):214 as *Pannaria corallinoides*; GK8
Kvarner littoral: Schuler (1902):214 as *Pannaria corallinoides*
*KL *Parmelina pastillifera* (Harm.) Hale
Gorski kotar: Ozimec et al. (2010):25; GK13; GK16; GK22
Kvarner littoral: KL2; KL6
Parmelina quercina (Willd.) Hale
Kvarner littoral: Christensen and Hansen (1994): 109 as *Parmelia quercina*; KL4
Parmelina tiliacea (Hoffm.) Hale
Gorski kotar: Schuler (1902):219 as *Parmelia tiliacea*; GK1; GK2; GK8; GK13; GK14
Kvarner littoral: Hazszlinszky (1884):62 as *Imbricaria tiliacea* c) *quercifolia*; Schuler (1902):219 as *Parmelia tiliacea*; Alebić-Juretić and Arko-Pijevac (1989):27; KL3; KL4; KL5
Parmeliopsis ambigua (Wulfen) Nyl.
Gorski kotar: Matković (1879):38 as *Imbricaria diffusa;* Schuler (1902):215 as *Parmelia diffusa*; Ozimec et al. (2010):25
Parmotrema perforatum (Jacq.) A.Massal.
Gorski kotar: Schuler (1902):218 as *Parmelia perforata*
Kvarner littoral: Schuler (1902):218 as *Parmelia perforata*
Parmotrema perlatum (Huds.) M. Choisy
Gorski kotar: Matković (1879):38 as *Imbricaria perlata*; Hazszlinszky (1884); Ozimec et al. (2010):25; GK11; GK16; GK17; GK18; GK26; GK27
Kvarner littoral: Matković (1879):38 as *Imbricaria perlata*; Alebić-Juretić and Arko-Pijevac (1989):30; Christensen and Hansen (1994):109 as *Parmelia coniocarpa*; KL5; KL7
Peltigera aphthosa (L.) Willd.
Gorski kotar: Schuler (1902):220 as *Peltidea aphthosa*
Kvarner littoral: Matković (1879):38
Peltigera canina (L.) Willd.
Gorski kotar: Hazszlinszky (1884):56; Schuler (1902):220
Kvarner littoral: Matković (1879):38; Schuler (1902):220
Peltigera collina (Ach.) Schrad.
Gorski kotar: Hazszlinszky (1884):56 as *Peltigera propagulifera*; Schuler (1902):221 as *Peltigera scutata*; Kušan (1933):110 as *Peltigera scutata*; Ozimec et al. (2010):25; GK4; GK8;GK18; GK20; GK22; GK23; GK29.
Peltigera horizontalis (Hudson) Baumg.
Gorski kotar: Hazszlinszky (1884):57; Schuler (1902):220; Kušan (1933):110; Ozimec et al. (2010):25; GK3; GK5; GK19; GK27.
Kvarner littoral: Matković (1879):38; Schuler (1902):220

*GK *Peltigera leucophlebia* (Nyl.) Gyeln.
Gorski kotar: GK21; GK32; GK33
*GK *Peltigera neckeri* Müll.Arg
Gorski kotar: GK7
Peltigera polydactyla (Neck.) Hoffm.
Gorski kotar: Ozimec et al. (2010):25
Kvarner littoral: Schuler (1902):221
Peltigera praetextata (Sommerf.) Zopf
Gorski kotar: Kušan (1933); Ozimec et al. (2010):25; GK1; GK3; GK5; GK8; GK12; GK17; GK19; GK20; GK22; GK27; GK29.
Peltigera rufescens (Weiss) Humb.
Gorski kotar: Schuler (1902):221; Kušan (1933): 110; GK34
Kvarner littoral: Hazszlinszky (1884):56; Schuler (1902):221; Christensen and Hansen (1994):109; KL3
Pertusaria albescens (Hudson) M.Choisy & Werner
Gorski kotar: Schuler (1902):222 as *Pertusaria globulifera*; Kušan (1933):112 as *Pertusaria globulifera*; Ozimec et al. (2010):25; GK5; GK6; GK10; GK14; GK16; GK17; GK18; GK19; GK26
Kvarner littoral: KL5
Pertusaria amara (Ach.) Nyl.
Gorski kotar: Schuler (1902); Kušan (1933):112 as *Pertusaria amara* f. *isidiata*; Ozimec et al. (2010):25; GK7; GK8; GK10; GK11; GK16; GK17; GK18; GK19; GK20; GK22
Kvarner littoral: Schuler (1902):221
*GK *Pertusaria coccodes* (Ach.) Nyl.
Gorski kotar: GK8
*GK *Pertusaria flavida* (DC.) J. R. Laundon
Gorski kotar: GK26
Pertusaria hemisphaerica (Flörke) Erichsen
Gorski kotar: Ozimec et al. (2010):25; GK5; GK17
Pertusaria hymenea (Ach.) Schaer.
Gorski kotar: Schuler (1902):224 as *Pertusaria wulfenii*
Kvarner littoral: Schuler (1902):224 as *Pertusaria wulfenii*
Pertusaria leioplaca DC.
Gorski kotar: Schuler (1902):224; GK12, GK14
Kvarner littoral: Schuler (1902):224
Pertusaria pertusa (Weigel) Tuck.
Gorski kotar: Matković (1879):42 as *Pertusaria communis;* Hazszlinszky (1884):248 as *Pertusaria commmunis*; Schuler (1902):222 as *Pertusaria communis*; Ozimec et al. (2010): 25; GK4; GK6, GK7; GK10; GK12; GK13; GK14; GK16; GK17; GK18; GK19; GK26; GK27
Kvarner littoral: Schuler (1902):222 as *Pertusaria communis*; KL2
*HR; *GK *Pertusaria pupillaris* (Nyl.) Th. Fr.
Gorski kotar: GK14
Pertusaria pustulata (Ach.) Duby
Kvarner littoral: Schuler (1902):224
Pertusaria trachythallina Erichsen
Kvarner littoral: Schuler (1902):223 as *Pertusaria laevigata*
Phaeographis dendritica (Ach.) Müll.Arg.
Kvarner littoral: Matković (1879):41
Phaeophyscia hirsuta (Mereschk.) Essl.
Kvarner littoral: Christensen and Hansen (1994): 109
Phaeophyscia insignis (Mereschk.) Moberg
Kvarner littoral: Christensen and Hansen (1994): 109
Phaeophyscia orbicularis (Neck.) Moberg
Kvarner littoral: Schuler (1902):228 as *Physcia obscura*
Phlyctis agelaea (Ach.) Flot.
Kvarner littoral: Schuler (1902):225
*KL *Phlyctis argena* (Spreng.) Flot.
Gorski kotar: Christensen (1987):163; Ozimec et al. (2010):25; GK4; GK8; GK10; GK11; GK13; GK14; GK17; GK18; GK19; GK22; GK27; GK29
Kvarner littoral: KL2
*GK *Physcia adscendens* H.Olivier
Gorski kotar: GK2
Kvarner littoral: Christensen and Hansen (1994): 110; KL2; KL5
Physcia aipolia (Humb.) Fürnrh.
Gorski kotar: Schuler (1902):226; Ozimec et al. (2010):25; GK6
Kvarner littoral: Schuler (1902):226; Zahlbruckner (1913):274; Christensen and Hansen (1994):110; KL2
Physcia clementei (Turner) Maas Geest.
Kvarner littoral: Schuler (1902):227 as *Physcia astroidea*
*GK *Physcia dubia* (Hoffm.) Lettau
Gorski kotar: GK14
Physcia leptalea (Ach.) DC.
Kvarner littoral: Schuler (1902):230 as *Physcia stellaris* var. *leptalea*

Physcia stellaris (L.) Nyl.
Gorski kotar: Schuler (1902):229; GK8
Kvarner littoral: Matković (1879):38 as *Parmelia stellaris;* Schuler (1902):229; Christensen and Hansen (1994):110
Physcia tenella (Scop.) DC.
Kvarner littoral: Schuler (1902):230
Physconia distorta (With.) J.R.Laundon
Gorski kotar: Schuler (1902):229 as *Physcia pulverulenta*; Ozimec et al. (2010):25; GK1; GK19; GK22
Kvarner littoral: Matković (1879):39 as *Parmelia pulverulenta;* Schuler (1902):229 as *Physcia pulverulenta*; Christensen and Hansen (1994):110; KL3; KL7
*GK *Physconia venusta* (Ach.) Poelt
Gorski kotar: GK1; GK27
Kvarner littoral: Schuler (1902) as *Physcia pulverulenta* var. *venusta*
Placynthiella icmalea (Ach.) Coppins & P. James
Gorski kotar: Ozimec (2000):136
Platismatia glauca (L.) W.L.Culb. & C.F.Culb.
Gorski kotar: Schuler (1902):165 as *Cetraria glauca*; Kušan (1933):114 as *Cetraria glauca*; Ozimec et al. (2010):25; GK4; GK6; GK9; GK10; GK12; GK18; GK20; GK22; GK27
Pleurosticta acetabulum (Neck.) Elix & Lumbsch
Gorski kotar: Hazslinszky (1884):65 as *Imbricaria acetabulum*; Schuler (1902):214 as *Parmelia acetabulum*; Ozimec et al. (2010): 25; GK1; GK16
Kvarner littoral: Schuler (1902):214 as *Parmelia acetabulum*; Christensen and Hansen (1994):108 as *Parmelia acetabulum*; KL2; KL6
Polyblastia sendtneri Kremp.
Gorski kotar: Schuler (1902):231.
Polyblastiopsis meridionalis Zahlbr.
Kvarner littoral: Zahlbruckner (1909a):223.
Porina aenea (Wallr.) Zahlbr.
Kvarner littoral: Schuler (1902):237 as *Sagedia carpinea*; Zahlbruckner (1923):39 as *Porina carpinea*
Protopannaria pezizoides (Weber) P. M. Jørg & S. Ekman
Gorski kotar: Schuler (1902):212 as *Pannaria pezizoides*; Kušan (1933):109 as *Pannaria pesisoides*
Kvarner littoral: Matković (1879):39 as *Pannaria brunnea*
Psora decipiens (Hedw.) Hoffm.
Kvarner littoral: Schuler (1902):203 as *Lecidea decipiens*
Pseudevernia furfuracea (L.) Zopf
Gorski kotar: Schuler (1902); Kušan (1933):114 as *Parmelia furfuracea*; Ozimec et al. (2010):26; GK1; GK2; GK3; GK5; GK6; GK8; GK9; GK10; GK11; GK12; GK13; GK17; GK20; GK21; GK22; GK25; GK26; GK27, GK29
Kvarner littoral: Schuler (1902); KL4; KL6; KL8
Punctelia subrudecta (Nyl.) Krog
Gorski kotar: Ozimec et al. (2010):26
Kvarner littoral: Schuler (1902):215 as *Parmelia dubia*; Christensen and Hansen (1994):109 as *Parmelia subrudecta*; KL1; KL3; KL4; KL9
Pyrenula laevigata (Pers.) Arnold
Kvarner littoral: Schuler (1902):232
Pyrenula nitida (Weigel) Ach.
Gorski kotar: Schuler (1902):232; Szatala (1927); Ozimec et al. (2010):26; GK16
Kvarner littoral: Schuler (1902):232
Ramalina calicaris (L.) Fr. var. *calicaris*
Gorski kotar: Schuler (1902):232
Ramalina farinacea (L.) Ach.
Gorski kotar: Schuler (1902):233; Ozimec et al. (2010):26; GK5; GK6; GK7; GK8; GK16; GK17; GK22
Kvarner littoral: Schuler (1902):233; KL4
Ramalina fastigiata (Pers.) Ach.
Gorski kotar: Schuler (1902):233; Ozimec et al. (2010):26; GK1; GK2; GK6; GK16; GK17; GK19; GK33
Kvarner littoral: Schuler (1902):233
Ramalina fraxinea (L.) Ach.
Gorski kotar: Schuler (1902):233; Ozimec et al. (2010):26; GK6; GK16; GK22;GK33
Kvarner littoral: Schuler (1902):233
Ramalina thrausta (Ach.) Nyl.
Gorski kotar: Schuler (1902):234
Rinodina colobina (Ach.) Th.Fr.
Kvarner littoral: Schuler (1902):235
Rinodina dalmatica Zahlbr.
Kvarner littoral: Schuler (1902):236
Rinodina exigua (Ach.) Gray

Kvarner littoral: Schuler (1902):236; Christensen and Hansen (1994):110
Rinodina plana H. Magn.
Kvarner littoral: Zahlbruckner (1909a):230 as *Rinodina metabolica*; Magnusson (1947):298; Ropin and Mayrhofer (1993):812
Rinodina pyrina (Ach.) Arnold
Kvarner littoral: Christensen and Hansen (1994): 111
Rinodina sophodes (Ach.) A.Massal.
Gorski kotar: Schuler (1902):237.
Kvarner littoral: Matković (1879):39; Schuler (1902):237; Zahlbruckner (1915):478.
Scoliciosporum umbrinum (Ach.) Arnold
Gorski kotar: Schuler (1902):146 as *Bacidia umbrina* var. *compacta*
Solorina saccata (L.) Ach.
Gorski kotar: Schuler (1902):239; Kušan (1933): 109; GK28; GK32;GK33
Kvarner littoral: Schuler (1902):239
Sphaerophorus globosus (Huds.) Vain.
Gorski kotar: Schuler (1902):239 as *Sphaerophorus coralloides*; Szatala (1927):434; Kušan (1933):107; GK22; GK33
Squamarina cartilaginea (With.) P.James
Gorski kotar: Kušan (1933):113 as *Lecanora crassa*; Ozimec et al. (2010):26
Strigula stigmatella (Ach.) R. C. Harris
Gorski kotar: Schuler (1902):237 as *Strigula faginea*
Kvarner littoral: Schuler (1902):237 as *Strigula faginea*
Teloschistes chrysophthalmus (L.) Th. Fr.
Kvarner littoral: Schuler (1902):241
Thelenella muscorum (Fr.) Vain.
Gorski kotar: Schuler (1902):207 as *Microglaena muscicola*
Kvarner littoral: Schuler (1902):207 as *Microglaena muscicola*
Thelotrema lepadinum (Ach.) Ach.
Gorski kotar: Hazslinszky (1884):137; Schuler (1902):242; Ozimec et al. (2010):26; GK4; GK5; GK11; GK12; GK22
Toninia sedifolia (Scop.) Timdal
Gorski kotar: Kušan (1933):111 as *Toninia coerulenigricans*; Ozimec et al. (2010):26
Kvarner littoral: Schuler (1902):243 as *Toninia caeruleonigricans*
Usnea diplotypus Vain.
Gorski kotar: Ozimec (2000):136
Usnea filipendula Stirt.
Gorski kotar: Matković (1879):37; Ozimec et al. (2010):26; GK6; GK8; GK25
Usnea florida (L.) F.H.Wigg.
Gorski kotar: Schuler (1902):245 as *Usnea barbata*
Usnea hirta (L.) Weber ex F. H. Wigg.
Kvarner littoral: Schuler (1902):245 as *Usnea barbata* var. *hirta*
*HR; *GK *Usnea intermedia* (A.Massal.) Jatta
Gorski kotar: GK3; GK22
Usnea rubicunda Stirt.
Kvarner littoral: Motyka (1936–1938):343
Usnea subfloridana Stirt.
Gorski kotar: Ozimec (2000):136; GK6
Xanthoria candelaria (L.) Th. Fr.
Kvarner littoral: Schuler (1902):249 as *Xanthoria lychnea*
Xanthoria parietina (L.) Th.Fr.
Gorski kotar: Schuler (1902):249; Ozimec et al. (2010):26; GK1; GK2; GK6; GK22
Kvarner littoral: Matković (1879):39 as *Physcia parietina*; Schuler (1902):249; Christensen and Hansen (1994):111; KL2; KL4
Xylographa parallela (Ach.) Behlen & Desberger
Gorski kotar: Schuler (1902):250; Szatala (1929): 842

Analysis of the flora

According to literature, collection records at herbaria and field survey results, the currently konwn epiphytic and terricolous lichen mycota of Gorski kotar and Kvarner littoral comprises 264 taxa (260 lichenized fungi and 4 non-lichenized fungi traditionally included in the lichenological literature), classified into 110 genera.

The lichen mycota of Gorski kotar consists of 184 taxa, and of Kvarner littoral contains 170 taxa.

The most diverse genera are: *Cladonia* (20 taxa); *Caloplaca* and *Lecanora* (12 taxa each); *Pertusaria* (11); *Collema* (10); *Peltigera* (9); *Physcia* and *Usnea* (7 taxa each); *Rinodina* (6); and *Bacidia, Mycobilimbia* and *Ramalina* (5 taxa each).

Nine species: *Bryoria implexa, Calicium glaucellum, Fellhanera bouteillei, Lepraria eburnea, Lepraria rigidula, Lobaria virens, My-*

cobilimbia sanguineoatra, Pertusaria pupillaris and *Usnea intermedia*, are new to Croatia.

Twenty-four species: *Aplotomma turgida, Arthonia spadicea, Baeomyces rufus, Bryoria implexa, Calicium glaucellum, Candelaria concolor, Fellhanera bouteillei, Fuscopannaria ignobilis, Lepraria eburnea, Lepraria rigidula, Lobaria virens, Mycobilimbia sanugineoatra, Mycoblastus sanguinarius, Ochrolechia androgyna, Ochrolechia turneri, Peltigera leucophlaebia, Peltigera neckeri, Pertusaria coccodes, Pertusaria flavida, Pertusaria pupillaris, Physcia adescendens, Physcia dubia, Physconia venusta* and *Usnea intermedia*, are new to Gorski kotar, while three species: *Cladonia squamosa, Parmelina pastillifera* and *Phylctis argena* are new to Kvarner littoral.

Ecological analyses

Distribution of mean indicator values of the environmental factors for the lichens recorded in Gorski kotar and Kvarner littoral is presented in Figs 2-6.

Mean indicator values of the lichen flora of Gorski kotar and Kvarner littoral (Tab. 1) were compared to those reported for selected areas in Dinaric floristic region of Slovenia: Snežnik, Goteniški Snežnik, Krokar, Trnovski gozd (Prügger 2005), and in the Alpine floristic area of Slovenia: Pohorje (Mayrhofer et al. 1996, 1998), and Uršlja gora (Suppan and Mayrhofer 2002). Comparison is shown in Fig. 7.

Phytogeographical analyses

Relief variety and climate with abundant rainfalls, high air humidity and frequent fog and dew, enables the occurrence of lichens classified into oceanic and suboceanic elements (Schauer 1965). Numbers of such species are: 46 or 25.0% of total recorded for the lichen flora of Gorski kotar and 42 (24.7%) for Kvarner littoral. Taking into account both areas, there are 70 species belonging to oceanic and suboceanic elements, which makes 26.5% of total lichen flora.

Discussion

The epiphytic and terricolous lichen flora of Gorski kotar and Kvarner littoral was compared to the lichenologically better investigated areas in Dinaric part of neighbouring Slovenia, as well as with areas in NE Italy. The number of 184 taxa reported for Gorski kotar is lower, compared to

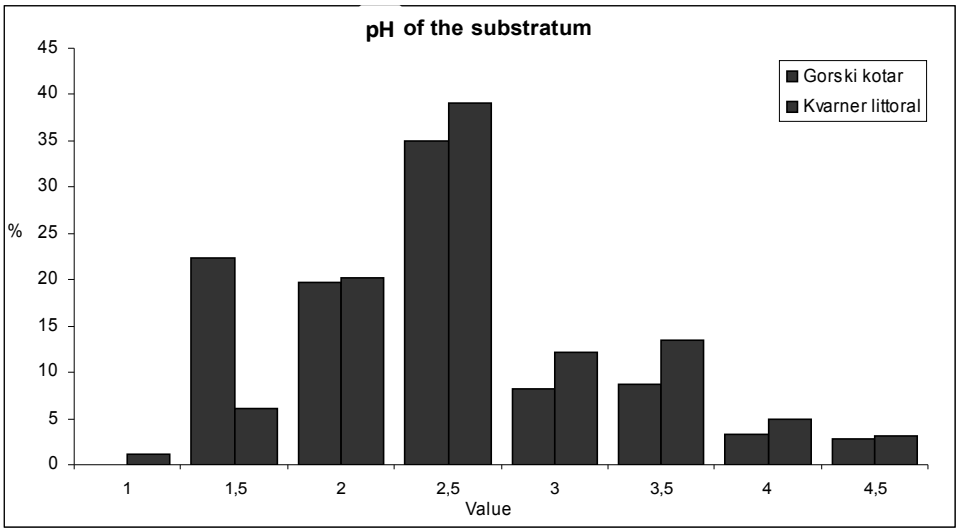


Figure 2: Distribution of indicator values for substrate reaction.
Slika 2: Razširjenost indikatorskih vrednosti glede na reakcijo substrata.

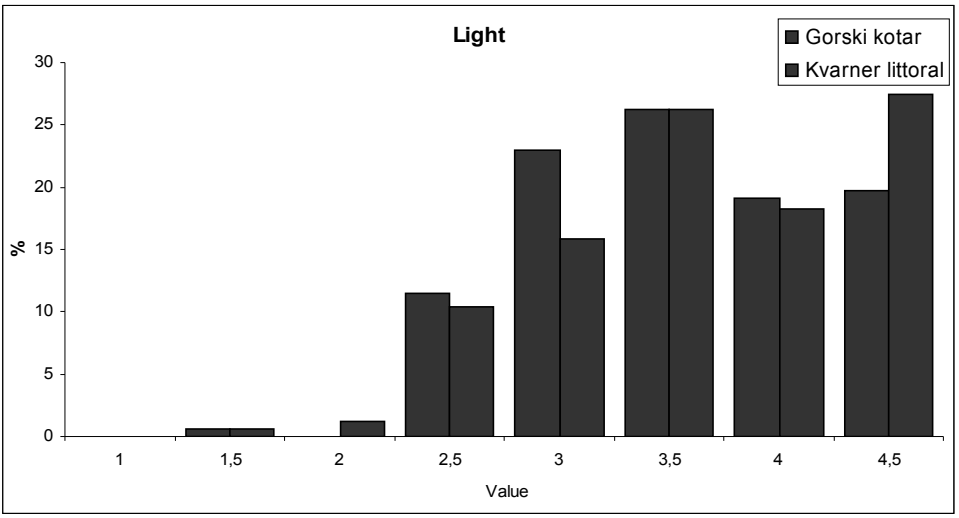


Figure 3: Distribution of indicator values for the lichens for light.
Slika 3: Razširjenost indikatorskih vrednosti za lišaje glede na potrebe po svetlobi.

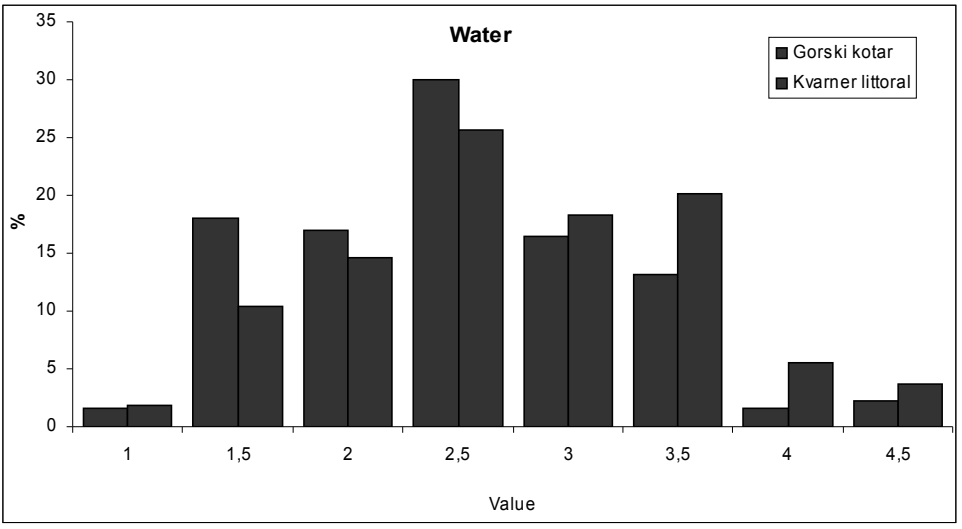


Figure 4: Distribution of indicator values for the lichens for moisture.
Slika 4: Razširjenost indikatorskih vrednosti za lišaje glede na vlažnostne razmere.

total of 330 taxa (excluding saxicolous) recorded for Snežnik and Javorniki area in southern Slovenia (Prügger 2005). For Goteniški Snežnik and Krokar area, total of 134 and 141 taxa, respectively, were reported by Grube et al. (1998). In Trnovski gozd, situated near the Italian-Slovenian border, Prügger et al. (2000) reported 203 taxa. Number of 170 lichen taxa recorded up today for Kvarner littoral is higher, compared to similar regions in Italy, situated in the vicinity of the Adriatic Sea. In NE Italy, 60 epiphytic lichen species were reported for the Province of Gorizia (Badin and

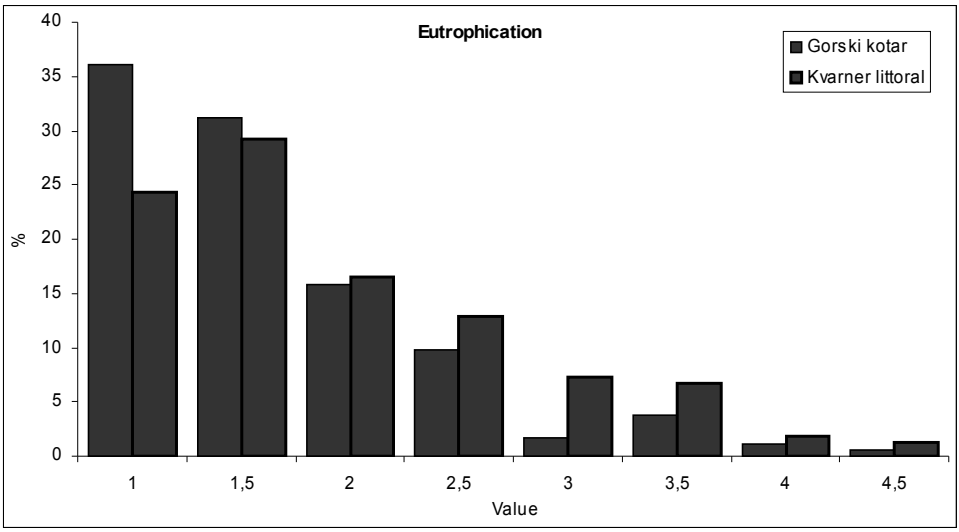


Figure 5: Distribution of indicator values for eutrophication.
Slika 5: Razširjenost indikatorskih vrednosti glede na trofične razmere.

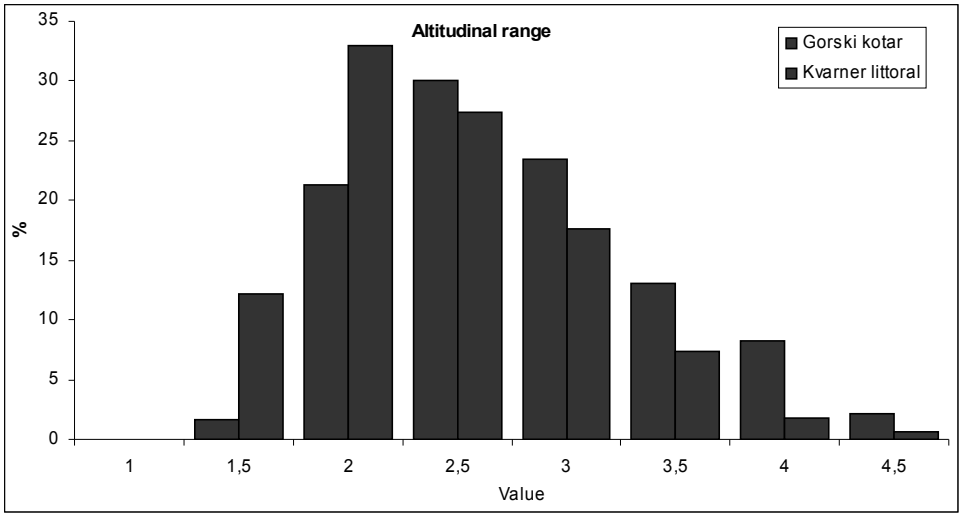


Figure 6: Distribution of indicator values for the lichens for altitudinal range.
Slika 6: Razširjenost indikatorskih vrednosti za lišaje glede na nadmorsko višino

Nimis 1996), 121 species from the Province of Trieste (Nimis 1982), and 80 species from the Veneto Region (Nimis et al. 1991).

Analyses of indicator values for substrate reaction (Fig. 2) shows that acidophilic lichens are more present in Gorski kotar then in Kvarner littoral, because the environmental conditions in Gorski kotar favorize growth of acid bark conifers, such as fir, spruce and pine. Lichens of weak acid to subneutral reaction dominates in both area, which is related to bark characteristics of deciduous trees as the most frequent phorophytes. Higher

Table 3

Region	Substrate reaction – R	Light L	Moisture F	Eutrophication N	Altitudinal range – A
Gorski kotar	2,37	3,49	2,45	1,62	2,75
Kvarner littoral	2,60	3,59	2,69	1,88	2,37
Slovenia – Dinaric area	2,45	3,47	2,45	1,90	2,58
Slovenia – Alpine area	2,24	3,66	2,60	1,95	2,65

Table 3: Mean indicator values of the lichen flora of Gorski kotar, Kvarner littoral and areas in Slovenia.
Tabela 3: Srednje indikatorske vrednosti lišajske flore Gorskega kotarja, Kvarnerja in območij v Sloveniji.

incidence of basophilous lichens in Kvarner littoral is result of bark pH modification due to effect of impregnation of trees with calcareous dust, as well as influence of dispersal of salt an ammonia particles by wind near the sea.

Analyses of indicator values for light (Fig. 3) shows negligible presence of lichens living in shade. The most of lichens in both areas lives on sites which are well exposed to light. Incidence of lichens requiring diffuse light is higher in Gorski kotar, where such light conditions are specific for the closed beech forests. Heliophytic lichens are largely present in Kvarner littoral, where low termophilous forests, thickets and open landscapes dominates.

Analyses of indicator values for humidity (Fig. 4) shows a higher presence of hygrophytic and moderately hygrophytic lichens in Gorski kotar. This indicates climate specifities of the area, with high air humidity (> 80%), abundant rainfalls and frequent fogs. The lichens indicating dryness are more present in the subalpine and alpine belt, where higher solar irradiation, strong wind and frost during the winter cause rapid dessication of thalli surface. The climate in Kvarner littoral is subhumid and warm, with pronounced dry period and low relative air humidity (60-70%), so the mesophytic and xerophytic lichens prevails in the area.

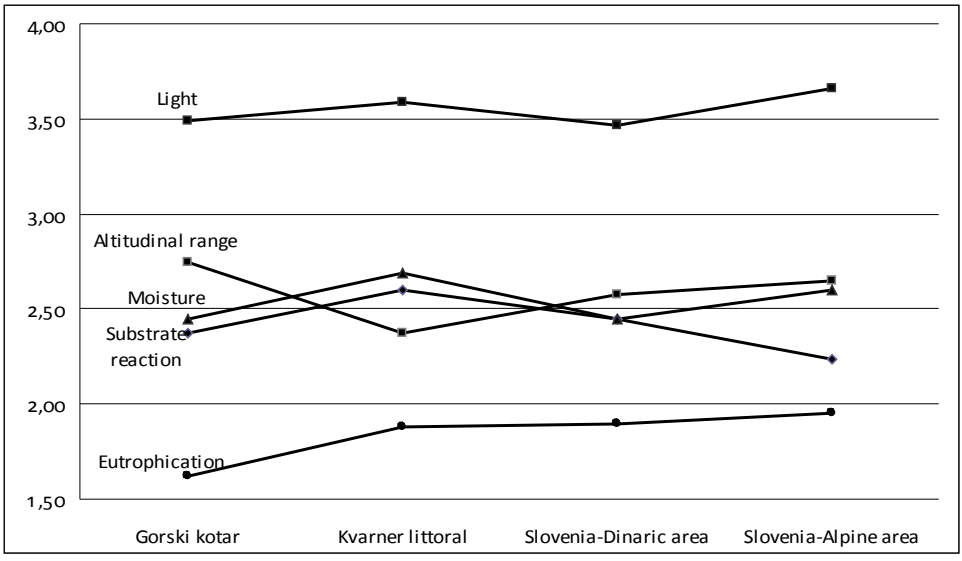


Figure 7: Comparison of mean indicator values of lichen flora of Gorski kotar and Kvarner littoral with regions in Slovenia.
Slika 7: Primerjava indikatorskih vrednosti lišajske flore Gorskega kotarja in Kvarnerja z območji v Sloveniji.

Analyses of indicator values for eutrophication (Fig. 5) shows dominance of lichens indicating absence or very weak eutrophication in both areas. Due to specificity in relief and climate, like short vegetational period, Gorski kotar is a region not suitable for intensive agricultural production, and human population density is low. Areas of Gorski kotar at 1,100-1,500 m altitude can be considered as least impacted by anthropogenic eutrophication. Higher percentage of lichens indicating weak to middle eutrophication in Kvarner littoral is a consequence of continuous anthropogenic impact, especially from the middle of 19th century up to present days. Characteristics of this impact are increased urbanisation, mainly in tourism, and industrialisation. Significant sources of eutrophication are emissions into air from road and marine transport, and industrial facilities, as well as long-range transboundary air pollution.

Analyses of indicator values for altitudinal range (Fig. 6), shows low presence of eumediterranean belt, and dominance of submediterranean belt in Kvarner littoral.

This corresponds to phytogeographical position of the area. The most of the coastal and insular area of Kvarner belongs to submediterranean vegetational zone, while the Eumediterranean vegetational zone is at boundary of its distribution (Vukelić et al. 2008). Lichens indicating montane and oroboreal vegetational belt prevails in Gorski kotar. Number of lichens decline in subalpine and alpine belt due to harsh weather conditions and lack of suitable phorophytes for epiphytic lichens, so terricolous and muscicolous are the most frequent (Prügger 2005).

In relation to substrate reaction, mean indicator value for the lichen flora of Gorski kotar is almost equal to that for Dinaric area in Slovenia, mainly due to similarities in relief, climate and phytogeographical position. Alpine area in Slovenia has lower value due to difference in forest cover and dominance of spruce, characterized with acid bark. The mean value for Kvarner littoral is higher then for areas in Slovenia (Tab 3). Mean values for light are almost equal for Gorski kotar and Dinaric area in Slovenia, while the values are higher in Kvarner littoral and Alpine area in Slovenia (Fig 7). Both areas in Slovenia and Gorski kotar are moderately hygrophytic, while Kvarner littoral is dryer. Comparison of mean indicator values for eutrophication shows that all of the areas are characterized by weak eutrophication. Kvarner littoral has the lowest mean value for altitudinal range, which corresponds to thermophillic submediterranean vegetation belt. Gorski kotar and Dinaric and Alpine areas in Slovenia have mean values indicating montane and subalpine belts, whose climazonal forest vegetation prevails.

High incidences of oceanic and suboceanic elements in the lichen flora of Gorski kotar and Kvarner littoral (70 species or 26.5%), shows significant similarity with the lichen flora of the Italian regions along the Tyrrhenian Sea. Nimis and Tretiach (1999) reported following values: 21.2% for Campania, 25.2% for Calabria, 27.1% for Tuscany and 27.5% for Lazio. Compared to Tyrrhenian coast and the eastern (Croatian) Adriatic coast, oceanic and suboceanic elements are significantly less frequent in the lichen flora of the western (Italian) Adriatic coast, with percentage of 11.1% in Molise, 14.0 % in Veneto, 15.2% in Emilia-Romagna and Marche and 16.6% in Venezia Giulia. Impact of orography on amount and precipitation pattern in the Adriatic Sea area is significant. The eastern Adriatic coast is characterized by the proximity of the coastal Dinaric Mountains, enabling humid climate with annual precipitation from 1,000 mm to above 3,000 mm. The western Adriatic coast has less broken relief and its inland is covered by lowlands. The climate is more drier with annual precipitation of 600-900 mm Thus, the occurence of oceanic and suboceanic lichens is reliable indicator of the climate humidity, as reported by Loppi et al. (1999).

Conclusions

1. A total of 264 taxa of epiphytic and terricolous lichen mycota were recorded for Gorski kotar and Kvarner littoral (western Croatia). The lichen mycota of Gorski kotar consists of 184 taxa, and of Kvarner littoral contains 170 taxa.
2. Nine species: *Bryoria implexa*, *Calicium glaucellum*, *Fellhanera bouteillei*, *Lepraria eburnea*, *Lepraria rigidula*, *Lobaria virens*, *Mycobilimbia sanguineoatra, Pertusaria pupillaris* and *Usnea intermedia*, are new to the lichen flora of Croatia.

3. Relief of the Karst Dinarides and climate characteristics along the eastern Adriatic coast enables high incidence (70 species or 26.5%) of oceanic and suboceanic elements in the lichen flora of Gorski kotar and Kvarner littoral.

Acknowledgement

The author would like to thank Professor Dr Helmut Mayrhofer (Institute for Plant Sciences, Karl-Franzens university of Graz), for the help with identification of lichen samples material and valuable comments.

Literature

Alebić-Juretić, A., Arko-Pijevac, M., 1989. Air pollution damage to cell membranes in lichens-results of simple biological test applied in Rijeka, Yugoslavia. Water, Air and Soil Pollution, 47, 25–33.

Alebić-Juretić, A., Arko-Pijevac, M., 2005. Lichens as indicators of air pollution in the city of Rijeka, Croatia. Fresenius Environmental Bulletin, 14, 40–43.

Badin, G., Nimis, P.L., 1996. Biodiversity of epiphytic lichens and air quality in the Province of Gorizia (NE Italy). Studia Geobotanica, 15, 73–89.

Beck, G., Zahlbruckner, A., 1898. Schedae ad „Kryptogamas exsiccatas" Centuria IV. Lichenes (Decades 10–12). Ann. K. K. Naturhist. Hofmus., 13, 460–468.

Benac, Č., Ružić, I., Žic, E., 2006. Ranjivost obala u području Kvarnera. Pomorski zbornik, 44 (1), 201–214.

Bucković, D., 2006. Jurassic section of Gorski Kotar (Western Karst Dinarides, Croatia) facies characteristics, depositional setting and paleogeographic implications. Acta Geologica Hungarica, 49 (4), 331–354.

Christensen, S. N., 1987. Contribution to the lichen flora of Yugoslavia. Acta Botanica Croatica, 46, 161–172.

Christensen, S. N., Hansen, E.S., 1994. Lichens from Croatia. Acta Botanica Croatica, 53, 101–113.

Clerc, P., 1998. Species concepts in the genus *Usnea* (lichenized ascomycetes). Lichenologist, 30, 321–340.

Grube, M., Mayrhofer, H., Batič, F., 1998. Contribution to the lichen flora of Slovenia III. Epiphytic lichens from Goteniški Snežnik and Krokar area. Herzogia, 13, 181–188.

Hazslinszky, F., 1884. A Magyar Birodalom Zuzmó-Flórája. Természettudományi társulat, Budapest, 1–304.

Hirc, D., 1896. Vegetacija Gorskoga kotara. Rad Jugoslavenske akademije znanosti i umjetnosti, 126, 1–82.

Horvat, I., 1962. Vegetacija planina zapadne Hrvatske. Prirodoslovna istraživanja Jugoslavenske Akademije 30, Acta Biologica 2, 1–179.

Knežević, B., Mayrhofer, H., 2009. Catalogue of the lichenized and lichenicolous fungi of Montenegro. Phyton (Horn, Austria), 48 (2), 283–328.

Kušan, F., 1933. Predradnje za floru lišaja Hrvatske i Dalmacije. II. izvještaj. Acta Botanica Croatica, 8, 105–117.

Kušan, F., 1953. Prodromus flore lišaja Jugoslavije. Jugoslavenska akademija znanosti i umjetnosti, Zagreb, 595 pp.

Loppi, S., Pirintsos, S.A., Olivieri; N., Pacioni, G., 1999. Distribution of epiphytic lichens on *Quercus pubescens* along an altitudinal gradient on the Adriatic side of Central Italy. Studia Geobotanica, 17, 85–90.

Magnusson, A. H., 1947. Studies in non-saxicolous species of *Rinodina* mainly from Europe and Siberia. Acta Horti Gothob., 17, 191–338.

Matković, P., 1879. Sulla flora crittogamica di Fiume. Programma della regia Scuola Media Superiore di Stato, 37–42.

Mayrhofer, H., Koch, M., Batič, F., 1996. Beiträge zur Flechtenflora von Slowenien II. Die Flechten des Pohorje. Herzogia, 12, 111–127.

Mayrhofer, H., Matzer, M., Belec, Z., 1998. Beiträge zur Flechtenflora von Slowenien V. Nachträge zur Flechtenflora des Pohorje. Hladnikia, 10, 5–10.

Motyka, J., 1936.–1938. Lichenum generis *Usnea*. Studium monographicum. Leopoli, 651 pp.

Munić, D., Strčić, P., Stražičić, N., 1996. Županija primorsko-goranska: povijesni pregled od najstarijih vremena do današnjih dana/The County of the Coast and Gorski kotar: historical overview from ancient times to the present day. Izdavački centar, Rijeka, 413 pp.

Nimis, P. L., 1982. I licheni epifiti della Provincia di Trieste. Gortania, 3, 101–122.

Nimis, P. L., Lazzarin, A., Lazzarin, G., Gasparo, D., 1991. Lichens as bioindicators of air pollution by SO_2 in the Veneto region (NE Italy). Studia Geobotanica, 11, 3–76.

Nimis, P. L., Tretiach, M., 1999. *Itinera Adriatica* – lichens from the eastern part of the Italian peninsula. Studia Geobotanica, 18, 51–106.

Nimis, P. L., Martellos, S., 2008. *ITALIC* – The Information System on Italian Lichens. Version 4.0. University of Trieste, Department of Biology, IN4.0/1 (http://dbiodbs.univ.trieste.it/)

Noè, W., 1858. Flora di Fiume e del suo litorale. Almanaco Fiumano per l'anno 1858, 78–79.

Orange, A., James, P. W., White, F.J., 2001. Microchemical methods for the identification of lichens. British Lichen Society, London, 101 pp.

Ozimec, S., 2000. Five lichen species new to the Croatian flora. Natura Croatica, 9 (2), 133–138.

Ozimec, S., Bošković, I., Florijančić, T., Jelkić, D., Opačak, A., Puškadija, Z., Labak, I., 2010. Contribution to the lichen flora of Risnjak National Park (Croatia). Acta Botanica Croatica, 69 (1),19–29.

Printzen, C., 1995. Die Flechtengattung *Biatora* in Europa. Bibliotheca Lichenologica, 60, 1–275.

Prügger, J., Mayrhofer, H., Batič, F., 2000. Beiträge zur Flechtenflora von Slowenien IV. Die Flechten des Trnovski gozd. Herzogia, 14, 113–143.

Prügger, J., 2005. Lišajska flora Snežnika in Javornikov. Studia Forestalia Slovenica – Strokovna in znanstvena dela, 122, 1–212.

Purvis, O. W., Coppins, B. J., Hawksworth, D. L., James, P. W., Moore, D. M., 1992. The lichen flora of Great Britain and Ireland. Natural History Museum and the British Lichen Society, London, 710 pp.

Ropin, K., Mayrhofer, H., 1993. Zur Kenntnis corticoler Arten der Gattung *Rinodina* (lichenisierte Ascomyceten) in den Ostalpen und angrenzenden Gebieten. Herzogia, 9, 779–835.

Santesson, R., Moberg, R., Nordin, A., Tønsberg, T., Vitikainen, O., 2004. Lichen-forming and lichenicolous fungi of Fennoscandia. Museum of Evolution, Uppsala University, Uppsala, 359 pp.

Schauer, T., 1965. Ozeanische Flechten im Nordalpenraum. Portugaliae Acta Biologica (B), 8, 17–229.

Schuler , J., 1902. Zur Flechtenflora von Fiume. Mittheilungen des Naturwissenschaftlichen Clubs in Fiume, 6, 131–250.

Suppan, U., Prügger, J., Mayrhofer, H., 2000. Catalogue of the lichenized and lichenicolous fungi of Slovenia. Bibliotheca Lichenologica, 76, 1–215.

Suppan, U., Mayrhofer, H., 2002. Beiträge zur Flechtenflora von Slowenien VI. Die Flechten der Uršlja gora. Herzogia, 15, 57–77.

Szatala, Ö., 1927. Lichenes Hungariae I. Folia Cryptogamica, 1(5), 337–434.

Szatala, Ö., 1929. Lichenes Hungariae II. Folia Cryptogamica, 1(7), 833–928.

Topić, J., Šegulja, N., 2005. Phytogeographical position and regions of Croatia. In: Nikolić, T., Topić, J. (eds): Red book of vascular flora of the Republic of Croatia. Ministry of Culture, State Institute for Nature Protection, Zagreb, pp. 564–567.

Vězda, A., 1969. Lichenes selecti exsiccati, Fasc. XXV. (no. 751–755). – Průhonice prope Pragam: Instituto Botanico Academiae Scientarium Čechoslovacae.

Vitikainen, O., 1994. Taxonomic revision of *Peltigera* (lichenized Ascomycotina) in Europe. Acta Botanica Fennica, 152, 1–96.

Vukelić, J., Mikac, S., Baričević, D., Bakšić, D., Rosavec, R., 2008. Forest Sites and Forest Communities in Croatia – National Ecological Network. State Institute for Nature Protection, Zagreb, 263 pp.

Wirth, V., 1995. Die Flechten Baden-Württembergs 1–2, 2nd ed. Verlag Eugen Ulmer, Stuttgart, 1006 pp.

Zahlbruckner, A., 1900. Schedae ad „Kryptogamas exsiccatas" Centuria V–VI. Lichenes (Decades 16–18). Ann. K. K. Naturhist. Hofmus., 15, 205–212.

Zahlbruckner, A., 1901. Schedae ad „Kryptogamas exsiccatas" Centuria VII. Lichenes (Decades 19–20). Ann. K. K. Naturhist. Hofmus., 16, 80–85.

Zahlbruckner, A., 1904. Schedae ad „Kryptogamas exsiccatas" Centuria X–XI. Lichenes (Decades 25–28). Ann. K. K. Naturhist. Hofmus., 16, 410–421.

Zahlbruckner, A., 1905a. Schedae ad „Kryptogamas exsiccatas" Centuria XII–XIII. Lichenes (Decades 29–32). Ann. K. K. Naturhist. Hofmus., 20, 339–351.

Zahlbruckner, A., 1905b. Vorarbeiten zu einer Flechtenflora Dalmatiens III. Österreichische Botanische Zeitschrift, 55, 1–6, 55–69.

Zahlbruckner, A., 1906a. Schedae ad „Kryptogamas exsiccatas" Centuria XIV. Lichenes (Decades 33–34). Ann. K. K. Naturhist. Hofmus., 21, 217–222.

Zahlbruckner, A., 1906b. Neue Flechten III. Annales Mycologici 4, 486–490.

Zahlbruckner, A., 1907. Schedae ad „Kryptogamas exsiccatas" Centuria XV–XVI. Lichenes (Decades 35–38). Ann. K. K. Naturhist. Hofmus., 22, 107–117.

Zahlbruckner, A., 1909a. Schedae ad „Kryptogamas exsiccatas" Centuria XVII. Lichenes (Decades 39–41). Ann. K. K. Naturhist. Hofmus., 23, 222–231.

Zahlbruckner, A., 1909b. Neue Flechten V. Annales Mycologici 7, 472–478.

Zahlbruckner, A., 1911. Schedae ad „Kryptogamas exsiccatas" Centuria XIX. Lichenes (Decades 44–46). Ann. K. K. Naturhist. Hofmus., 25, 237–248.

Zahlbruckner, A., 1912. Schedae ad „Kryptogamas exsiccatas" Centuria XX. Lichenes (Decades 47–49). Ann. K. K. Naturhist. Hofmus., 26, 169–179.

Zahlbruckner, A., 1913. Schedae ad „Kryptogamas exsiccatas" Centuria XXI. Lichenes (Decades 50–52). Ann. K. K. Naturhist. Hofmus., 27, 265–275.

Zahlbruckner, A., 1914. Schedae ad „Kryptogamas exsiccatas" Centuria XXII. Lichenes (Decades 53–55). Ann. K. K. Naturhist. Hofmus., 28, 134–145.

Zahlbruckner, A., 1915. Schedae ad „Kryptogamas exsiccatas" Centuria XXIII. Lichenes (Decades 56–58). Ann. K. K. Naturhist. Hofmus., 29, 472–479.

Zahlbruckner, A., 1916. Schedae ad „Kryptogamas exsiccatas" Centuria XXIV. Lichenes (Decades 59–61). Ann. K. K. Naturhist. Hofmus., 30, 210–218.

Zahlbruckner, A., 1923. Schedae ad „Kryptogamas exsiccatas" Centuria XXV. Lichenes (Decades 62–64). Ann. K. K. Naturhist. Hofmus., 36, 39–40.

Zaninović, K., Gajić-Čapka, M., Perčec Tadić, M., 2008. Klimatski atlas Hrvatske/Climate atlas of Croatia 1961–1990., 1971–2000. Državni hidrometeorološki zavod, Zagreb, 200 pp.

ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 39–50

Rescue of the critically endangered long-stalked pondweed (*Potamogeton praelongus*) in the Czech Republic

Ohranjanje močno ogroženega podaljšanega dristavca (*Potamogeton praelongus*) na Češkem

Romana Prausová[a*], Jana Janová[a] & Lubomír Adamec[b]

[a] University Hradec Králové, Faculty of Science, Rokitanského 63, CZ-500 02 Hradec Králové, Czech Republic
[b] Institute of Botany of the Academy of Sciences of the Czech Republic, Section of Plant Ecology, Dukelská 135, CZ-379 82 Třeboň, Czech Republic
*correspondence: r.prausova@seznam.cz

Running title
Prausová et al.: *Potamogeton praelongus* in the Czech Republic

Abstract: *Potamogeton praelongus* occurs in the Czech Republic at only one natural site. As part of a rescue programme, micropopulations were introduced into new locations. The aim of the paper is to describe the realised measures: monitoring micropopulations and habitat factors at *P. praelongus* sites, investigation of seed germination, and preparation of a sterile *in-vitro* culture for plant propagation and conservation purposes. Between 2008–2010, both micropopulations in the Orlice floodplain increased their size by three times annually. In 2010, 1461 shoots occurred at the natural site and 199 at the artificial one. In 2010, stand areas varied between 12–50 m^2. The most effective treatment to break seed dormancy involved 2-h surface sterilisation in 5 % or 2.5 % NaClO solution proceeded by a period of desiccation, temperature variation, hypoxic conditions, and mechanical abrasion of the seed coat. Using similar methods of NaClO sterilisation, an *in-vitro* culture of *P. praelongus* was prepared and 30 clones with an expected genetic variability are available.

Key words: long-stalked pondweed, conservation programme, monitoring, seed germination tests, sterile culture *in vitro*

Izvleček: Vrsta *Potamogeton praelongus* se na Češkem v naravi pojavlja le na eni lokaciji. V okviru programa ohranjanja vrste smo vnesli rastline na nove lokacije. V članku predstavljamo celoten postopek: spremljanje stanja mikropopulacije in habitatne parametre na območjih uspevanja vrste *P. praelongus*, raziskave kalitve semen ter postopek priprave sterilnih *in-vitro* kultur za razširjanje. V času od 2008–2010 sta se obe mikropopulaciji na poplavni ravnici reke Orlice povečali za 3-krat letno. Leta 2010 je bilo1461 poganjkov na naravni in 199 na novi lokaciji. Leta 2010 so bili sestoji veliki od 12 do 50 m^2. Za najbolj učinkovit način prekinitve dormance se je izkazala 2-h površinska strerilizacija s 5 % oz. z 2.5 % razstopino NaClO, ki ji je sledilo obdobje izsuševanja, izpostavljanja različnim temperaturam, anoksičnim razmeram in abrazija semenske lupine. S sterilizacijo z NaClO smo pripravili *in-vitro* kulturo vrste *P. praelongus*; 30 klonov z ustrezno gensko variabilnostjo.

Ključne besede: podaljšani dristavec, načrt ohranjanja, spremljanje stanja, kalitev semen, sterilna kultura *in vitro*

Introduction

The perennial aquatic plant *Potamogeton praelongus* Wulfen, listed among the critically endangered plant taxa of the Czech flora, is restricted to just a single natural location in the Czech Republic, near the town of Hradec Králové in E Bohemia (Prausová and Janová 2010), where it grows in an oxbow tributary of the Orlice river. Globally, *P. praelongus* is a rare species of a nordic, partly suboceanic, and circumpolar distribution, spread predominantly throughout northern Europe (Vöge 1992). Within the same latitudes, it is also spread throughout Asia and North America, however is rare throughout its entire distribution. The species occurs in unpolluted mesotrophic waters in humic or sandy soils, clayish, muddy, or peaty beds (Casper and Krausch 1981). It is a distinctly stenotopic species for which characteristic growth is in clean, deeper, hard lowland waters on calcareous sediments (Husák and Adamec 1998). Ellenberg (1991) categorised *P. praelongus* as a photophilous plant growing only exceptionally at a relative irradiance below 40 %. The fruit of *P. praelongus*, morphologically an achene and herein referred to as "seed", germinate very poorly (Janová 2010, Prausová et al. 2010). Recent molecular-genetic analyses have revealed only minimal genetic variability of *P. praelongus* micropopulations in the Czech Republic (Kitner et al. unpubl.), suggesting that the species propagates predominantly vegetatively. Recent studies have however noted methods of markedly increasing seed germination through breaking physical seed dormancy (Janová 2010, Prausová et al. 2010). Propagation in this manner could be used in rescuing the species in the Czech Republic.

The last native Czech population of *P. praelongus* is endangered by sedimentation due to a nutrient-rich sediment in the standing oxbow reach, covering leaf surfaces in fine sedimentary particles (Prausová and Janová 2010). High concentrations of mineral nutrients in the water also lead to the growth of detrimental filamentous algae, and the disturbance of plants and micropopulations during flood events is of potential concern. To support the last micropopulation in the Transient Protected Area, several principal measures have so far been conducted (Prausová et al. 2010). Muddy sediment was excavated from the standing oxbow reach in 2001, and inshore tree stands were cut in 2002 to clear the water surface. In 2003, the Czech Ministry of Environment approved a rescue programme for *P. praelongus*, involving the clearing of surplus mud using a suction dredge from a part of the oxbow inhabitated by *P. praelongus* near the estuary of the Orlice river. Since 2005, regular monitoring of all Czech *P. praelongus* micropopulations has occurred, in conjunction with monitoring habitat factors including water and sediment chemistry. Simultaneously, re-patriation of the species to the Orlice river floodplain has been conducted using plants raised in an outdoor rescue culture at the Institute of Botany at Třeboň, Czech Republic (Husák and Adamec 1998, Prausová et al. 2010).

During 2009–2010, the dominant part of the rescue programme within the project "Rescue of long-stalked pondweed (*Potamogeton praelongus*) in the Czech Republic", raised by the Czech Ministry of Environment, was carried out. The aim of this paper is to describe the main biological measures which have been realised within the programme so far: monitoring plant fitness and habitat factors at natural and artificial *P. praelongus* sites, an investigation of seed germination, and preparation of a sterile tissue culture for plant propagation and consequent re-patriation purposes.

Material and methods

Recent distribution of Potamogeton praelongus in the Czech Republic

Orlice river floodplain near Hradec Králové

Recently, *P. praelongus* occurs natively only in the Transient Protected Area "Rameno u Stříbrného rybníka" at Malšova Lhota in the suburb of Hradec Králové (50°12′35″N, 15°53′17″E) in E Bohemia (Prausová and Janová 2010). The site, a standing oxbow, is situated at an altitude of 232 m a.s.l. in the left-bank part of the Orlice river floodplain and its lower reach has its estuary into the river. The oxbow sustains considerable deposition by organic sediments, the main source of which is tree litter originating from bank stands. Water chemistry at the site is weakly eutrophic and stagnant (Prausová et al. 2010). As a result of re-patriation efforts as part

of a rescue programme for this species, a new micropopulation has been successfully established in the Lake Kašparovo jezero (50°12′47″N, 15°52′19″E). It is an oxbow in the Orlice river floodplain on the right river bank, with similar ecological characteristics as the existing native site. Both oxbows are inhabited by dense stands of *Nuphar lutea* and loose stands of *Potamogeton crispus, Ranunculus trichophyllus* and *R. circinatus*.

The Protected Landscape Area Kokořínsko

Introduced *P. praelongus* populations have been growing in restored backwater pools in the Protected Landscape Area Kokořínsko in Central Bohemia (50°28‘ N, 14°31‘ E), since 2001–2005. Four populations exist, including pools below Plešivec, pools above the fishpond Harasov, pools near Štampach, and backwater pools in the Liběchovka rivulet floodplain (Prausová et al. 2010). The source plants for these introductions originated from the last native site.

Rescue cultivation at the Institute of Botany at Třeboň, Czech Republic

A rescue culture of *P. praelongus,* using plants sourced from the last native site, has been maintained at the Institute of Botany at Třeboň (IBT) since 1988 (see Husák and Adamec 1998). One plastic container (volume 1.5 m^3), which is used for aquatic plant collection and is never emptied, houses *P. praelongus* plants potted in 26x26x26 cm plastic pots. Several further plastic containers of the same size, which are regularly emptied over winter, are maintained as *ex-situ* cultures, with *P. praelongus* planted directly into a shallow soil layer. For both methods a mixture of sand, garden loam, fishpond clay (mud), fen soil, and milled limestone fertilised by organic compost provides substrate. Over the warm summer season, all containers are partly shaded due to the growth of filamentous algae as surface water temperatures increase, with algal mats removed regularly. The plants overwinter either innundated (collection container) or in moist substrate (rescue culture) under a 15-cm layer of dry leaves covered by plastic plates (Husák and Adamec 1998). The water depth in both types of cultures is 40–50 cm.

Micropopulation monitoring

Regular monitoring of all Czech *P. praelongus* micropopulations was carried out, as part of the rescue programme, since 2005 (Prausová and Janová 2010, Prausová et al. 2010). At both sites in the Orlice river floodplain (Rameno u Stříbrného rybníka and Kašparovo jezero), individual shoots occurring in distinct bunches or visually distinguishable groups were counted using a boat. Observations were made in mid-July during the flowering or fruiting period, at a time of high water transparency and normal water level (Prausová et al. 2010). Both total number and proportion of flowering shoots were counted. Individual shoots could not be counted at sites within the Protected Landscape Kokořínsko (PLK), and the method of assessment of the plant stand area (in m^2) was used during monitoring in the 2005 and 2007–2010 seasons. At all sites, plant occurrence was recorded in geographical coordinates using the GARMIN eTrex H (resolution ±4 m) GPS-instrument.

Monitoring of site-specific habitat factors

For monitoring habitat factors at *P. praelongus* sites, at all sites water samples were collected twice a year for water chemistry analyses (July, September). Electrical conductivity and pH were measured using portable instruments (Multimetric water Quality Sonde YSI600XLM) directly in the field. No pre-treatment of the water sample was used for chemical oxygen demand (COD) determination using the $KMnO_4$ titratory method. For all other analyses, water samples were filtered using a membrane filter (mesh size 0.45 µm). Concentrations of NO_2^-, NH_4^+, NO_3^- and PO_4 were determined (Flow injection ion analyzer Alliance) colorimetrically, while those of Ca^{2+}, Mg^{2+}, K^+ using atomic absorption spectrometry (Spectrometer ICP/OES GBC Integra). See Pekárková and Lischke (1974) for all analytical details. Measured factors are presented for 11 individual measurements at the natural site between 2005–2010, and for 4 sites at Kašparovo jezero and the Protected Landscape Kokořínsko during 2009–2010. This excludes the pools near Štampach, where only two measurements were conducted in 2010.

Seed dormancy and germination biology

Germination tests investigated seed dormancy type and alleviation in *P. praelongus*, as well as assessing the species capacity for long-term hermetic storage (Janová 2010, Prausová et al. 2010). Seed was sequentially harvested from plants in cultivation at IBT or collected from the PLK, and stored in darkness either dry at room temperature (21±2 ºC) or in water (8±1 ºC) for up to six months before beginning experimental work. To assess natural cycles of desiccation and rewetting on germination, some treatments involved direct rehydration of seed and subsequent storage in water at room temperature for one month prior to germination testing. In all treatments seed were placed in 10 cm Petri dishes and allowed to germinate in dark conditions on moistened filter paper, incubated either at a slightly variable temperature of 21±2 ºC or in a thermostatted chamber at 23±0.5 ºC or 28±0.5 ºC. The filtered water collected from the natural site was used to wet the seeds. Where microbial contamination of replicates occurred, seeds were immediately removed, thoroughly washed in distilled water, and transferred to new Petri dishes. Replicates placed in 1–6 parallel Petri dishes varied in number due to the sequential availability of seed, and ranged from 34 to 294 per treatment. To assess the effect of a chemical agent in alleviating dormancy, SAVO Prim (Bochemie, Bohumín, Czech Republic), containing 5 % NaClO and saponate, was applied in varying concentration and for varying duration (see below; Janová 2010). After chemical treatment, seeds were thoroughly washed in distilled water before placing in Petri dishes. Germination was determined by development of the cotyledon, as radicle emergence in the species occurs at a later developmental stage (Janová 2010), with the tests running for four months. Germinants with 1–2 leaves were transferred to 4L aquaria to allow continued growth. In total, 27 variants of seed germination tests were conducted (Janová 2010, Prausová et Janová 2010).

1. Controls: 34 seeds collected in the IBT, kept in water at 8±1 ºC, no treatment of seeds, germination at ca. 21±2 ºC;
2. Controls: 68 seeds collected in the IBT, kept in water at 8±1 ºC, no treatment of seeds, germination at 23±0.5 ºC;
3. Freeze tolerance: 34 seeds collected in the IBT, kept in water at 8±1 ºC, exposed at –18 °C in a refrigerator for 36 h before the germination test, germination at ca. 21±2 ºC;
4. Freeze tolerance: 68 seeds collected in the IBT, kept in water at 8±1 ºC, exposed at –18 °C in a freezer for 36 h before the germination test, germination at 23±0.5 ºC;
5. Treatment with gibberellic acid (GA_3): 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months till the experiment, washed in distilled water, addition of GA_3 to the germination solution (final concentration 15 mg.l^{-1}), germination at 28±0.5 ºC;
6. Treatment with GA_3: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month till the experiment, washed in distilled water, addition of GA_3 to the germination solution (final concentration 15 mg.l^{-1}), germination at 28±0.5 ºC;
7. Scarification: 100 seeds collected from the PLK, kept in dry state at room temperature for 3 months till the experiment, seed testa abrased thoroughly by an abrasive paper, germination at 28±0.5 ºC;
8. Scarification: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month till the experiment, seed testa abrased thoroughly by an abrasive paper, germination at 28±0.5 ºC;
9. Hypoxic conditions: 100 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month till the experiment, ethanol droplets added to the germination water to cause hypoxia, Petri dishes thoroughly sealed by 3 layers of sealing tape, germination at 28±0.5 ºC;
10. Long cold stratification: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in dry state in a refrigerator at 8 ºC for 2.5 months followed by ca. 21±2 ºC for 14 d, then wetting and germination at 28±0.5 ºC;
11. Long cold stratification: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water

for one month, kept in a refrigerator at 8 °C for 2.5 months followed by ca. 21±2 °C for 14 d, then germination at 28±0.5 °C;
12. Short cold stratification: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month, kept in a refrigerator at 8 °C for 1 month, in a freezer at –20 °C for 1 month, again in a refrigerator at 8 °C for 14 d followed by ca. 21±2 °C for 14 d, then germination at 28±0.5 °C;
13. Short cold stratification: 100 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month, kept in a refrigerator at 8 for 1 month followed by ca. 21±2 °C for 14 d, then germination at 28±0.5 °C;
14. Long desiccation: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then germination at 28±0.5 °C;
15. Short desiccation: 34 seeds collected in the IBT, kept in water at 8±1 °C till the experiment, dried out at ca. 21±2 °C for 36 h, then wetting and germination at ca. 21±2 °C;
16. Short desiccation: 68 seeds collected in the IBT, kept in water at 8±1 °C till the experiment, dried out at ca. 21±2 °C for 36 h, then wetting and germination at 23±0.5 °C;
17. Long desiccation: 100 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then germination at ca. 21±2 °C;
18. Transient long desiccation: 218 seeds collected from the PLK, kept in water at 8±1 °C for 3 months, then kept at dry state at room temperature for 3 months, germination at 28±0.5 °C;
19. One-fourth strength SAVO for 2 h: 74 seeds collected from the PLK, kept in dry state at room temperature for 3 months, treated by one-fourth strength SAVO for 2 h, then germination at 28±0.5 °C;
20. Half strength SAVO for 2 h: 75 seeds collected from the PLK, kept in dry state at room temperature for 3 months, treated by half strength SAVO for 2 h, then germination at 28±0.5 °C;
21. Half strength SAVO for 2 h: 50 seeds collected from the IBT, kept in water at 8±1 °C till the experiment, treated by half strength SAVO for 2 h, then germination at 28±0.5 °C;
22. Half strength SAVO for 2 h: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month, treated by half strength SAVO for 2 h, then germination at 28±0.5 °C;
23. Full strength SAVO for 36 h: 34 seeds collected from the IBT, kept in water at 8±1 °C till the experiment, treated by full strength SAVO for 36 h, then germination at ca. 21±2 °C;
24. Full strength SAVO for 36 h: 68 seeds collected from the IBT, kept in water at 8±1 °C till the experiment, treated by full strength SAVO for 36 h, then germination at 23±0.5 °C;
25. Full strength SAVO for 2 h: 132 seeds collected from the PLK, kept in dry state at room temperature for 3 months, treated by full strength SAVO for 2 h, then germination at ca. 21±2 °C;
26. Full strength SAVO for 2 h: 294 seeds collected from the PLK, kept in dry state at room temperature for 3 months, treated by full strength SAVO for 2 h, then germination at 28±0.5 °C;
27. Full strength SAVO for 2 h: 50 seeds collected from the PLK, kept in dry state at room temperature for 3 months, then kept in the water for one month, treated by full strength SAVO for 2 h, then germination at 28±0.5 °C.
28. We are aware of the fact that all seeds within one treatment are pseudoreplicates and no statistical treatment of the results is possible. Thus, the results basically show the qualitative effects.

Preparation of a sterile in-vitro culture

Seeds harvested at the IBT in September 2009 were used for the preparation of a sterile *in-vitro* culture. All seeds were kept in a refrigerator at 3 °C in darkness, with some in a dry state and others in tap water. Before sterilisation, both dry and wet seeds were shortly shaken in a diluted saponate solution (v/v 1:200), washed in streaming tap water for around 30 h, and the remains of the pericarp were mechanically removed. Seeds were surface sterilised using half or full strength SAVO Prim for 4, 8 or 16 h. The seeds were then thoroughly washed in three bottles filled with sterile tap or distilled water. A tenth strength Murashige-Skoog medium (Murashige and Skoog

1962) supplemented with 2 % sucrose was used as a germination medium. The medium was either liquid or solidified with 0.6 % gerlite (natural anionic polysaccharide, Duchefa, Haarlem, The Netherlands). The pH of both solutions was 6.5 before autoclaving. Test-tubes (3 cm diameter) were filled each with either 10 ml of the solid or 20 ml of the liquid medium. One seed was placed in each test-tube and all seeds were spread evenly between each media type. In total, 238 seeds were used. Seed germination took place in darkness, at 14 to 18 °C during the first month and then at 18±0.5 °C. Upon germination test tubes were transferred to flourescently illuminated boxes (PAR irradiance of ca. 30–40 μmol.m^{-2}.s^{-1} and 12–h photoperiod) kept at 21±1 °C.

After two months growth post-germination, seedlings were transplanted into a fresh liquid culture of higher concentration (half strength Gamborg B5 medium with 500 mg.l^{-1} KNO_3, with 2.5 % sucrose, pH 5.7 or 6.5; Adamec and Pásek 2000). The volume of renewed sterile culture medium was 50–70 ml in 350 ml flasks or 300 ml in 0.5 l flasks. Seedlings rapidly resumed vigorous growth after transferral to new medium. Plants outgrew flasks in 2–3 month cycles (ca. 8–15 shoot apices produced), exhausted the medium (the final pH of media was 4.65–6.25), and at this point 1–3 apical shoot segments were transplanted into new flasks. Excess plants were planted outdoors in rescue culture (IBT) to maturate.

Results

Monitoring of populations and habitat factors

The remaining natural *P. praelongus* micropopulation at Rameno u Stříbrného rybníka has increased since 2005, with marked increase since 2008 (Fig. 1). Original shoot numbers rose from 32 in 2005 to 1461 growing in 115 colonies in 2010; of these 199 shoots were fertile. Though the micropopulation is still concentrated in the oxbow reach in front of the estuary to the Orlice river, the re-patriation of plants in 2008 has led to spread along both oxbow banks further away from the main estuary. New colonies originate both from the original and also from re-patriated shoots. At the artifical site Kašparovo jezero in the Orlice river floodplain, where a successful introduction

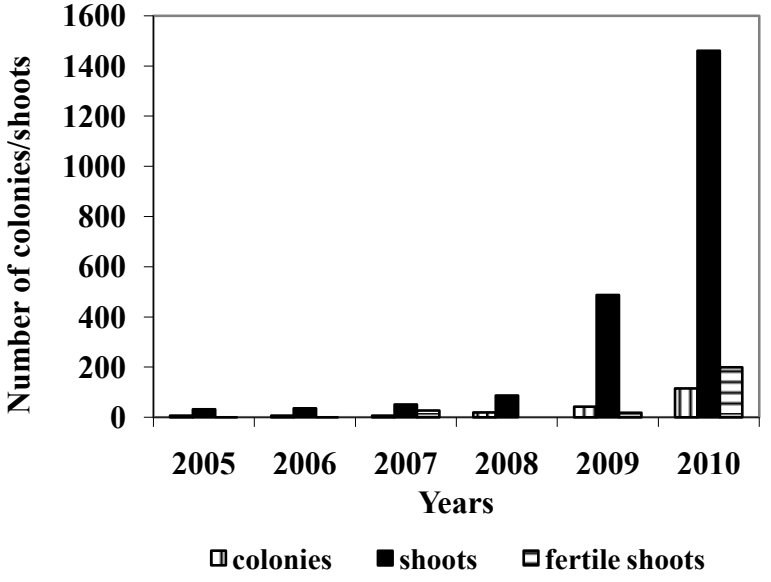


Figure 1: Development of the natural micropopulation of P. praelongus at the site Rameno u Stříbrného rybníka in the Orlice river floodplain (2005–2010).

Slika 1: Spremljanje naravnih mikropopulacij vrste P. praelongus na lokacijah Rameno u Stříbrného rybníka na poplavni ravnici reke Orlice v letih 2005–2010.

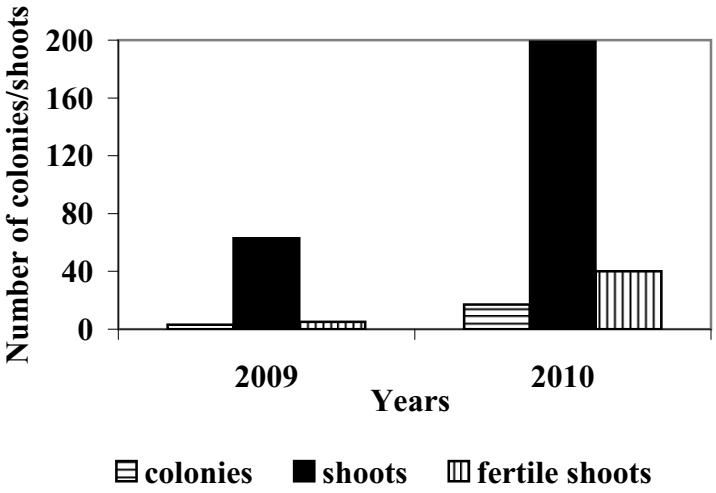


Figure 2: Development of the introduced micropopulation of P. praelongus at the site Kašparovo jezero in the Orlice river floodplain (2009–2010).

Slika 2: Spremljanje vnešenih mikropopulacij vrste P. praelongus na lokaciji Kašparovo jezero na poplavni ravnici reke Orlice v letih 2009–2010.

was conducted in 2008, 199 shoots (40 fertile) in 17 colonies were recorded in 2010 (Fig. 2).

The total population area of all four micropopulations in the PLK was rather variable between 2005–2010 (Fig. 3). All but the Štampach pools partly stabilised between 2007–2010, but area still varied in relation to intensity of overgrowing (infilling) of the relatively small, shallow pools by a littoral emergent vegetation. In 2010, the stand areas were 12–50 m^2.

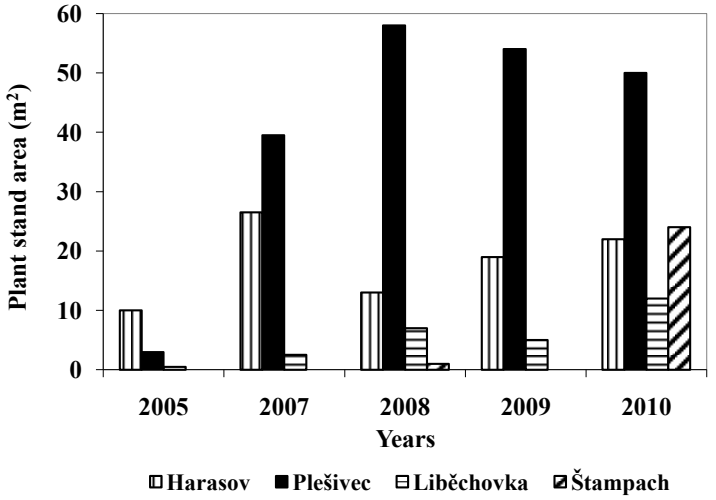


Figure 3: Comparison of plant stand area of the four introduced micropopulations of P. praelongus in the Kokořínsko region (2005–2010).

Slika 3: Spremljanje površine sestojev štirih vnešenih mikropopulacij vrste P. praelongus na območju Kokořínsko v letih 2005–2010.

Parameter	Natural site (Rameno u Stříbrného rybníka)	Kašparovo jezero near the Orlice river	Pools in the Liběchovka river floodplain	Pools above Harasov fishpond	Pools below Plešivec	Pools near Štampach
pH	7.2–7.7 (7.4)	7.5–8.3 (8.0)	7.5–8.4 (8.0)	7.5–8.3 (7.7)	7.4–7.7 (7.7)	7.7–7.9 (7.8)
El. Cond. (mS m^{-1})	11.9–49.1 (36.7)	15.0–36.7 (31.1)	10.4–51.8 (28.1)	6.7–28.9 (13.3)	10.6–36.9 (27.3)	33.5–42.9 (38.2)
COD (mg l^{-1})	5.1–8.1 (5.5)	3.4–6.7 (4.9)	4.1–6.4 (5.1)	8.8–16.0 (10.8)	4.8–11.0 (7.2)	6.7–6.8 (6.8)
NO_3^--N (mg l^{-1})	2.6–12.8 (7.4)	6.4–14.0 (12.5)	<0.5 (<0.5)	<0.5 (<0.5)	<0.5 (<0.5)	<0.5 (<0.5)
NH_4^+–N (µg l^{-1})	40–230 (110)	40–270 (120)	30–50 (37)	30–80 (43)	7–50 (34)	20–60 (40)
PO_4–P (µg l^{-1})	140–400 (260)	200–370 (245)	30–70 (37)	30–1100 (173)	30–80 (37)	30–60 (45)
Ca^{2+} (mg l^{-1})	48.6–77.0 (60.8)	44.5–63.3 (56.8)	35.0–94.9 (49.2)	18.6–61.1 (37.4)	40.7–75.5 (52.3)	50.9–70.6 (60.8)
Mg^{2+} (mg l^{-1})	4.6–7.4 (5.5)	3.7–4.9 (4.1)	3.5–5.7 (4.8)	1.8–4.6 (2.6)	3.4–5.8 (4.4)	9.9–11.3 (10.6)
K^+ (mg l^{-1})	3.0–4.5 (4.0)	3.0–4.2 (3.6)	0.23–3.5 (0.38)	0.96–5.8 (2.1)	3.0–4.1 (1.5)	2.1–2.2 (2.2)

Table 1: Water chemistry at P. praelongus sites monitored during 2005-2010. Ranges of values and medians (in parentheses) are shown.

Tabela 1: Kemizem vode na lokacijah z vrsto P. praelongus v obdobju 2005-2010. Predstavljeni so rangi in mediane izmerjenih vrednosti (v oklepaju).

At all sites, *P. praelongus* grows in neutral to slightly alkaline waters (Tab. 1). The waters can be considered meso- to eutrophic as determined by to N and P concentrations. NO_2^--N concentration ranged between 0 and 0.28 mg.L^{-1} between sites (data not shown). Despite relatively high Ca^{2+} concentrations across sites, K^+ concentrations at some PLK sites were <1 mg.L^{-1} and may act to co-limit plant growth.

Testing of seed germination

No germination was observed in control seeds stored in water (Fig. 4). Highest germination percentage was noted among SAVO treatments (germination between 5–98 %). While full-strength SAVO treatment for 36 h proved highly effective in promoting seed germination, the treatment appeared to injure seed embryos, resulting in non-normal growth of the first leaves. This growth inhibition was not noted at 2-h SAVO treatment (Fig. 5). Germination does not appear to be enhanced by periods of freezing or cold stratification, and seed do not appear capable of surviving hypoxic storage at –18ºC for 36 hours. Seed germination was also stimulated by transient desiccation (1–35 % germination), hypoxia (14 % germination), and scarification (4–8 % germination). Overall, germination occurred during the day 4 to 101. No seeds germinated after exposure to 15 mg.l^{-1} GA_3 for the next 4 months.

Preparation of a sterile in-vitro culture

Out of the total 238 sterilised seeds, 49 (28 %) germinated; 25 on solid and 24 in liquid medium. This would imply that media type has little effect on germination. Germination of desiccated seeds was 42 %, compared with 24 % for seeds stored in water. High concentrations of SAVO slightly increased germination. Longer exposure to SAVO also increased germination (37 % at 16 h; 19 % at 8 h). Contamination was noted in all seeds sterilised for only four hours. Germination frequency was greatest during the first two months (data not shown).

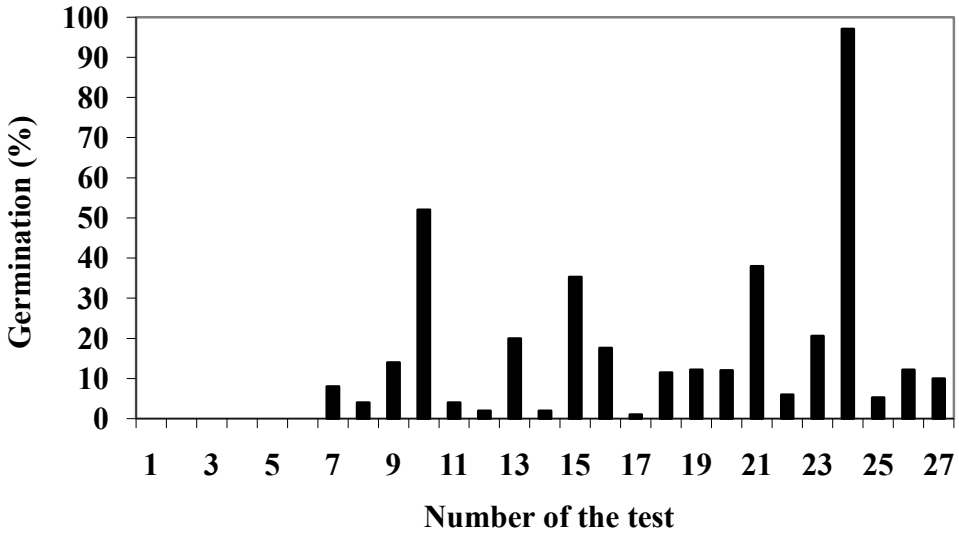


Figure 4: Results of germination tests with P. praelongus seeds. For the description of experimental conditions (the numbers 1–27) see the text.
Slika 4: Rezultati kalitvenih testov semen vrste P. praelongus. Opis poskusnih razmer je podan v tekstu (alineje 1–27).

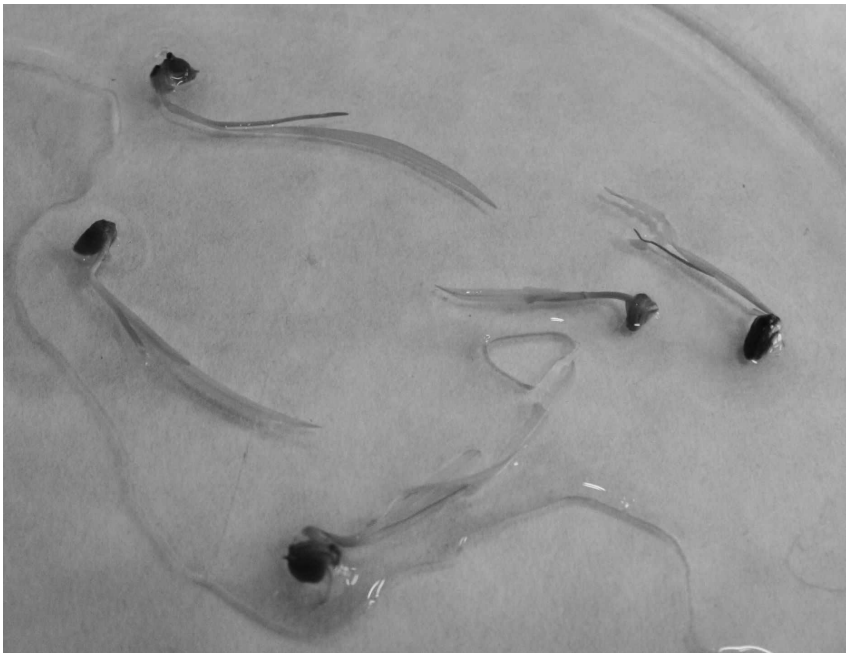


Figure 5: Small plantlets of P. praelongus after the test of seed germination to be transferred to the growth chamber (Photo R. Prausová).
Slika 5: Mlade rastlinice vrste P. praelongus po uspešni kalitvi, pred prenosom v rastne komore (foto R. Prausová).

Figure 6: Plants of P. praelongus raised in the in-vitro culture before their transfer to the outdoor rescue culture (Photo L. Adamec).
Figure 6: Primerki vrste P. praelongus vzgojeni v in-vitro kulturah pred prenosom v naravno okolje (foto L. Adamec).

Plants grew vigorously *in-vitro* in liquid half strength Gamborg B5 medium, outgrowing flasks within 2–3 months (Fig. 6). No growth malformations or disorders were apparent on the plants. To maintain continuous and vigorous growth, it was necessary to transplant individuals to new medium when flasks became outgrown. The minimal volume of medium (300 ml in a 0.5 l flask, 7 cm deep) appears to be a prerequisite for vigorous plant growth. A pH of 6.5 in the medium is preferred as it better meets ecological demands. Plants raised *in-vitro* resumed growth in the outdoor rescue culture at IBT around 2 weeks after transplanting.

Discussion

Monitoring has revealed a marked increase of *P. praelongus* micropopulations at the last natural Czech site between 2008–2010, compared with only slight increases during the 2005–2007 period (Fig. 1). Between 2008–2010, micropopulation size (both number of colonies and shoots) increased around threefold annually, with 14 % of all shoots producing flowers. New colonies were located in areas with markedly lower sediment depth, influenced indirectly by sediment dredging in 2003. Of all experimental introductions in the Hradec Králové region in the last decade, only those at the oxbow Kašparovo jezero have been successful so far (Fig. 2). From the 18 shoots introduced to this site between 2008–2009, in total 199 shoots (40 fertile) were scored in 2010. This new site is located in 1.5 km distance from the last known natural site, and the habitat characterisitcs and geomorphology of both sites are very similar (see Tab. 1): both micropopulations grow in oxbows of the Orlice river which are at least by one side connected with the river. Additionally, they grow near the oxbow estuary to the river within a riprap where the plants are protected during flood events but can favourably utilise the nutrient-rich sediment between boulders on the bottom and are positively influenced by the streaming river water (Prausová et al. 2010). Contrary to the Kašparovo jezero success, no backwater pools in the Orlice river floodplain, which are gradually filled in by sediments, have become suitable for introduced *P. praelongus* populations (Prausová et al. 2010).

A different situation occurs at PLK where micropopulations were introduced to newly built up backwater pools in 2003–2005 (Prausová et al. 2010). Here the small and shallow pools are prone to rapidly overgrowth by reeds, and succession followed by decline occurs in submerged species. High water temperature during the summer season is an important factor for the decline of *P. praelongus*, with upper parts of the shoots exposed to higher water temperature turning brown and senescing. Positive pool management maintains many of the pools in an early state of succession, which is favourable for *P. praelongus* and several other submerged macrophyte species (Prausová and Janová 2010, Prausová et al. 2010). It would appear from water chemistry at *P. praelongus* sites (Tab. 1) that the species is also capable of vigorous growth in eutrophic waters.

In conclusion, the data presented (Figs. 2–3) suggests that the selection of suitable sites for the stenotopic species *P. praelongus* in flood-

plain regions is possible. Creating new stable micropopulations presents an active method of conserving the species diversity. The prerequisite for successful introductions or re-patriations is to raise a sufficient number of plants, maintaining genetic variability using a sterile, seed-based tissue culture. Recent findings have revealed very low natural genetic variability within Czech *P. praelongus* micropopulations (Kitner et al. unpubl.), suggesting that vegetative propagation is dominant in natural populations. All existing Czech sites as well as the rescue culture in the IBT contain only the plants from the last natural site.

Testing of *P. praelongus* seeds using different treatments shows the seeds have a very high germination potential (to 98 %; Fig. 4). Results suggest that disturbance of the seed testa plays a part in breaking seed dormancy (Janová 2010, Prausová et al. 2010). Highest germination rates were noted in response to 2-h exposure in full- or half-strength SAVO (5 % or 2.5 % NaClO solution), desiccation, temperatures around 21–28ºC, hypoxia, and scarification by abrasive paper (Fig. 4). It would appear thus that chemical disturbance to the seed testa provides better stimulation for seed germination than mechanical abrasion (Janová 2010). Similar results were reported for *Potamogeton* spp. seeds by Teltscherová and Hejný (1973), noting higher percentages of seed germination after a treatment with fouling water than nicking of the seed testa by a razor blade. Results from the present study (Fig. 4; Janová 2010) conform to similar studies on other *Potamogeton* species (Crocker 1907, Teltscherová and Hejný 1973). It is suggested that low germinability in *Potamogeton* seeds is not caused by embryo dormancy, but rather by mechanical restriction of growth by the seed testa (i.e., by physical dormancy).

Using the combined effect of NaClO on germination stimulation and seed sterilisation, sterile *in-vitro* cultures of *P. praelongus* have been prepared. Thirty new clones with expected genetic variability are available. Sterile growth of the plants *in-vitro* in a common liquid medium is rapid, and 5–15 cm long, healthy shoots (Fig. 6) can be cultured abundantly in this manner (over a 2–3 month period). Such plants are capable of surviving transplantation into an outdoor rescue culture, before subsequent introduction or re-patriation to new sites.

Povzetek

Vrsta *Potamogeton praelongus* se je na Češkem v naravi pojavljala le na eni lokaciji; in sicer na poplavni ravnici reke Orlice, v bližini mesta Hradec Králové. V okviru programa ohranjanja vrste smo leta 2008 vnesli rastline na novo lokacijo v bližini, v mrtvem rokavu reke Orlice. Mikropopulacije so bile v letih 2003–2005 vnešene tudi v vodna telesa na zaščitenem območju Kokořínsko v osrednji Bohemji. Spremljanje stanja obeh mikropopulacij vrste *P. praelongus* na poplavni ravnici reke Orlice je pokazalo, da se je velikost populacij v letih med 2008 in 2010 povečala za tri-krat letno (število kolonij, vegetativnih in fertlnih poganjkov).

Septembra 2010 smo na naravni lokaciji našteli 1461 in na novi lokaciji 199 poganjkov. Kar 14–20 % poganjkov je bilo fertilnih. Skupna površina sestojev na zaščitenem območju Kokořínsko je bila v letih 2005–2010 variabilna, vendar se je velikost večine sestojev v letih 2007–2010 ustalila. Septembra leta 2010 so bili sestoji veliki od 12 do 50 m^2. Na vseh čeških lokacijacijah vrsta *P. praelongus* uspeva v nevtralnih do rahlo alkalnih, mezo do eutrofnih vodah. Za prekinitev dormance je bila potrebno 2-h površinsko obravnavanje s 5 % oz. z 2.5 % razstopino NaClO, izsuševanje semen, stratifikacija, izpostavljanje anoksičnim razmeram in abrazija semenske lupine z grobim brusilnim papirjem. Vsi testi so pokazali, da je abrazija ključna za prekinitev dormance. Kemična razgradnja semenske lupine se je izkazala za uspešnejšo kot mehanska. Z dvojnim učinkov delovanja NaClO na kalitev in sterilizacijo semen smo pripravili *in-vitro* kulturo vrste *P. praelongus* v obsegu 30 klonov z ustrezno gensko variabilnostjo. Rast rastlin *in-vitro* v običajnem mediju je zelo hitra, saj so od 5 do15 cm dolgi, zdravi poganjki, zrasli v 3 mesecih.

Acknowledgements

The authors are grateful to M. Kitner for conducting the genetic analyses of plant material, to K. Pásek for the preparation of the sterile *in-vitro* culture, and to J. Dvořák for his assistance with monitoring the field sites. Special thanks are due to A. Cross for critically reading the manuscript and

correction of the language. Thanks are also due to two anonymous reviewers for valuable comments. The study was supported from the funds awarded by EHP/Norway and the Ministry of Environment of the Czech Republic. The study was also partly supported (to L.A.) from the Research Programme of the Academy of Sciences of the Czech Rep. (AV0Z 60050516).

Literature

Adamec, L., Pásek K., 2000. Medium optimization for growing *Aldrovanda vesiculosa* in vitro. Carniv. Plant. Newslett. (Fullerton), 29, 122–124.

Casper S. J., Krausch H. D., 1981. Süsswasserflora von Mitteleuropa, Band 24: Pteridophyta and Anthophyta. VEB Gustav Fischer Verlag, Jena.

Crocker, W., 1907. Germination of seeds of water plants. Bot. Gaz., 44, 375–380.

Ellenberg H., Weber H. E., Düll R., Wirth Y., Werner W., Pauliben D., 1991. Zeigerwerte der Gefässpflanzen Mitteleuropas. Scripta Geobot., 18, 248 pp.

Husák, Š., Adamec, L., 1998. Záchranné kultivace ohrožených druhů vodních a mokřadních rostlin v Botanickém ústavu AV ČR v Třeboni. Příroda (Prague), 12, 7–26.

Janová J., 2010. Rdest dlouholistý (*Potamogeton praelongus* WULFEN) v České republice. MSc-thesis, Faculty of Science, Univ. Hradec Králové, Czech Republic. 101 pp.

Murashige, T., Skoog, F., 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant., 15, 473–497.

Pekárková K., Lischke P., 1974. Chemické metody analýzy vod. SNTL, Prague.

Prausová, R., Janová, J., 2010. Současný stav výskytu rdestu dlouholistého (*Potamogeton praelongus*) v České republice. Příroda (Prague), 27, 155–168.

Prausová, R., Adamec, L., Kitner, M., Pásek, K., Dvořák, V., Janová, J., Myšák, J., 2010. Záchrana rdestu dlouholistého (*Potamogeton praelongus*) v České republice. Final report. Agency for Nature Protection of the Czech Republic, Prague, 51 pp.

Teltscherová, L., Hejný, S., 1973. The germination of some *Potamogeton* species from South Bohemian fishponds. Folia Geobot. Phytotax., 8, 231–239.

Vöge, M., 1992. Die Entwicklung von *Potamogeton praelongus* im Grossensee bei Hamburg. Tuexenia, 12, 275–284.

ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 51–60

Localities and sites of protected and endangered species *Bellevalia romana* (L.) Reichenb. (*Hyacinthaceae*) in Slovenia

Nahajališča in rastišča zavarovane in prizadete vrste *Bellevalia romana* (L.)Reichenb. (*Hyacinthaceae*) v Sloveniji

Igor Dakskoblera & Branko Vrešb*

a Institute of Biology, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Regional unit Tolmin, Brunov drevored 13, SI-5220 Tolmin, Slovenia
b Institute of Biology, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Novi trg 2, SI-1000 Ljubljana.
*correspondence: branevr@zrc-sazu.si

Running title
Dakskobler, Vreš: Localities of *Bellevalia romana*

Abstract: The article describes three new localities of a rare and endangered species of lowland meadows *Bellevalia romana* in Slovenia: at Ankaran in Slovenian Istria (confirmed in 2002, but not found yet in 2011) and at Golo Brdo and between Golo Brdo and Mišček in the Idrija valley (Goriška Brda). Only a total of four localities of this species can be confirmed in Slovenia in the year 2011 – in the Goriška region also under Sv. Katarina above Kromberk and in Istria on more places at Sečovlje. As regards their sites, the localities in the Goriška region on flysh and riparian meadows differ from those in Istria, where it grows on wet meadows and in reed and tall herb communities, on trampled soil in the immediate vicinity of the sea. The endangered species can be preserved through adequate protection of its sites. That usually means annual, but not too early, mowing of the meadows on which it grows.

Key words: *Bellevalia romana, Hyacinthaceae*, new localitites, endangered species, *Scorzonero-Chrysopogonetalia*, Goriška Brda, Istria, Slovenia

Izvleček: V članku opisujemo tri nova nahajališča v Sloveniji zelo redke in prizadete vrste nižinskih travnikov *Bellevalia romana*: pri Ankaranu v Slovenski Istri (najdba iz leta 2002, v letu 2011 ni več potrjena), pri Golem Brdu in med Golim Brdom in Miščkom v dolini Idrije (Goriška Brda). Skupno v Sloveniji v letu 2011 lahko potrdimo samo štiri nahajališča te vrste, na Goriškem še pod Sv. Katarino nad Kromberkom in v Istri pri Sečovljah. Po rastiščih se nahajališča na Goriškem na flišnih in obrečnih travnikih nekoliko razlikujejo od tistih v Istri, kjer raste na vlažnih travnikih in v trstičju, na zbitih tleh v neposredni bližini morja. Prizadeto vrsto lahko ohranimo z ustreznim varovanjem njenih rastišč, to pa je pogosto vsakoletna in ne prezgodnja košnja travnikov, na katerih raste.

Ključne besede: *Bellevalia romana, Hyacinthaceae*, nova nahajališča, ogrožene vrste, *Scorzonero-Chrysopogonetalia*, Goriška Brda, Istra, Slovenija

Introduction

In Slovenia, the Mediterranean species *Bellevalia romana* is a protected (Skoberne 2007: 75) and endangered species (En) – Anon. (2002: 8896). The chronology of the knowledge on its sites in the territory of today's Slovenia was described by T. Wraber (1990: 154) and Seljak (2001: 88–89). With his find of *Bellevalia romana* on a flysh meadow under Sv. Katarina above Kromberk, the latter substantially supplemented the knowledge of its distribution in Slovenia. T. Wraber (ibid.), Seljak (ibid.) and Skoberne (ibid.) all agreed that for the past two decades only one more locality could be confirmed in Slovenian Istria, the one in the vicinity of the airport at Sečovlje. Its growth in this locality was last confirmed by B. Dolinar (Bavcon & al. 2011: 45) and by our research in 2011. The locality in Graviže near Koper, where it was found in 1864 by A. Loser, is historic and there are no contemporary confirmations. The find near Ankaran is the result of floristic mapping in the spring of 2002 and has not been published until now, so this species was missing from the conspectus of the flora from the vicinity of Ankaran, which was published two years ago (Glasnović & Jogan 2009). During our phytosociological survey of dry and semi-dry meadows of western Slovenia in early spring 2010 and 2011 we found *Bellevalia romana* also on two places in the Idrija valley between Golo Brdo and Mišček (Goriška Brda). It was noticed only after the third repeated inventory, which was first conducted in the summer of 2008 and once again in the spring of 2009.

Materials and methods

Floristic records and phytosociological relevés were made according to the established Central European methods (Ehrendorfer & Hamann 1965, Braun-Blanquet 1964) and entered into the FloVegSi database (T. Seliškar et al. 2003). This application was used also in the preparation of the distribution map. When processing the relevés we transformed the combined cover-abundance values with numerical values (1– 9) according to van der Maarel (1979). Numerical comparisons were performed with the SYN-TAX 2000 program package (Podani 2001). The relevés were compared by means of "(unweighted) average linkage method" – UPGMA and principal coordinates analysis (PCoA). Wishart's similarity ratio was used in both methods. A census approach (complete population counts) was used to estimate population size of *Bellevalia romana* on three localities (two in Idrija valley, one at Kromberk). On fourth, the largest locality (at Sečovlje), the population size of the species was estimated by quadrat sampling. Twenty-one 1x1m plots were choosen randomly in the study site of 2600 m2. The number of individuals was counted in each plot. Because of a not-normal distribution of the data, the non-parametric statistic was used to estimate the population size. It was expressed as a median number of individuals per plot within the study site. A large sample ($n \geq 20$) confidence interval for median was calculated according to Campbell & Gardner (1988).

The nomenclature source for the names of vascular plants is the Mala flora Slovenije (Martinčič et al. 2007). Geoelemental, ecological and phytosociological designation of the studied species and syntaxonomic nomenclature follow the Flora alpina (Aeschimann et al. 2004a, b, c), the names of the syntaxa also according to the conspectus prepared by Šilc and Čarni (2011).

Results and discussion

New localities and the description of the Bellevalia romana sites

9947/1(UTM 33T UM80): Primorska, Goriška Brda, Golo Brdo, the Idrija valley, along the road towards Mišček, Zagrad, (semi)dry meadow on river alluvia on the left bank of the Idrija, 100 m a.s.l. Leg. & det. I. Dakskobler, 21. 4. 2010, Herbarium LJS (SRC SASA) and author's photo shots.

9947/1(UTM 33T UM80): Primorska, Goriška Brda, the Idrija valley between Golo Brdo and Mišček, Travnik, pioneer wood on the edge of the abandoned meadow, 135 m a.s.l. Det. I. Dakskobler, 4. 4. 2011 and I. Dakskobler & A. Trnkoczy, 8.4.2011, photo shots of A. Trnkoczy.

10448/1(UTM 33T VL04): Primorska, Slovenian Istria, Ankaran, the swamp at Sv.

Katarina, 7 m a.s.l. Det. B. Vreš, 24. 5. 2002, floristic relevé.

Distribution of *Bellevalia romana* supplemented with the new finds is presented on Fig. 1 and two larger scale maps with three new localities in Fig. 2.

The first site in Goriška Brda is a species-rich, semi-dry riparian meadow (Tab. 1, relevés 1 and 2). More than 90 species were determined there, some of them protected (*Orchis morio, O. militaris, O. Tridentate, Ophrys holosericea, O. sphegodes, Anacamptys pyramidalis*) and some vulnerable (*Muscari comosum, M. neglectum, Equisetum ramosissimum*). The number of detected specimens of *Bellevalia romana* was only 6. According to phytosociological affinity this meadow is dominated by the species of dry and semi-dry meadows of the class *Festuco-Brometea* and is therefore for the time being classified into the association *Danthonio-Scorzoneretum villosae*. There are very similar riparian meadows also downstream towards Golo Brdo and slightly upstream towards Mišček. These were recorded too, but for now the Roman squill has not been noticed in these meadows, except for one locality on their wooded edge (relevé 9 in Tab. 1, only three recorded specimens of *Bellevalia romana,* pioneer community has elements of two syntaxa, *Galantho-Coryletum* (*Berberidion*, *Rhamno-Prunetea*) and *Ornithogalo-Carpinetum betuli* (*Erythronio-Carpinon, Querco-Fagetea*). There is, however, also a known locality on the right, Italian bank of the Idrija, in the vicinity of the hamlet Kras (Seljak 2001: 89, Poldini 2002: 75). In the neighbouring Friuli, the species is known to grow even further north, in the foothills of the Julian Alps. Most riparian meadows on the Slovenian side upstream of the Idrija towards Mišček (further away from the hamlet of Kras on the other bank) have been abandoned and are overgrown with tall herbs (including anthropophytes, e.g. *Solidago gigantea*), *Robinia pseudacacia*, *Fraxinus excelsior,Ulmus minor* and other woody plants. Although rather late in the summer (end of June), the researched meadow at Golo Brdo is still mowed for now, even though only vineyards

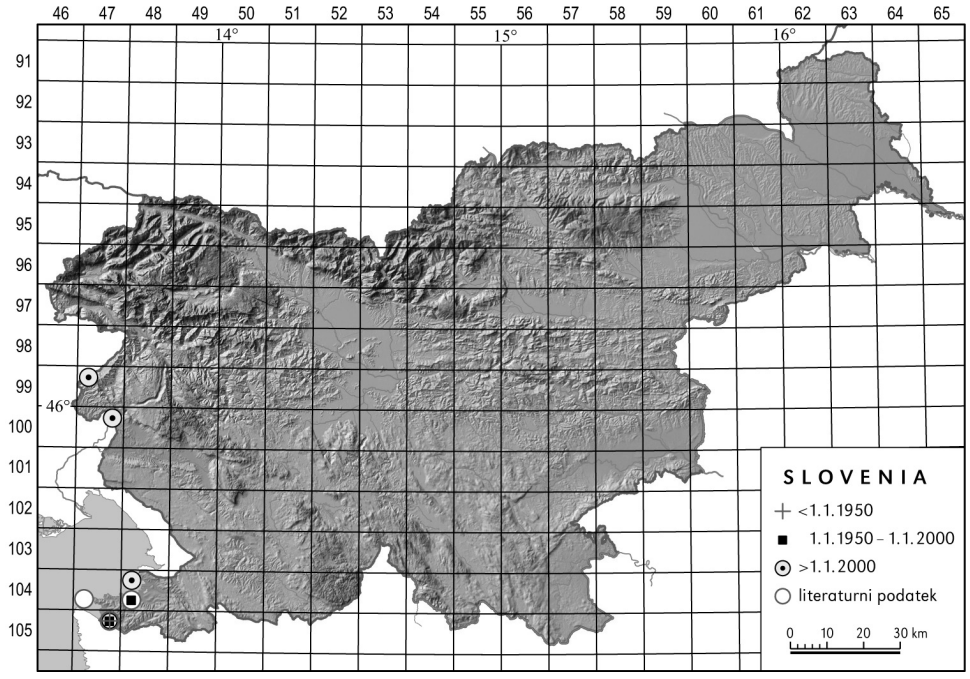


Figure 1: Distribution of Bellevalia romana in Slovenia.
Slika 1: Razširjenost vrste Bellevalia romana v Sloveniji.

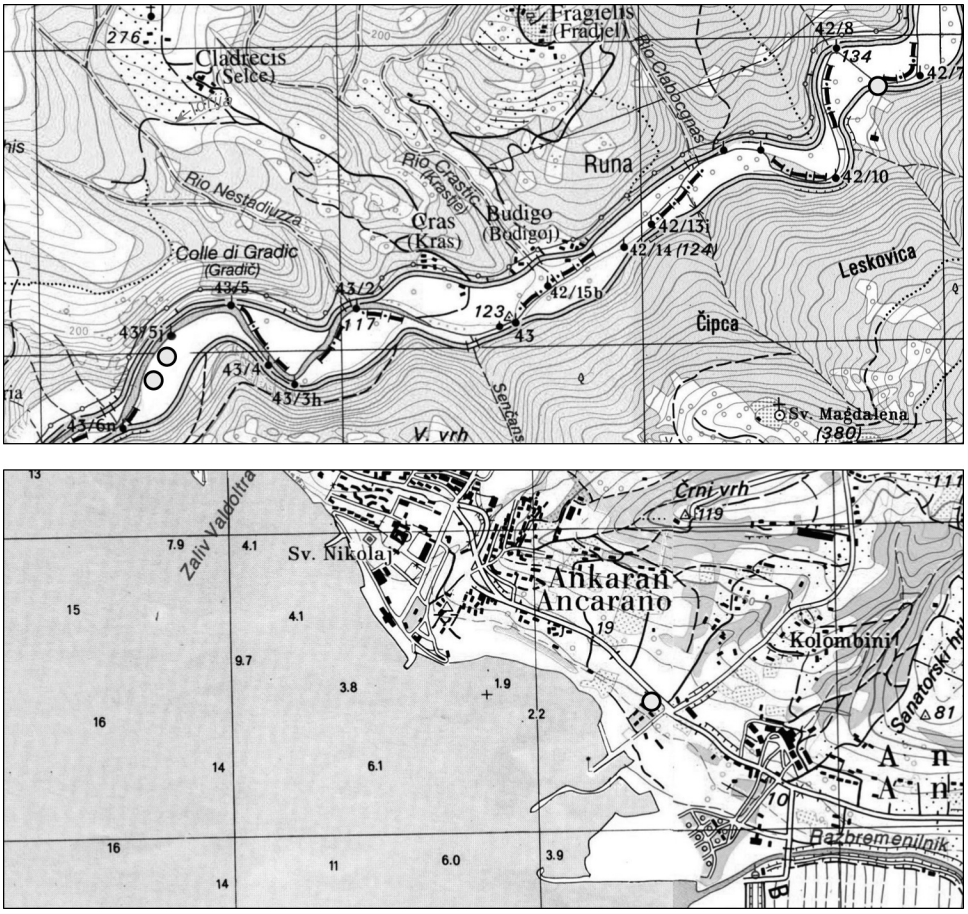


Figure 2: Location of the three new localities of Bellevalia romana at Golo Brdo (upper map) and one at Ankaran (lower map).

Slika 2: Lokacija treh novih nahajališč vrste Bellevalia romana pri Golem Brdu (zgornji zemljevid) in enega pri Ankaranu (spodnji zemljevid).

in the immediate vicinity still have any economic significance in these parts.

The third locality of *Bellevalia romana* in the Goriška region above Kromberk was phytosociologically researched in the year 2011 (relevés 3–8 in Tab. 1). The studied species, a total of 46 specimens, was recorded in six spots in an enclosed estate that measures a total of 0.7 hectare and is covered mainly by a meadow (first mowed in the second half of April) and an orchard. As the recorded communities are subject to early mowing they are for the time being not incorporated in the syntaxonomic system at the rank of associations. The relevés are dominated by the species of (semi) dry and cultivated meadows (*Festuco-Brometea, Molinio-Arrhenatheretea*); *Bellevalia romana* was frequent also in fringe communities and robinia shrubs.

The site of *Bellevalia romana* near Sv. Katarina at Ankaran is in a swamp of anthropogenic origin undergoing spontaneous afforestation where it was found during our inventory of marsh flora in May 2002. We missed its flowering when we repeated the inventory on the same site in the following years (10.6. 2004, 3.6. and 30.6. 2005, 14.4.2011) and have not seen it since, so it cannot be said

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8
	Working number of relevé (Delovna številka popisa)		219216	235098	239290	239291	239292	239293	239294	239295
	Altitude in m (Nadmorska višina v m)		100	100	185	190	190	180	180	180
	Aspect (Lega)		0	0	SW	S	S	SE	SW	SE
	Slope in degrees (Nagib v stopinjah)		0	0	5	2	5	5	3	3
	Parent material (Matična podlaga)		Al	Al	Fly	Fly	Fly	Fly	Fly	Fly
	Soil (Tla)		Fl	Fl	E	E	E	E	E	E
	Cover of tree layer in % (Zastiranje zeliščne plasti v %):	E3	.	.	.	.	.	.	5	70
	Cover of shrub layer in % (Zastiranje zeliščne plasti v %):	E2	.	.	.	.	.	.	20	10
	Cover of herb layer in % (Zastiranje zeliščne plasti v %):	E1	100	100	100	90	90	80	80	70
	Relevé area (Velikost popisne ploskve)	m^2	20	40	10	2	2	3	2	10
	Number of species (Število vrst)		79	72	48	25	26	39	30	43
	Date of taking relevé (Datum popisa)		09.06.2008	06.05.2010	08.04.2011	08.04.2011	08.04.2011	08.04.2011	08.04.2011	08.04.2011
	Locality (Nahajališče)		GB	GB	KR	KR	KR	KR	KR	KR
	Quadrant (Kvadrant)		9947/1	9947/1	0047/2	0047/2	0047/2	0047/2	0047/2	0047/2
SC	***Scorzonero-Chrysopogonetalia***									
TB	*Muscari comosum*	E1	.	1	+	+	.	.	.	1
	Knautia illyrica	E1	1	1	.	.	.	+	.	.
	Centaurea scabiosa subsp. *fritschii*	E1	2	1	.	.	.	.	.	.
	Chrysopogon gryllus	E1	2	3	.	.	.	.	.	.
	Scorzonera villosa	E1	+	1	.	.	.	.	.	.
	Bothriochloa ischaemum	E1	+	.	+	.	.	.	.	.
	Festuca valesiaca	E1	+	.	.	.	.	.	.	.
FB	***Festuco-Brometea***									
	Brachypodium rupestre	E1	1	2	+	1	.	1	+	+
	Galium verum	E1	1	1	.	.	.	.	.	.
	Carex caryophyllea	E1	1	1	2	.	2	1	.	.
	Muscari neglectum	E1	+	+	.	.	.	.	.	.
	Plantago media	E1	+	+	+	.	+	+	.	.
	Bromopsis erecta	E1	4	4	3	.	.	+	.	.
	Buphthalmum salicifolium	E1	1	1	+	.	.	+	.	.
	Salvia pratensis	E1	1	3	+	.	2	.	.	.
	Sanguisorba minor	E1	+	+	+	.	+	.	.	.
	Thymus pulegioides	E1	+	1	.	.	+	+	.	.
	Ranunculus bulbosus	E1	.	+	1	.	+	+	.	.
	Koeleria pyramidata	E1	+	1	+	.	.	.	.	.
	Peucedanum oreoselinum	E1	1	1	+	.	.	.	.	.
	Orchis tridentata	E1	1	1	.	.	.	.	.	.
	Arabis hirsuta	E1	+	.	1	.	+	.	.	.
	Pimpinella saxifraga	E1	+	.	+	.	.	+	.	.
	Euphorbia cyparissias	E1	+	.	.	.	.	.	.	.
	Onobrychis viciifolia	E1	1	2	.	.	.	.	.	.
	Anacamptis pyramidalis	E1	1	1	.	.	.	.	.	.
	Asperula cynanchica	E1	1	1	.	.	.	.	.	.

Table 1: Communities with Bellevalia romana in Slovenia.
Tabela 1: Združbe z belvalovko (Bellevalia romana) v Sloveniji.

with certainty that the plant still grows there. The following threatened species also grew on this site: *Carex distans* L., *Scirpoides holoschoenus* (L.) Soják subsp. *australis* (Murray) Soják and *Juncus maritimus* Lam.; later we recorded also *Carex extensa* Good., *Equisetum ramosissimum* Desf. and *Equisetum variegatum* Schleicher ex Weber & Mohr. Seliškar (in litt.), who made several relevés in the afforested swamp, determined the associations *Holoschoenetum romani* Tchou 1948 and *Phragmitetum australis*, and in the open area the presence of some species, characteristic for the class *Isoëto-Nanojuncetea* (e.g. *Plantago intermedia*, *Centaurium minus*). Despite its anthropogenic origin, the marsh is an important habitat for several threatened plant species of both the Primorska region and Slovenia.

Our comparison (Tab. 1, Figs. 3 and 4) demonstrates that the grassland, fringe and mantle communities above Kromberk (KB) on a flysh bedrock are much more similar to the meadow community and pioneer woods along the Idrija river (GB) than to the weed, ruderal, and wet meadow communities at Sečovlje (SE, relevés 10–20 in Tab. 1). The locality of *Bellevalia romana* on the edge of the Sečovelje saltpans and at the Portorož international airport is undoubtedly the biggest in Slovenia (median number of individuals per m2 was 16 with 95% confidence interval from 10 to 23 individuals/m2; min = 0, max = 71) and for the time being also the least threatened. The studied species in this locality grows in ruderal communities along cart tracks, in the vineyard, on wet meadows largely overgrown with *Cornus sanguinea* and *Prunus spinosa*, on mowed wet meadows and in marsh communities with dominant *Phragmites australis*, *Carex riparia* and *Carex divisa*. In terms of phytosociology, these communities cannot be classified at the rank of associations as of yet.

Potential new localities of *Bellevalia romana* in Slovenia can therefore be expected at least on the sites of seven phytosociological classes – preferential on the sites of semi-dry meadows from

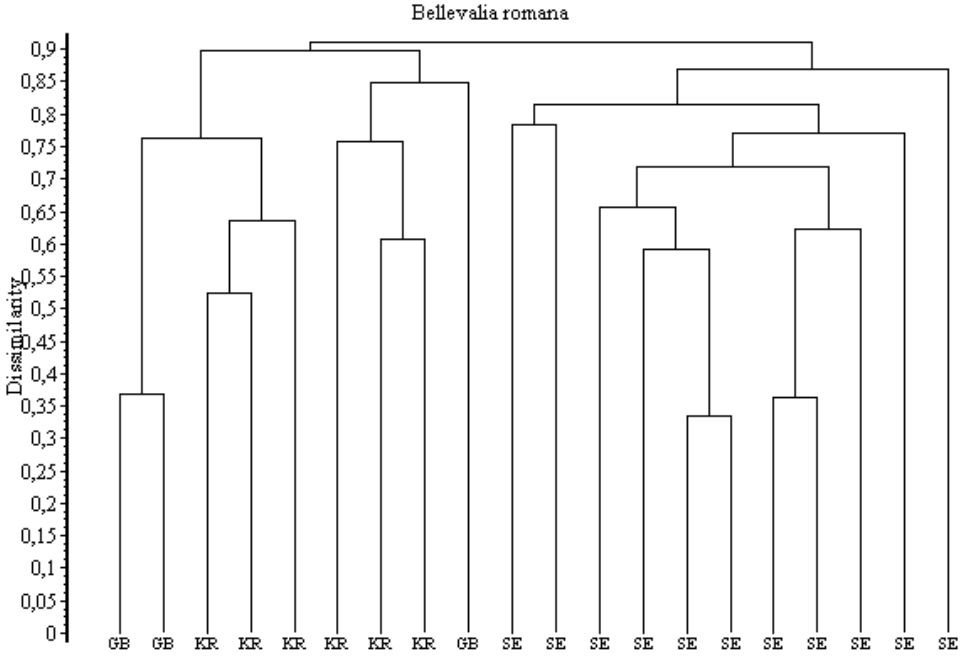


Figure 3: Dendrogram of the communities with Bellevalia romana in Slovenia (UPGMA, similarity ratio): GB (the Idrija valley), KR (Kromberk), SE (Sečovlje).

Slika 3: Dendrogram preučenih združb z vrsto Bellevalia romana v Sloveniji (UPGMA, similarity ratio): GB (dolina Idrije) KR (Kromberk), SE (Sečovlje).

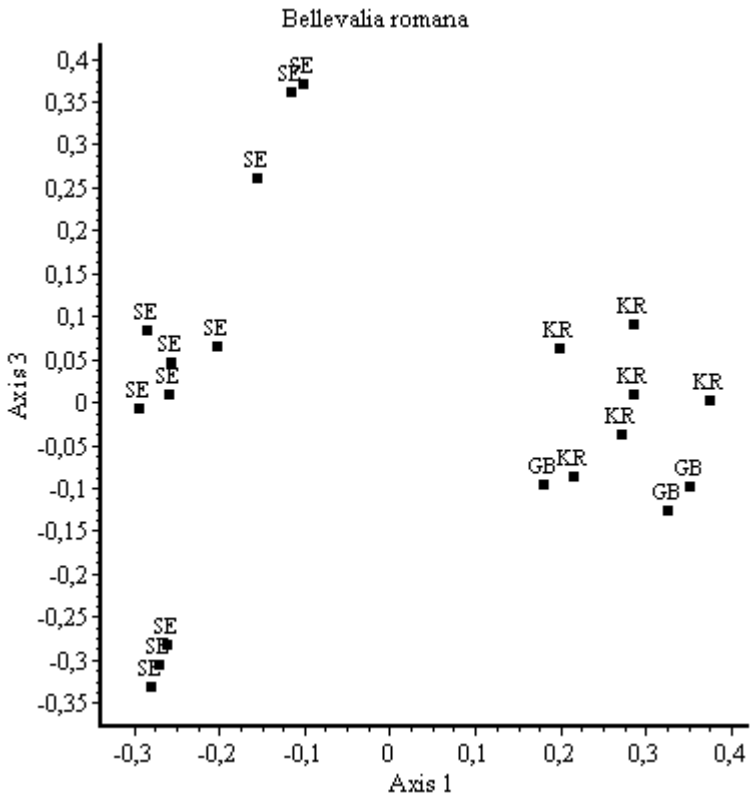


Figure 4: Two-dimensional scatter-diagram of the communities with Bellevalia romana in Slovenia (PCoA, similarity ratio): GB (the Idrija valley), KR (Kromberk), SE (Sečovlje).

Slika 4: Dvorazsežni ordinacijski diagram združb z vrsto Bellevalia romana v Sloveniji (PCoA, similarity ratio): GB (dolina Idrije) KR (Kromberk), SE (Sečovlje).

the class *Festuco-Brometea* and order *Scorzonero-Chrysopogonetalia*, of wet meadows from the class *Molinio-Arrhenathheretea* and order *Molinietalia caeruleae*, and of reed and tall herb communities from the class *Phragmiti-Magnocaricetea* (and order *Phragmitetalia communis*), on some places also in thermo- and mesophilous shrub communities from the classes *Rhamno-Prunetea* and *Quercо-Fagetea,* ruderal and weed communities from the class *Stellarietea mediae* and coastal marshes of the class *Juncetea maritimi*. While the meadow communities are threatened mainly by abandonment of mowing and afforestation, the wetlands along the Slovenian coast, on the other hand, are exposed above all to drainage, accumulation of material and building developments.

Conclusions

Four reliable localities can be confirmed for the rare and endangered species of Slovenian flora, *Bellevalia romana*, for the past two years (2010, 2011). One of them, the biggest, is in Slovenian Istria (at Sečovlje, on the surface area of 2600 m2 the median number of individuals per m2 was 16) and three are in the Goriška region (at Kromberk, on a 0.7 ha large enclosed estate with 46 counted specimens in 2011, and on two places in the Idrija valley between Golo Brdo and Mišček with a total of only 9 specimens counted in 2010 and 2011). The locality at Ankaran, found in 2002, could not be confirmed in the spring of 2011. According to their sites, the Istrian locality and wet meadows,

marsh and even weed communities immediately next to the sea, are slightly different from the semi-dry flysh and riparian meadows and shrubs in the Goriška region. In both cases, the threat to the habitats is considerable. The new localities on river alluvia along the Idrija between Golo Brdo and Mišček (9947/1) are so far the northernmost in Slovenia and the smallest in terms of the size of its population. We propose that the species-rich, and at present still mowed meadow at Golo Brdo, which is also the site of six protected orchids, is protected by the authorised services and that its current role is preserved.

Povzetek

Kronologijo poznavanja nahajališč redke mediteranske vrste *Bellevalia romana* na ozemlju zdajšnje Slovenije sta opisala T. Wraber (1990: 154) in Seljak (2001: 88–89). Po njunih spoznanjih sta bili do nedavna znani le dve recentni nahajališči – pri Sečovljah v Slovenski Istri in nad Kromberkom na Goriškem. Z našimi raziskavami, ki smo jih opravili po ustaljenih srednjeevropskih metodah, smo v letih 2002 in 2010 našli in popisali tri nova nahajališči te prizadete vrste, dve v dolini Idrije med Golim Brdom in Miščkom (9947/1m UTM 33T UM80), na rečnih nanosih na levem bregu Idrije (100 m nm. v. in 130 m nm. v.9) in pri Ankaranu v Slovenski Istri (10448/1, UTM 33TVL04), pri Sv. Katarini (7 m nm. v.). Rastišče v Goriških Brdih je vrstno bogat polsuh obrečni travnik (popisa 1 in 2 v Tab. 1) in mejica (grmišče) na njegovem robu (popis 9 v Tab. 1). Na še košenem (konec junija) travniku smo določili več kot 90 vrst, med njimi še nekaj zavarovanih (*Orchis morio,O. militaris,O. tridentata,Ophrys holosericea,O. sphegodes, Anacamptys pyramidalis*) in nekaj ranljivih (*Muscari comosum, M. neglectum, Equisetum ramosissimum*). Število opaženih primerkov belvalovke v dolini Idrije je bilo le 9. Po fitocenološki pripadnosti v dveh popisih pri Golem Brdu prevladujejo vrste suhih in polsuhih travnikov razreda *Festuco-Brometea*, zato ta travnik za zdaj uvrščamo v asociacijo *Danthonio-Scorzoneretum villosae*, grmišče na njegovem robu pa vsebuje elemente sintaksonov *Galantho-Coryletum* in *Ornithogalo-Carpinetum*. Drugo nahajališče belvalovke na Goriškem, nad Kromberkom, smo fitocenološko popisali aprila 2011. Na okoli 0,7 ha veliki ograjeni posesti, na kateri prevladujeta travnik in sadovnjak, smo belvalovko našli na šestih krajih in skupno opazili 46 primerkov. Mezobrometalni travnik, mejica in grmišče na robu posesti so vsaj nekoliko podobni rastiščema belvalovke ob reki Idriji (Tab. 1, Sl. 3 in 4). Rastišče belvalovke pri Ankaranu je v zaraščajočem močvirju antropogenega nastanka pri Sv. Katarini, kjer smo jo našli pri popisovanju močvirske flore v maju 2002. Pri ponovitvah popisov na istem nahajališču v kasnejših letih (10.6. 2004, 3.6. in 30.6. 2005, smo njeno cvetenje zamudili in je nismo več videli, prav tako je bil neuspešen obisk 14. 4. 2011. Na rastišču so skupaj z belvalovko rasle naslednje ogrožene vrste: *Carex distans* L., *Scirpoides holoschoenus* (L.) Soják subsp. *australis* (Murray) Soják in *Juncus maritimus* Lam., kasneje pa smo zabeležili še vrste *Carex extensa* Good., *Equisetum ramosissimum* Desf. in *Equisetum variegatum* Schleicher ex Weber & Mohr. Seliškar (in litt.), ki je v zaraščajočem močvirju naredil nekaj fitocenoloških popisov, je ugotovil asociaciji *Holoschoenetum romani* Tchou 1948 in *Phragmitetum australis*, na odprtih tleh pa tudi prisotnih nekaj vrst, značilnih za razred *Isoëto-Nanojuncetea* (npr. *Plantago intermedia*, *Centaurium minus*). Kljub antropogenemu nastanku je močvirje pomemben habitat za več ogroženih rastlinskih vrst Primorske in Slovenije. Edino v letu 2011 potrjeno in hkrati najobsežnejše slovensko nahajališče je pri Sečovljah (Slovenska Istra), v mejicah na robu Sečoveljskih solin, v bližnjem vinogradu in na vlažnih travnikih mednarodnega letališča Portorož. Na površini okoli 2600 m2 smo pri vzorčenju (štetju primerkov) na 21 naključno izbranih vzorčnih ploskvah velikosti 1 m2 ugotovili povprečno populacijsko gostoto (izraženo kot vrednost mediane) 16 osebkov/m2 (minimum = 0, maksimum = 71; 95% interval zaupanja: 10 – 23 osebkov/m2).

Morebitna nova nahajališča belvalovke v Sloveniji lahko pričakujemo na rastiščih vsaj sedmih fitocenoloških razredov, prednostno na obrečnih in flišnih travnikih iz razreda *Festuco-Brometea* in reda *Scorzonero-Chrysopogonetalia*, na mokrotnih travnikih iz razreda *Molinio-Arrhenatheretea* in reda *Molinietalia caeruleae* ter v trstičevju iz razreda *Phragmiti-Magnocaricetea* (in reda *Phragmitetalia communis*), ponekod tudi v toplih

in vlažnih grmišč in pionirskih gozdičih iz razredov Rhamno-Prunetea in *Querco-Fagetea,* v plevelnih združbah vinogradov iz razreda *Stellarietea mediae* ter v obmorskih močvirij iz razreda *Juncetea maritimi*. Travniške združbe ogroža predvsem opuščanje košnje in zaraščanje, mokrišča ob naši obali pa izpostavljena izsuševanju, nasipanju in pozidavam. Novi nahajališči na rečnih nanosih ob Idriji pri Golem Brdu sta doslej najbolj severno v Sloveniji (v sosedni Furlaniji to vrsto poznajo še bolj severno, v prigorju Julijskih Alp) in po velikosti populacije najmanjši. Za še košeni vrstno bogat travnik, na katerem uspeva tudi šest zavarovanih kukavičevk, predlagamo, da ga pristojne službe poskušajo ustrezno zavarovati in na njem ohraniti obstoječo rabo.

Acknowledgements

Sincere thanks to Mag. Andrej Seliškar for the phytosociological description of the vegetation in the locality at Ankaran and his review of the article, to Mag. Gabrijel Seljak, who showed us the locality of *Bellevalia romana* above Kromberk several years ago and also in the year 2011, and to Dr. Tatjana Čelik for valuable help by population statistics. Iztok Sajko prepared the Fig. 1. English translation was provided by Andreja Šalamon Verbič.

References

Aeschimann, D., Lauber, K., Moser, D. M. & Theurillat, J.-P., 2004a. Flora alpina. Bd. 1: *Lycopodiaceae-Apiaceae*. Haupt Verlag, Bern, Stuttgart, Wien, 1159 pp.

Aeschimann, D., Lauber, K., Moser, D. M. & Theurillat, J.-P., 2004b. Flora alpina. Bd. 2: *Gentianaceae-Orchidaceae*. Haupt Verlag, Bern, Stuttgart, Wien, 1188 pp.

Aeschimann, D., Lauber, K., Moser, D. M. & Theurillat, J.-P., 2004c. Flora alpina. Bd. 3: Register. Haupt Verlag, Bern, Stuttgart, Wien, 322 pp.

Anonymous, 2002. Pravilnik o uvrstitvi ogroženih rastlinskih in živalskih vrst v rdeči seznam 2002: Priloga 1: Rdeči seznam praprotnic in semenk (Pteridophyta & Spermatophyta*)*. Uradni list RS 12 (82), 8893–8910.

Bavcon, J., Dakskobler, I., Dakskobler, L., Dolinar, B., Marinček, A., Fišer, S., Makše, J., Seliškar, A., Vreš, B., Ravnjak, B., 2011. Semina e plantis spontaneis in loco natali annis 2010 et 2009 lecta. In: Bavcon, J. (ed.): Franc Hladnik: founder of the Ljubljana Botanic Garden. Isndex seminum anno 2010 collectorum. Hortus Botanicus Universitatis Labacensis Slovenia, Ljubljana, pp. 44–54.

Braun-Blanquet, J., 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde. 3. Auflage. Springer, Wien – New York, 865 pp.

Campbell, M. J. & Gardner, M. J., 1988. Calculating confidence intervals for some non-parametric analyses. British Medical Journal, 296: 1454–1456.

Ehrendorfer, F., Hamann, U., 1965. Vorschläge zu einer floristischen Kartierung von Mitteleuropa. Berichte der Deutschen Botanischen Gesellschaft 78, 35–50.

Glasnović, P., Jogan, N., 2009. Flora okolice Ankarana (kvadranta 0448/1 in 0448/2). Scopolia (Ljubljana) 67, 1–86.

Jogan, N., Bačič, T., Frajman, B., Leskovar, I., Naglič, D., Podobnik, A., Rozman, B., Strgulc – Krajšek S., Trčak, B., 2001. Gradivo za Atlas flore Slovenije. Center za kartografijo favne in flore, Miklavž na Dravskem polju, 443 pp.

Maarel van der, E., 1979. Transformation of cover-abundance values in phytosociology and its effects on community similarity. Vegetatio 39 (2), 97–114.

Martinčič, A., Wraber, T., Jogan, N., Podobnik, A., Turk, B., Vreš, B., Ravnik, V., Frajman, B., Strgulc Krajšek, S., Trčak, B., Bačič, T., Fischer, M. A., Eler, K., Surina, B., 2007. Mala flora Slovenije. Ključ za določanje praprotnic in semenk. Četrta, dopolnjena in spremenjena izdaja. Tehniška založba Slovenije, Ljubljana, 967 pp.

Podani, J., 2001. SYN-TAX 2000. Computer Programs for Data Analysis in Ecology and Systematics. User's Manual, Budapest, 53 pp.

Poldini, L. (with collaboration of G. Oriolo & M. Vidali), 2002. Nuovo Atlante corologico delle piante vascolari nel Friuli Venezia Giulia. Regione Autonoma Friuli Venezia Giulia, Azienda Parchi e Foreste Regionali & Università degli Studi di Trieste, Dipartimento di Biologia, Udine, 529 pp.

Seliškar, T., Vreš, B., Seliškar, A., 2003. FloVegSi 2.0. Fauna, Flora, Vegetation and Paleovegetation of Slovenia. Computer programme for arranging and analysis of biological data. Jovan Hadži Institute of Biology SRC SASA, Ljubljana.

Seljak, G., 2001. Rimska belvalovka (*Bellevalia romana*) tudi na Goriškem. Proteus (Ljubljana) 64 (2), 88–89.

Skoberne, P., 2007. Zavarovane rastline Slovenije. Narava na dlani. Žepni vodnik. Mladinska knjiga, Ljubljana, 116 pp.

Šilc, U., Čarni, A., 2011. Pregled sintaksonomskega sistema rastlinskih združb Slovenije. Biološki inštitut Jovana Hadžija ZRC SAZU, Ljubljana.

Wraber, T., 1990. Sto znamenitih rastlin na Slovenskem. Prešernova družba, Ljubljana, 239 pp.

ABS ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 61–70

Origins of the Dinaric troglobiotic mussel and its correct taxonomical classification. *Congeria* or *Mytilopsis* (Bivalvia: Dreissenidae)?

Izvor dinarske troglobiotske školjke in njena pravilna taksonomska uvrstitev. *Congeria* ali *Mytilopsis* (Bivalvia: Dreissenidae)?

Boris Sket, Oddelek za biologijo, Biotehniška fakulteta, Univerza v Ljubljani
Ljubljana, p.p. 2995, 1001 Ljubljana, Slovenia
*correspondence: boris.sket@bf.uni-lj.si

Running title
Sket: Troglobiotic mussel *Congeria kusceri*

Abstract: After an analysis of the literature, it is proposed to taxonomically reorder the troglobiotic mussel *Congeria kusceri* Bole 1962 as *Mytilopsis kusceri* (Bole 1962). The species had been described and attributed to *Congeria* when the extant and fossil *Mytilopsis* spp. were all regarded members of that genus. The position of the cave species within the genus *Mytilopsis* and Dreisseninae is discussed and its inclusion into *Mytilopsis* is substantiated. In this way we will avoid further missapprehension in biogeographical and phylogenetic discussions. The cave mussel may further be regarded a relict of the diverse fauna in the Miocene Dinaric Lakes System.

Key words: Mollusca, Bivalvia, cave fauna, *Congeria kusceri*, taxonomy

Izvleček: Po analizi literature je podan predlog, da se troglobiotsko školjko *Congeria kusceri* Bole 1962 taksonomsko prerazporedi kot *Mytilopsis kusceri* (Bole 1962). Vrsta je bila opisana in dodeljena rodu *Congeria*, ko so tako recentne, kot fosilne vrste rodu *Mytilopsis* obravnavali kot pripadnice rodu *Congeria*. Obravnavan je položaj vrste znotraj rodu *Mytilopsis* in poddružine Dreisseninae, podana je utemeljitev prerazporeditve. S tem se bomo lahko izognili nadalnjim nesporazumom pri filogenetskih in biogeografskih razpravah. Jamsko školjko lahko še vedno imamo za relikt pestre favne v miocenskem Dinarskem pojezerju.

Ključne besede: Mollusca, Bivalvia, jamska favna, *Congeria kusceri*, taksonomija

Introduction

The shells of a tentatively troglobiotic mussel were found by the Slovene malacologist Ljudevit Kuščer in 1930s in the spring Stinjevac near Vrgorac in Croatian Dalmacija. They were recognized as *Congeria* sp. and published in a list of the Dinaric cave fauna by Stanko Karaman (1935). J. Štirn, in 1956 (pers. com.) found live '*Dreissena*' in the cave Žira jama in Turkovići, Popovo polje, S Hercegovina. It could be immediately supposed that this animal can only be conspecific or related to the Kuščer's *Congeria*, since no *Dreissena* was known to occur within the inner parts of the Dinaric karst (own data). The closest localities of *Dreissena* are in lower reaches of the subpannonian river Sava (Matoničkin and Pavletić 1972) and in the Drim drainage at the SE extreme of Dinarides and in the Northern Hellenides (Albrecht et al. 2007; Wilke et al. 2010), namely in the lakes of Skadar, Ohrid, and Prespa (Skadarsko jezero/Liqueni i Shkodrës, Ohridsko ezero/L. i Ohrit, Prespansko ezero/Limni Megáli Préspa/L. i Prespes). Triggered by the Štirn's finding and after our joint visiting the Žira jama (Fig. 1), Bole described the mussel taxonomically as *Congeria kusceri* (Bole 1962) (Fig. 2).

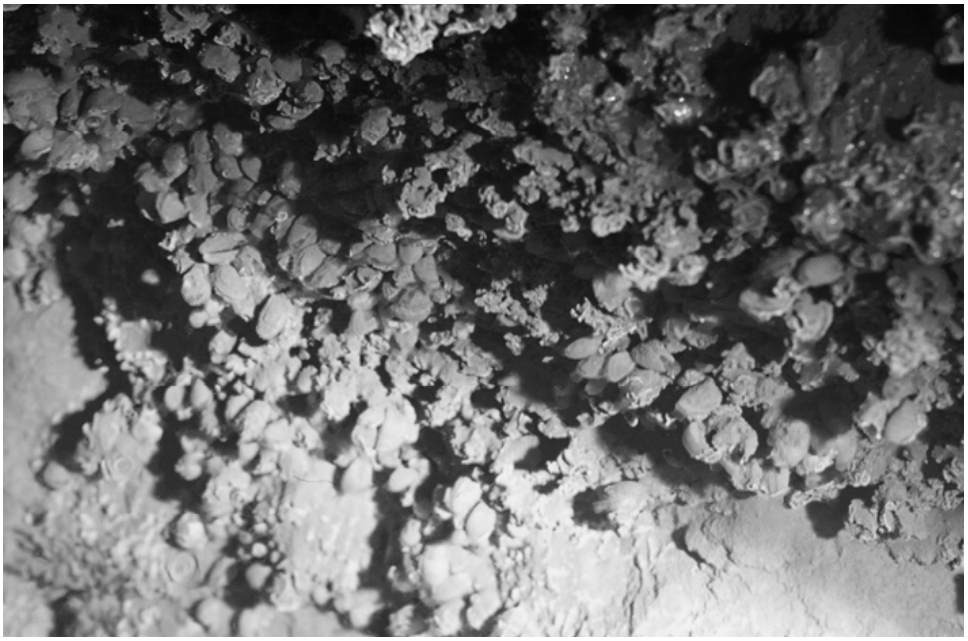


Figure 1: Aggregations of mussels Mytilopsis kusceri (Bole 1962) (syn. Congeria kusceri) in the cave Žira jama, Popovo polje in 1950s.
Slika 1: Agregacija školjke Mytilopsis kusceri (Bole 1962) (syn. Congeria kusceri) v jami Žira, Popovo polje v 1950ih letih.

Figure 2: A shell of Mytilopsis kusceri (Bole 1962) (syn. Congeria kusceri) from its type locality, Žira jama, Popovo polje, Bosnia and Herzegovina.
Slika 2: Lupina Mytilopsis kusceri (Bole 1962) (syn. Congeria kusceri) iz tipskega nahajališča, jame Žira jama, Popovo polje, Bosna in Hercegovina.

In the meantime and after that, representatives of the same or a related taxon could be recognized also in the '*Dreissensia polymorpha fluviatilis* var. *elata* or var. *occidentalis*' found and published by the karstologist Katzer already in 1921 from karst springs in Lušci polje, Bosnia and Herzegovina. The same with '*Dreissena polymorpha*' found in some caves of Hercegovina by Remy (1953). These literature data were 'discovered' only after the Bole's description. We also found the mussels in some additional localities in Hercegovina, Bosanska Krajina (W Bosna), Croatian Dalmacija and Lika, and the most north-western in Bela Krajina (SE Slovenia) (Sket 1970, 1992; Bole and Velkovrh 1986; Bole 1992; Jalžić 1998, 2001; Schütt 2000). So, *Congeria kusceri* joined the other most prominent Dinaric troglobionts as a truncated 'holodinaric' biogeographic element (Sket 1994; ammended in Sket and Zagmajster 2006), with scattered localities along all the Dinarides from their NW, up to the SE Hercegovina and Dalmacija. Some other holodinaric elements are *Proteus anguinus* Laurenti (Amphibia; Sket 1997),

Marifugia cavatica Absolon et Hrabe (Polychaeta: Serpulidae; Sket 1983; Kupriyanova et al. 2009), *Troglodiaptomus sketi* Petkovski (Copepoda: Diaptomidae; Brancelj 1991), genus *Titanethes* s. str. (Oniscidea: Trichoniscidae; Strouhal 1939) etc. However, they all are reaching as far to the NW to include a bit of the Italian territory, which is not the case with the mussel. Some anatomical data and biological considerations have been published by Morton et al. (1998).

Stepien et al (2001) analyzed the DNA and compared *C. kusceri* with the related *Mytilopsis leucophaeata* and *Dreissena polymorpha*. The attribution of this species to the genus *Congeria* they took for granted. Finally, Bilandžija et al. (2010) are trying to molecularly establish relations between extant populations of *C. kusceri*. Their study is in progress.

Dinaric karst developed on the Adriatic microplate dividing the western branch of Tethys into a smaller Paratethys sea and the paleo-Mediterranean. During middle Miocene this land was intermittently an island or attached as a peninsula to the European plate (Rögl and Steininger 1984; Popov et al. 2004). A series of lakes forming the Dinaric Lake System developed in the Dinaric depressions and the bivalvian genus *Mytilopsis* radiated in it exceedingly (Kochansky-Devide et Slišković 1978; Harzhauser and Mandic 2004, 2008; Prelogović 1975). Karstification started to form underground water conduits here in Pliocene at the latest (Melik 1958), but according to new findings already in the Early Miocene (Bosák 2010). This enabled surface animals to extend their populations into subterranean habitats.

Discussion

Position of Congeria kusceri within Dreissenidae

With its relatives, *Congeria* constitutes the subfamily Dreissenidae: Dreisseninae (Nuttall 1990; Harzhauser and Mandic 2004). The genus ***Congeria*** Partsch, 1836 was erected for an extinct thick-shelled species *Congeria subglobosa* Partsch, 1836 (Fig. 3). All other fossil species of the genus, as it is conceived today, are similar, they are supposed to have been inhabitants of the

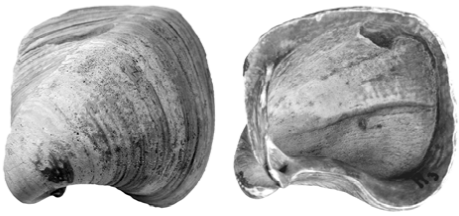


Figure 3: A fossil shell of Congeria subglobosa Partsch 1836 from Pannonian (Late Miocene) strata in Vösendorf, S of Wien, Austria. Photo NHM Wien.

Slika 3: Fosilna lupina vrste Congeria subglobosa Partsch 1836 iz panonskih (pozni miocen) plasti v Vösendorf, južno od Dunaja, Avstrija. Foto NHM Wien.

dysoxic muddy lake bottom, probably living in symbiosis with chemosynthetic bacteria; such a group of species was endemic to the Paratethyan basins, exhibiting a particular radiation in the long-lived lake Pannon during the Pannonian (Tortonian) (Harzhauser and Mandic 2004, 2010). The stratigraphic range of the genus ranges between 11.5 and 5.5 Ma. The probably last representatives were several Pontian (Messinian) species of the Eastern Paratethys getting extinct with the end of the Miocene (Stevanović et al. 1989; Krijgsman et al. 2010).

However, morphologically closer to *Congeria kusceri* are species of the related genus ***Mytilopsis*** Conrad 1958, erected for the extant species *Mytilus leucophaeatu*s Conrad, 1831, i.e. for the actual *Mytilopsis leucophaeata* (Conrad, 1831), synonym *M. cochleata* (Kickx, 1835). The generally accepted eight extant species of *Mytilopsis* are all mytiliform, byssate, inhabiting brackish waters at the sea edges, mainly in tropics. This is presented as the most ancient genus of Dreisseninae, originating probably from the Eocene brackish Corbiculidae (Nuttall 1990). The initial important morphological diversification of *Mytilopsis* started only in the Early Miocene (Kochansky-Devide and Slišković 1978, 1981; Harzhauser and Mandic 2004). Their diversity was particularly rich in the Dinaric Lake System on the Dinaric land. That radiation occurred distinctly prior to the late Miocene branching of *Congeria*. The late Miocene history of the Dinaride Lake System is still obscure (De Leeuw

et al. 2010; Mandic et al., 2011) but also if partly synchronous with Lake Pannon, *Congeria* never managed to invade that fresh water environment (Harzhauser and Mandic 2010). *Mytilopsis* was treated as vanished in Europe towards the end of Pliocene and appeared again in historic times due to anthropogenic introduction (Verween et al. 2010). The relation between *Congeria* and *Mytilopsis* is supported by the shared character of attachment of the anterior byssal retractor muscle to a special lobe of the anterior shell septum called the *apophysis* (Morton 1993).

The third from the extant dreissenine genera, *Dreissena*, also developed from within *Mytilopsis*; it was characterized by a reduction of the apophysis. Virtually the only character by which fossil shells of *Mytilopsis* may be distinguished from *Dreissena* is the presence of the *apophysis*. However, at the occasion of description of a large series of Miocene *Mytilopsis* species from Dinaric area (as *Congeria*), Kochansky-Devide and Slišković (1978: 34) say (translated from Serbo-Croatian): 'In the rich … material the apophysis … could rarely be seen … (Most) species could only be attributed to *Congeria* by their phylogenetic bounds or by external similarity … Probably a *Dreissena* is among them …'. This means that the reduction of the apophysis evidently took place a number of times convergently. Therefore, it is questionable when did just the phyletic line (clade) containing the type species *Dreissena polymorpha* split off the main *Mytilopsis* lineage. In the scheme by Nuttall (1990: Fig. 1) the split between *Mytilopsis* and *Dreissena* is approximately 7 Mya, ("million years ago") while according to Verween et al. (1910: Fig. 2) as much as 30 Mya; although all authors refer to Steininger et al. 1985. According to Harzhauser and Mandic (2004, 2010) the first certain *Dreissena* representatives inhabited the late Miocene Lake Pannon. Particular diversity peaks lasted up to the Pleistocene extinction, since then being only slightly diversified but highly invasive. It spread beyond Europe first in recent times (Thienemann 1950; Steininger et al. 1985; Harzhauser and Mandic 2004).

Thus, the **actual concept of Dreisseninae** is as follows: *Mytilopsis* sensu the recent authors (Nuttall 1990; Harzhauser and Mandic 2004, 2010) is the earliest and most plesiomorphic genus, originating in the Eocene and still existing in brackish waters circumtropically. *Dreissena* originated from within *Mytilopsis*, retaining generally its shape, developing higher resistance towards fresh water, but a lower ability to distribute. The aberrant, apomorphic genus *Congeria*, branched from *Mytilopsis* developing complex morphologic and physiological adaptations. In contrast to the troglobiotic freshwater '*Congeria*' *kusceri*, the genuine *Congeria* was limited to the brackish water Paratethys basins and finished its existence at approximately 5.5 Ma.

This scheme might be formally questionable, but it is evolutionarily most logical and therefore reasonable, appealing. Under a strict analysis it might appear to be in discord with the priority law of ICZN (1999; which is valid for extant as well as for extinct species). It violates also the cladists' principle interdicting paraphyletic taxa (Mayr and Ashlock 1991: 223). And finally, it is seemingly in contradiction with the existence of the extant mytiloid mussel *Congeria kusceri* in European fresh waters.

I will try to entangle here only the last problem, which is of only a formal character. I am suggesting to transfer the cave mussel into the other genus and recombine its name as *Mytilopsis kusceri* (Bole 1962) comb. n. This proposal can be supported at least by four facts. First, *C. kusceri* is conchiologically and anatomically similar to *Mytilopsis* being mytiloid in shape, developing byssus threads and possessing the characteristic apophysis. Second, the genetic distances between *C. kusceri* and *M. leucophaeata* is only of the same size category as between two species of the related *Dreissena, D. polymorpha* (Pallas 1771) and *D. bugensis* (Andrusov 1897) (Stepien et al. 2001). Third, *M. leucophaeata* used to be in some periods mainly mentioned as *Congeria cochleata* (e.g. Wolff 1969; Thienemann 1950) and most fossil species from the Dinaric area were described as *Congeria* spp. (e.g. Kochanski-Devide and Slišković 1981). As such, *'Congeria'* was also known to Bole (1962; pers comm.); in fact, Bole explicitely considered his *C. kusceri* to be closely related to *Congeria cochleata* (= *Mytilopsis leucophaeata*) rather than to fossil Pannonian *Congeria* spp. In other words, the Bole's classification of his new species was meant as for *Congeria* which included the branch *Mytilopsis*. Most probably, the same was true with the cave mussel's first discoverer L. Kuščer. And

fourth, *Congeria* s. str. has never been found in the area of Dinaric lakes, while *C. kusceri* inhabits just the Dinaric karst. This new combination will be valid as long as *Congeria* and *Mytilopsis* persist to be regarded separate genera.

Position of C. kusceri within Mytilopsis; a relict?

Stepien et al. (2001), according to genetic markers suppose the split between *M. leucophaeata* and *C. kusceri* approximately 5–15 Mya (while it was calculated to 10–13 Mya for *Dreissena bugensis* and *D. polymorpha*). The species may well have been separated soon after the decline of the Miocene Dinaric Lake System (ca 15 Mya according to Harzhauser and Mandic 2008) in which the genus *Mytilopsis* radiated. The Miocene species were morphologically (conchologically) very diverse, but mytiloid shape was not uncommon. The mytiloid shape of shells is very common in byssate mussels in general, one may suppose that it developed (or even re-stored) in many unrelated lineages also within the genus in question. Similar fossil species are e.g. *M. hercegovinensis* (Kochansky-Devide et Slišković 1978) or *M. acuta* (Kochansky-Devide et Slišković 1981). Although *M. hercegovinensis* is explicitely defined as 'sharply carinate' and with a 'curved and sharp top', the figures (Kochansky-Devide et Slišković 1978: Sl. 4, 1-4; Tab. II, 1-18) show a wide intraspecies variation including also rounded shells. All extant *Mytilopsis* spp. and *C. kusceri* may fall within this spectrum of polymorphsm. *M. hercegovinensis* was found widely across NW Hercegovina, N and W Bosna and Middle Dalmacija. According to authors, the sediments with *M. hercegovinensis* were of the lower part of the middle Miocene which would mean their origin at the down of the Dinaric Lake System. The similar but more local *M. acuta* was even younger.

The direct ancestor-descendant relationship between *M. hercegovinensis* and *C. kusceri* is not impossible, but the dreissenid shells are too poor in diagnostic characters and at the same time too variable to allow any serious hypothesis. It is in any case probable that either *M. hercegovinensis* or a related species, with the progressing karstification of the territory found possibility to invade subterranean waters. This could have happened polytop, in different locations, as it happened or is even happening now in some crustaceans: *Asellus aquaticus* (Sket 1965; Prevorčnik et al. 2002; Verovnik et al. 2001), the genus *Monolistra* (Sket 1986), *Proteus* (Sket 1997). After the strong reduction of surface lake- and river-systems which caused extinction of surface populations, cave mussel populations got isolated and developed further independently. Molecular analyses clearly show that most holodinaric subterranean elements diversified into endemic local races or even species. This was shown for e.g. the shrimp *Troglocaris* s. str. (Sket and Zakšek 2009), the serpulid tube worm *Marifugia* (Zakšek et al. in prep.). Recent investigations in *C. kusceri* (Bilandžija et al. 2010) show that we may expect similar results in this mussel.

Conclusion

Congeria kusceri is only distantly related to the extinct Pannonian *Congeria* spp. It is purely **freshwater, troglobiotic**, and biogeographicaly a truncated **holodinaric** (Fig. 4) animal. As long as *Mytilopsis* and *Congeria* are taxonomically regarded separate genera, *C. kusceri* has to be attributed to the former. Such a way we will avoid some misapprehension in biogeographical and speleobiological discussions.

Its relatives naturally closest in time, ecology (mainly freshwater) and space (Europe) are: *M. rhodanica* (Fontannes 1882) in West European Messinian (Late Miocene, ca 6 Ma; Nuttall, 1990), ca. 6 latest, probably late Miocene species from the residual Dinaric freshwater lakes (ca. 10 Mya, Kochansky-Devidé and Slišković 1981), ca. 30 Late Pannonian species of Lake Pannon and Lake Kosovo (Late Miocene, ca. 6 Mya; Harzhauser and Mandic 2008, 2010; Geary et al. 2010) and about 20 Dacian/Kimmerian Eastern Paratethys species (Pliocene, ca. 5 Mya; Harzhauser and Mandic 2010).

Locally, it shows some morphological and distributional similarity with *M. hercegovinensis* from the middle Miocene deposits of the Dinaric Lake System. So, the Dinaric mussel *Mytilopsis kusceri* (Bole 1962) (synonyma: *Congeria* sp. Kuščer, in Karaman 1935; *Congeria kusceri* Bole 1962) seems to be a **relict** of the Miocene lake fauna of the same region where it is still living.

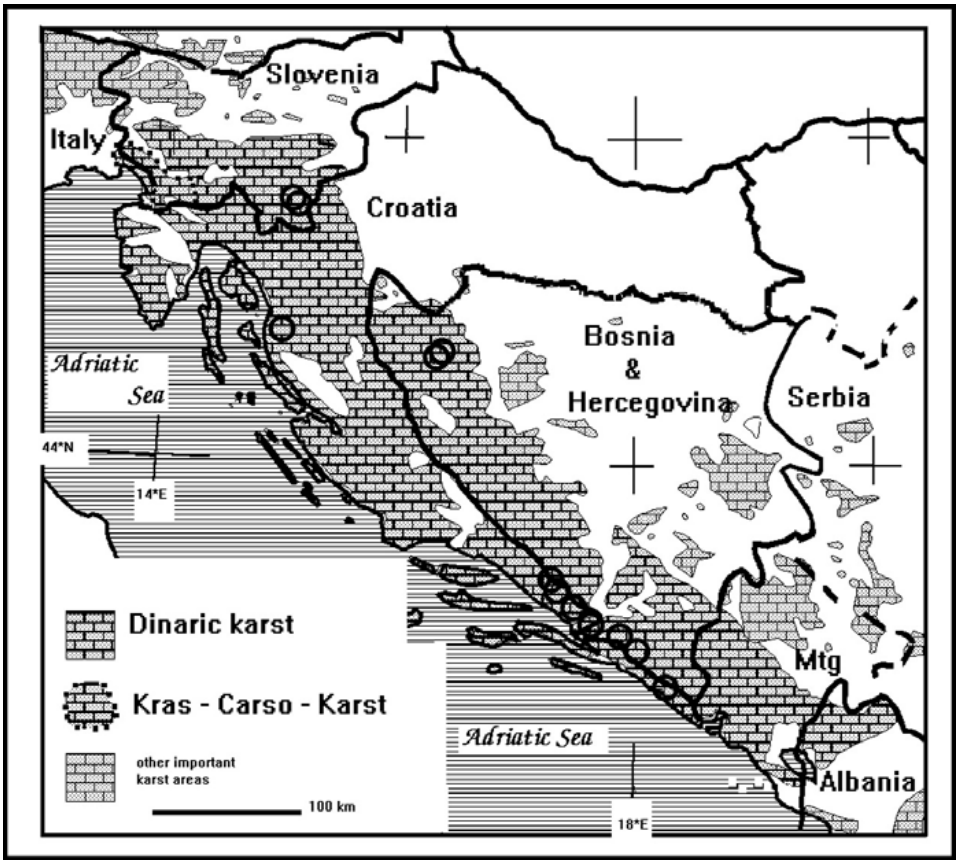


Figure 4: Known distribution of Mytilopsis kusceri (Bole 1962), syn. Congeria kusceri; open circles – localities.
Slika 4: Znana razširjenost školjke Mytilopsis kusceri (Bole 1962), syn. Congeria kusceri; krogci - lokalitete.

Povzetek

Lupine domnevno troglobiotske školjke je našel slovenski malakolog Ljudevit Kuščer v 1930h letih v izviru Stinjevac v Dalmaciji. Pod imenom *Congeria* sp. je najdbo objavil Karaman (1935). Že pred tem in pozneje so najdbe školjk, ki so jih pripisali rodu *Dreissena* našli tudi drugi, a trikotničarke v resnici ni v dinarskem krasu. J. Štirn je našel žive školjke v jami Žira ob Popovem polju, na kar je J. Bole (1962) vrsto opisal kot *Congeria kusceri*.

Pozneje smo to vrsto našli po obsežnem območju dinarskega krasa; nahajališča so raztresena po Hercegovini in Dalmaciji, v Bosanski Krajini, Liki in Beli Krajini. Tako se je jamska školjka izkazala za holodinarski biogeografski element, le da ne sega do skrajnih meja območja na severozahodu. Popolnejšo holodinarsko razširjenost izkazujejo najimenitnejši dinarski troglobionti: močeril *Proteus anguinus* Laurenti (Amphibia), jamski cevkar *Marifugia cavatica* Absolon et Hrabe (Polychaeta: Serpulidae), ceponožec *Troglodiaptomus sketi* Petkovski (Copepoda: Diaptomidae), rod mokric *Titanethes* s. str. (Oniscidea: Trichoniscidae) in še nekateri.

Dinarski kras se je razvil na Jadranski mikroplošči, ki je nekaj časa kot otok ali k Evropski plošči prislonjen polotok delila rokav Tetide na manjšo Paratetis in večji paleo Mediteran. V miocenu je bilo na tem območju obsežno Dinarsko pojezerje (Dinarski jezerski sistem), najpozneje

v pliocenu pa je začelo zakrasevanje. S tem so se nekatere živali lahko razširile tudi v podzemlje.

Rod *Congeria* Partsch 1836 je bil postavljen za fosilno, debelolupinasto vrsto *Congeria subglobosa* Partsch 1836, sorodne vrste iz Vzhodne Paratetide in iz jezera Panon so ji podobne. Morfološko pa je *Congeria kusceri* bolj podobna vrstam sorodnega rodu *Mytilopsis* Conrad 1958; ta je bil postavljen za živečo vrsto *Mytilus leucophaeatus* Conrad 1831, s tem prerazporejeno kot *Mytilopsis leucophaeata* (Conrad 1831), sinonim še *M. cochleata* (Kickx 1835). Rod naj bi nastal v eocenu in se posebej razbohotil v sladkovodnem miocenskem Dinarskem pojezerju.

Danes imajo *Mytilopsis* za izvorno vejo podružine Dreissenidae: Dreisseninae, od nje pa naj bi se odcepila rodova *Congeria* in *Dreissena*. *Congeria* je bila omejena na Vzhodno Paratetido in jezero Panon in je z zatonom slednjega tudi izumrla. *Dreissena* je bila po naravi omejena na Ponto-kaspijski sistem, a se je *D. polymorpha* s posredovanjem človeka v preteklem stoletju razširila po Evropi, invazivni vrsti *D. polymorpha* in *D. bugensis* sta celo hud ekološki problem v ZDA. Osem splošno priznanih vrst rodu *Mytilopsis* danes poseljuje somornico, večinoma v tropih, semkaj pa štejejo tudi obilico fosilnih vrst.

Ugotovili so, da se *C. kusceri* od vrste *M. leucophaeata* molekulsko razlikuje le približno toliko, kot sta različni vrsti sorodnega rodu *Dreissena*, *D. polymorpha* in *D. bugensis*. Omeniti tudi velja, da je Bole poimenoval vrsto *C. kusceri* v času, ko so ime *Mytilopsis* večinoma imeli za sinonim rodu *Congeria*; in Bole celo izrecno omenja, da je *C. kusceri* podobna vrsti *M. cochleata*.

Lahko torej domnevamo, da je vrsta *C. kusceri* dejansko nastala iz ene od dinarskih vrst rodu *Mytilopsis*, ki se je ob zatonu Dinarskega pojezerja in zakrasevanju dinarskega območja uspela razširiti v podzemlje in tam tudi ohraniti. Torej dejansko je relikt tamkajšnje terciarne favne.

Navidez obrobna taksonomska sprememba, ki jo predlagam, sploh ni nepomembna. S prerazporeditvijo in preimenovanjem jamske školjke v *Mytilopsis kusceri* (Bole 1962) se bomo izognili marsikateremu nesporazumu v filogenetskih in speleobioloških razpravah.

Acknowledgement

M. Harzhauser and O. Mandić (Wien) are thanked for some useful remarks and improvement of some paleontological data. Our data were collected during investigations supported by Slovenian research agencies, nowadays of ARRS.

Literature

Albrecht, C., Schultheiss, R., Kevrekidis, T., Streit, B., Wilke, T., 2007. Invaders or endemics? Molecular phylogenetics, biogeography and systematics of Dreissena in the Balkans. Freshwater Biology, 52, 1525–1536.

Bilandžija, H., Podnar, M., Jalžić, B., Patarčić, I., Tvrtković, N., Ćetković, H., 2010. Phylogeny and phylogeography of the cave bivalve *Congeria kusceri*, with an outline for its endangerment in Croatia. In: Moškrič A., Trontelj, P. (eds.). 20th Intern. Conf.on Subterranean Biology, Abstract book, Postojna: organizing committee, pp. 56–57.

Bole, J., Velkovrh, F., 1986. Mollusca from continental subterranean aquatic habitats. In: Botosaneanu, L. (ed.): Stygofauna mundi, E. J. Brill/Dr. W. Backhuys, Leiden, pp. 177–208.

Bole, J., 1962. *Congeria kuščeri* sp. n. (Bivalvia, Dreissenidae). Biološki vestnik, 10, 55–61.

Bole, J., 1992. The Red List of Terrestrial and Freshwater Mollusca in Slovenia. Varstvo narave, 17, 183–189.

Bosák, P., 2010. Results of paleomagnetic dating in Slovenia: some provocative questions for application to karstogenesis and speleogenesis of the region. 18th International Karstological School – Classical Karst: Dinaric Karst, June 14, 2010, Postojna/Slovenia.

Brancelj, A., 1991. Stygobiotic Calanoida (Crustacea: Copepoda) from Yugoslavia with the description of a new species – *Stygodiaptomus petkovskii* from Bosnia and Hercegovina. Stygologia 6, 165–176.

De Leeuw, A., Mandic, O., Vranjković, A., Pavelić, D., Harzhauser, M., Krijgsman, W., Kuiper, K. F., 2010. Chronology and integrated stratigraphy of the Miocene Sinj Basin (Dinaride Lake System, Croatia). – Palaeogeography, Palaeoclimatology, Palaeoecology, 292, 155–167.

Geary, D. H., Hunt, G., Magyar, I., Schreiber, H., 2010. The paradox of gradualism: phyletic evolution in two lineages of lymnocardiid bivalves (Lake Pannon, central Europe. Paleobiology, 36, 592–614.

Harzhauser, M., Mandic, O., 2004. The muddy bottom of Lake Pannon – a challenge for dreissenid settlement (Late Miocene; Bivalvia). Palaeogeography, Palaeoclimatology, Palaeoecology, 204, 331–352.

Harzhauser, M., Mandic, O., 2008. Neogene lake systems of Central and South-Eastern Europe: Faunal diversity, gradients and interrelations. Palaeogeography, Palaeoclimatology, Palaeoecology, 260, 417–434.

Harzhauser, M., Mandic, O., 2010. Neogene dreissenids in Central Europe: evolutionary shifts and diversity changes. In: van der Velde, G., Rajagopal, S., bij de Vaate, A. (Eds.) The Zebra Mussel in Europe. 11-28, 426-478, Backhuys Publishers, Leiden.

International Commission on Zoological Nomenclature, 1999. International Code of Zoological Nomenclature. Fourth Edition. adopted by the International Union of Biological Sciences. The International Trust for Zoological Nomenclature. The Natural History Museum. London

Jalžić, B., 1998. The stygobiont bivalve *Congeria kusceri* Bole, 1962 (Bivalvia, Dreissenidae) in Croatia. Natura Croatica 7(4), 341–347.

Jalžić, B., 2001. The first finding of a live stygobiont bivalve *Congeria* in the Lika region, Croatia. Natura Croatica 10(3), 213–220.

Karaman, S., 1935. Die Fauna der unterirdischen Gewässern Jugoslawiens. Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie, 7(52).

Katzer, F., 1921. Die Hydrographie des Lušci Polje in Westbosnien. Glasnik geografskog društva, 6, 102–119.

Kochansky-Devidé, V., Sliškovic, T., 1978. Miocenske Kongerije Hrvatske, Bosne i Hercegovine. Palaeontologia Jugoslavica, 19, 1–98.

Kochansky-Devidé, V., Sliškoviċ, T., 1981. Mlađe Miocenske Kongerije Livanjskog, Duvanjskog i Kupreškog Polja u jugozapadnoj Bosni i Hodova u Hercegovini. Palaeontologia Jugoslavica, 25, 1–25.

Krijgsman, W., Stoica, M., Vasiliev, I., Popov, V.V., 2010. Rise and fall of the Paratethys Sea during the Messinian Salinity Crisis. Earth and Planetary Science Letters, 290, 183–191.

Kupriyanova, E. K., ten Hove, H. A., Sket, B., Zakšek ,V., Trontelj, P. & Rouse, G. W., 2009. Evolution of the unique freshwater cave-dwelling tube worm *Marifugia cavatica* (Annelida: Serpulidae). Systematics and Biodiversity, 7(4), 1–13.

Mandic, O., de Leeuw, A., Vuković, B., Krijgsman, W., Harzhauser, M., Kuiper, K. F., 2011. Palaeoenvironmental evolution of Lake Gacko (NE Bosnia and Herzegovina): impact of the Middlle Miocene Climatic Optimum on the Dinaride LakeSystem. Palaeogeography, Palaeoclimatology, Palaeoecology, 299, 475–492.

Matoničkin, I., Pavletić, Z., 1972. Život naših rijeka. Školska knjiga, Zagreb. 198 pp.

Mayr, E., Ashlock, P. D., 1991. Principles of systematic zoology. McGraw Hill, Inc., New York.

Melik, A., 1958. Jugoslavija. Državna založba Slovenije, Ljubljana.

Morton, B. S., 1993. The anatomy of *Dreissena polymorpha* and the evolution and success of the heteromyarian form in the Dreissenoidea. Chapter 12. In: Nalepa, T. F. , Schloesser, D. W. (eds). Zebra mussels, Biology, impacts and control. CRC Press, Boca Raton, FLA., pp. 185–212.

Morton, B. S., Velkovrh, F., Sket, B., 1998. Biology and anatomy of the »living fossil« *Congeria kusceri* (Bivalvia: Dreissenidae) from subterranean rivers and caves in the Dinaric karst of the former Yugoslavia. Journal Zoology London, 245, 147–174.

Nuttall, C. P., 1990. Review of the Caenozoic heterodont bivalve superfamily Dreissenacea. Palaeontology (Lond.), 33, 707–737.

Popov, S. V., Rögl, F., Rozanov, A. Y., Steininger, F. F., Shcherba, I. G., Kovac, M. (eds), 2004. Lithological-paleogeographic maps of Paratethys. 10 maps late Eocene to Pliocene. Cour. Forsch.-Inst. Senckenberg, 250, 1–46.

Prelogović, E., 1975. Paleogeografska evolucija teritorije Jugoslavije od tercijera do danas. Acta seismologica jugoslavica, 2–3, 7–11, maps.

Prevorčnik, S., Verovnik, R., Sket, B., 2002. Diversity of *Asellus aquaticus* (Crustacea: Isopoda) subpopulations in the Postojna-Planina Cave System testifies for recurrent immigration of the species underground. XVI International Symposium of Biospeleology. Abstracts, p. 88.

Remy, P., 1953. Description des grottes Yougoslaves. Glasnik Prirodnjačkog muzeja Srpske zemlje, Beograd. Biološke nauke, serija B, knj. 5–6, 175–234.

Rögl, F., Steininger, F. F., 1984: Neogene Paratethys, Mediterranean and Indo-Pacific seaways. Implications for the paleobiogeography of marine and terrestrial biotas. – In: Brenchley, P. (ed.): Fossils and Climate: 171-200, figs. 10.1-10.13. – (John Wiley & Sons Ltd.) Chichester.

Kupriyanova, E. K., ten Hove, H. A., Sket, B., Zakšek, V., Trontelj, P., Rouse, G.W., 2009. Evolution of the unique freshwater cave-dwelling tube worm *Marifugia cavatica* (Annelida: Serpulidae). Systematics and Biodiversity, 7(4), 1–13.

Schütt, H., 2000. Die Höhlenmollusken der Ombla-Quelle. Natura Croatica. 9(3), 203–215.

Sket, B., 1965. Taksonomska problematika vrste Asellus aquaticus (L.) Rac. (Crust., Isopoda), s posebnim ozirom na populacije v Sloveniji (Taxonomische Problematik der Art Asellus aquaticus (L.) Rac. mit besonderer Rucksicht auf die Populationen Sloweniens). Razprave SAZU, cl. IV., 8. 177–221, 1 priloga.

Sket, B., 1970. Interesting news about underground fauna of Bosanska Krajina. Naše jame. 11, 94–99.

Sket, B., 1983. Je *Marifugia* res ubežnik iz morja? (Is *Marifugia* really a fugitive from the sea?). Proteus, 46(3), 102–104.

Sket, B., 1986. Evaluation of some taxonomically, zoogeographically, or ecologically interesting finds in the hypogean waters of Yugoslavia (in the last decades). Comunicacions, Vol. 2, 9. Congreso Internacional de Espeleologia, 1, 126–128.

Sket, B., 1992. Rdeči seznam ogroženih živali podzemeljskih voda v Sloveniji (The Red List of the inhabitants of hypogean waters in Slovenia). Varstvo narave, 17, 193–204.

Sket, B., 1994. Distribution patterns of some subterranean Crustacea in the territory of the former Yugoslavia. Hydrobiologia, 287, 65–75.

Sket, B., 1997. Distribution of *Proteus* (Amphibia: Urodela: Proteidae) and its possible explanation. Journal of Biogeography, 24, 263–280.

Sket, B., Zagmajster, M., 2006. Subterranean fauna of Montenegro: its biodiversity and biogeographical character. In: Pešić, V. & Hadžiablahović, S. (eds.). II international symposium of ecologists of the Republic of Montenegro, Kotor, 20–24. 09. 2006. Book of abstracts and programme. Podgorica: Centre for biodiversity of Montenegro, 2006, pp. 23–24.

Sket, B., Zakšek, V., 2009. European cave shrimp species (Decapoda: Caridea: Atyidae), redefined after a phylogenetic study; redefinition of some taxa, a new genus and four new *Troglocaris* species. Zoological Journal Linnean Society, 155, 786–818.

Steininger, F. F., Senes, J., Kleemann, K., Rögl, F., 1985. Neogene of the Mediterranean Tethys and Paratethys. Stratigraphic correlation tables and sediment distribution maps. Vol. I. University of Vienna. 536 pp.

Stepien, C. A., Morton, B., Dabrowska, K. A., Guarnera, R. A., Radja, T., Radja, B., 2001. Genetic diversity and evolutionary relationships of the troglodytic 'living fossil' Congeria kusceri (Bivalvia: Dreissenidae). Molecular Ecology, 10, 1873–1879.

Stevanović, P., Nevesskaja, L. A., Marinescu, F. L., Sokač, A., Jámbor, A., 1989. Pl1. Pontien (sensu F. Le Play, N.P. Barbot De Marny, N.I. Andrusov). Chronostratigraphie und Neostratotypen 8, 1–952.

Strouhal, H., 1939. *Titanethes* Schiödte (Landasseln aus Balkanhöhlen in der Kollektion »Biospeologica balcanica« von Prof. Dr. Absolon. 6. Mitteilung). – Studien aus dem Gebiete der allgemeinen Karstforschung, der wissenschaftlichen Höhlenkunde, der Eiszeitforschung und den Nachbargebietzen, Biologische Serie, **5,** 1–34.

Thienemann, A., 1950. Verbreitungsgeschichte der Süsswassertierwelt Europas. E. Schweitzerbartshe Verlagsbuchhandlung, Stuttgart.

Verovnik, R., Trontelj, P., Prevor(č)nik, S., Sket, B., 2001. Speciation and recurrent cave invasions of *Asellus aquaticus* (Crustacea: Isopoda) in Slovenian karst as revealed by molecular markers. Abstracts of the XVth International Symposium of Biospeleology, p. 69.

Verween, A., Vincx, M., Degraer, S., 2010. *Mytilopsis leucophaeata*: The brackish water equivalent of *Dreissena polymorpha*? A review. In van der Velde, G., Rajagopal, S., & A. bij de Vaate (eds.), The Zebra Mussel in Europe pp. 29-44. Backhuys Publishers, Leiden Margraf Publishers, Weikersheim, Vienna. 536 pp.

Wilke, T., Schultheiss, R., Albrecht, C., Bornmann, N., Trajanovski, S., Kevrekidis, T., 2010. Native Dreissena freshwater mussels in the Balkans: in and out of ancient lakes. Biogeosciences, 7, 3051–3065.

Wolff, W. J., 1969. The Mollusca of the estuarine region of the rivers Rhine, Meuse and Scheldt in relation to the hydrography of the area. II. The Dreissenidae. Communication no. 79 of the Delta Institute for Hydrobiological Research Yerseke, Netherlands.

ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2011 Vol. 54, Št. 1: 71–84

Assessing primary school pupils' knowledge of and behaviour concerning waste management

Ocena znanja in delovanja osnovnošolcev glede ravnaja z odpadki

Iztok Tomažič and Tatjana Vidic

a University of Ljubljana, Biotechnical Faculty, Department of Biology, Večna pot 111, SI-1001 Ljubljana, Slovenia
b Simon Jenko Primary School Kranj, Ulica 31. divizije 7a, 4000 Kranj, Slovenia
*correspondence: iztok.tomazic@bf.uni-lj.si

Running title
Tomažič, Vidic: Pupils' knowledge of waste management

Abstract: Topics involving waste management and other environmental issues are scarce in Slovenian curricula, and mainly covered during the first and second cycles of the nine-year compulsory school (pupils aged 6–12) (Učni načrt: program osnovnošolskega izobraževanja, 1998). In the present study we investigated how well pupils in Slovenia aged 10–15 (second and third cycles of the compulsory school) have developed their competences for sound waste management behaviour. We found that they seldom act in accordance with the recommendations for waste treatment and disposal that they learn in school. We also found that third cycle pupils (8th and 9th grade, i.e. aged 13–15) are less willing to take pro-environmental action. Hence these pupils should be engaged in a learning process through which they would improve their knowledge about waste management, and become more willing to take pro-environmental action. In order to facilitate a change in pupils' behaviour and raise their environmental awareness, we propose that environmental education should be an integral part of the curriculum throughout all three cycles of compulsory education.

Key words: pro-environmental action, waste management, waste, compulsory education.

Izvleček: Vsebine, ki vključujejo ravnanje z odpadki in drugimi okoljskimi problemi, so v slovenskem učnem načrtu za naravoslovje in biologijo skopo zastopane (Učni načrt: program osnovnošolskega izobraževanja, 1998). V večji meri so del učnih načrtov prve in druge triade devetletne osnovne šole (starost učencev 6–12 let).

Z raziskavo smo želeli ugotoviti, kako slovenski učenci stari od 10 do15 let (druga in tretja triada) ravnajo z odpadki (ločevanje, zbiranje in odlaganje odpadkov).

Ugotovili smo, da učenci le z nekaterimi odpadki ravnajo tako, kot zahtevajo priporočila ravnanja z odpadki, o katerih so se učili v šoli. Ugotovil smo še, da so učenci tretje triade (8. in 9. razred; 13–15 let) manj pripravljeni delovati pro-okoljsko kot njihovi vrstniki iz druge triade. Učenci bi morali biti vključeni v učni proces, preko katerega bi lahko usvojili dodatna znanja o ravnanju z odpadki in bili (bolj) pripravljeni delovati pro-okoljsko. Za spreminjanje delovanja učencev in dviga njihove okoljske zavesti, predlagamo, da se okoljske vsebine vključijo v izbrane učne načrte vseh triad.

Ključne besede: pro-okoljsko delovanje, ravnanje z odpadki, odpadki, osnovnošolsko izobraževanje.

Introduction

EU member states have committed themselves to reducing their waste output, and making a step toward an effective waste pick-up, disposal, and recycling system between 2011 and 2020 (COM(2010)235). Slovenia is one of six EU members in which the proportion of municipal waste dumped in landfills increased in between 1995 and 2007. There is evidence that in terms of waste management Slovenia is lagging behind the more developed EU countries (http://kazalci.arso.gov.si).

Topics involving waste management and other environmental issues are scarce in Slovenian curricula, and mainly covered during the first and second cycles of the nine-year compulsory school (pupils aged 6–12). Although it has been suggested that the most appropriate age to foster environmental concern and action in students is 13 years (Kellert 1985), this appears to have been overlooked when science and biology curricula were designed in Slovenia (Učni načrt: program osnovnošolskega izobraževanja 1998). Leeming et al. (1995) argue that it is important that environmental education start at an appropriate age, since early attitudes and knowledge shape the later thinking of adolescents and adults. Younger pupils have a longer period to influence environmental quality (Leeming et al. 1995), and may serve as effective agents to promote environmentally responsible behaviour in others (Leeming et al. 1995, Evans and Gill 1996). Several authors also report about gender differences in environmental attitudes and behaviours (see Zelezny et al. 2000). Research on environmentalism and gender has been limited in the past. Howewer, Zelezny et al. (2000) find that girls express greater proenvironmental attitudes than boys. In theirs study **girls reported stronger** overall **concern** for the **environment**, and **personal responsibility** for improving the environment. Also, girls expressed greater proenvironmental attitudes than did boys on concern about trash, interest in recycling, and interest in school recycling.

Pupils familiarity with environmental issues is vital. Conceptions of the environment are likely to be influenced by television and other external sources as well as formal schooling (Chan 1998, Rickinson 2001, Kobierska et al. 2007, Shepardson 2007). Beside school educational programmes, government has an important role in informing public about environmental issues e.g. waste management, too (Chung and Poon 1996). In Slovenia the latter is reflected in various governmental projects which aim to promote environmentally friendly behaviour in people. For a more environmentally responsible behaviour environmental issues should be addressed through education (Chan 1998). Lester et al. (2006) provide evidence that pupils with better knowledge of science are more environmentally active than those whose knowledge is poor. However, knowledge itself could be a precursor of some pro-environmental behaviours (e.g. Hornik et al. 1995), but research has unconvincing data supporting this. Kuhlemeier et al. (1999) find that relationships between knowledge and pro-environmental behaviour or attitudes and behaviour are extremely low. Therefore, pupils should be educated in a way that would raise their environmental awareness and improve their knowledge so that they could make informed and responsible decisions as adults (Fernández-Manzanal et al. 2007, Littledyke 2008). They should also be made aware that environmental problems result from human behaviour, and that solving them requires a profound change in the behavioural paradigm (Zelezny and Schultz 2000**)**.

If pupils are to acquire the competences that will help them to develop pro-environmental behaviour (which also includes sound waste management practices) they need a solid knowledge base (Jensen 2002) and a positive attitude toward the environment (Kraus 1995). Beside that environmental education should also stream into an active role-taking in the protection, and not into the 'use' of nature and the environment (Bogner 1999).

In the present study we investigated how well pupils in Slovenia aged 12–15 (second and third cycles of the compulsory school) have developed their competences for sound waste management behaviour.

Studies about waste management behaviour of children and adults could provide useful knowledge for policy development in waste management.

The study addressed four questions:

1. Do Slovenian primary school pupils know which waste is hazardous to the environment and organisms if disposed of in the nature?
2. Do pupils follow the recommendation of (non) hazardous waste disposal at home (Uradni list RS, št. 45/2009)
3. How pupils behave if they come across any waste outdoors?
4. Where do they get the most information about the influence of hazardous waste on living organisms and the environment?

Method

Participants

A total of 215 **pupils** (aged 10–15) from one school participated in the study, which was conducted in the school year 2009/10. They attended the **5th (**14.9%), **6th (**24.7%), **7th (**19.1%), **8th (**18.6%), **and 9th (**22.81%) **grade, respectively.** There were 49.8% male and 50.2% female pupils.

Instrument

Leeming et al. (1995) stress that there is no single and widely recognised scale for measuring children's attitudes toward and knowledge of a broad range of environmental issues. In mid-1990s, meaningful comparisons across studies about environmental attitude and knowledge were impossible due to a lack of suitable instruments. For this reason some instruments were developed such as CHEAKS and NEP (Leeming et al. 1995, Dunlap et al. 2000). In this study we did not use any of the above-mentioned scales, since we focused on the pupils' behaviour and their knowledge about waste management. Although the Leeming's (1995) scale includes statements about pollution and recycling it is too generalised to suit the needs of our research. We therefore designed our own questionnaire which consisted of 4 parts.

First, the pupils were required to rate waste as predominantly hazardous or non-hazardous on a 5-point Likert scale, with the items rated as follows: 1 – *not at all hazardous*, 2 – *not hazardous*, 3 – *not sure if hazardous*, 4 – *hazardous*, and 5 – *very hazardous*.

Then the pupils were instructed to indicate how they usually dispose of waste (e.g. packaging, fruit skins, used vegetable oil, motor oil, batteries, tins containing lacquers, varnishes or similar agents, bottles of aggressive detergents, and antibiotics) at home. They **were asked to s**elect the **most appropriate of the six offered possibilities**: "*We put waste in a bin for mixed waste*.", "*We separate waste, and then put each fraction in an appropriate waste bin*.", "*We dispose of waste when the waste collection company collects hazardous waste*.", "*We do nothing, we leave the waste in the basement." "We put waste in a compost bin.*", "*We take waste to a waste collection and treatment centre*." The pupils were also given the option of describing an alternative way of waste disposal.

In the third part the pupils wrote what they did if they saw discarded waste (candy wrappers, old tyres, paper handkerchiefs, skin fruits or puddles of motor oil) outdoors. They were asked to s**elect** one of the following five **answers that best described their behaviour**: "*I do nothing, I just walk on.*", "*I pick up the waste and put it in a bin. I also contact the waste disposal company and tell them about the waste*.", *I feel shocked to see what people do*.", "*I do nothing, it will eventually decompose*.", and "*I have never seen such things being disposed of in the nature*."

In the fourth part we asked the pupils where they usually get the most information about the impact of waste on the environment, and gave them the following 5 possibilities: *Home*, *School*, *TV*, *Books*, and *Internet*.

Results

Pupils' evaluations of waste hazardousness

Figure 1, which presents the pupils' waste hazardousness ratings, shows that they found fruit skins, stable litter, and decomposing wood as non hazardous to the environment and organisms. They could not decide, however, whether paper handkerchiefs and paper bags are hazardous or not. They also correctly rated candy wrappers, tins, plastic bags, damaged detergent bottles, antibiotics, batteries and motor oil as hazardous if disposed of outdoors.

We found statistically significant differences in the evaluations of waste hazardousness for fruit skins, batteries and antibiotics between pupils of different grades. The difference for fruit skins on account of 5th grade pupils was ($\chi 2 = 10.22$, df = 4, p = 0.037), for batteries on account of 6th grade pupils was ($\chi 2 = 37.34$, df = 4, $p < 0.001$), while for antibiotics it was ($\chi 2 = 9.59$, df = 4, p = 0.048) on account of 9th grade pupils. 5th grade pupils rated fruit skins higher, 6th and 7th graders rated batteries, and 9th grade pupils rated antibiotics lower in comparison to other pupils.

When we compared pupils' perceptions of waste hazardousness according to gender, we found that girls on average rated paper handkerchiefs, paper bags, tins, and plastic bags as more hazardous to the environment than boys (Tab. 1).

Pupils' reports about how they dispose of various waste

In addition to which waste pupils perceive as an environmental hazard, we also wanted to find if they behave in an environmentally responsible way. We therefore asked them how they disposed of particular kind of waste at home. **Among** six possible options they were asked to chose the one they felt best described their behaviour. They were also allowed to provide their own answer. We categorised their answers in 2 groups: *Proper* and *Improper* waste disposal. For example, a case of proper disposal of a plastic yogurt cup would be to put it in a bin for plastic waste, whereas it would be improper to put it in a bin for mixed waste.

We found that pupils from 5th to 9th grades follow the recommendation of nonhazardous waste disposal (Uradni list RS, št. 45/2009). Over a half of the pupils treat fruit skins as recommended. The number of those who would dispose of a yoghurt

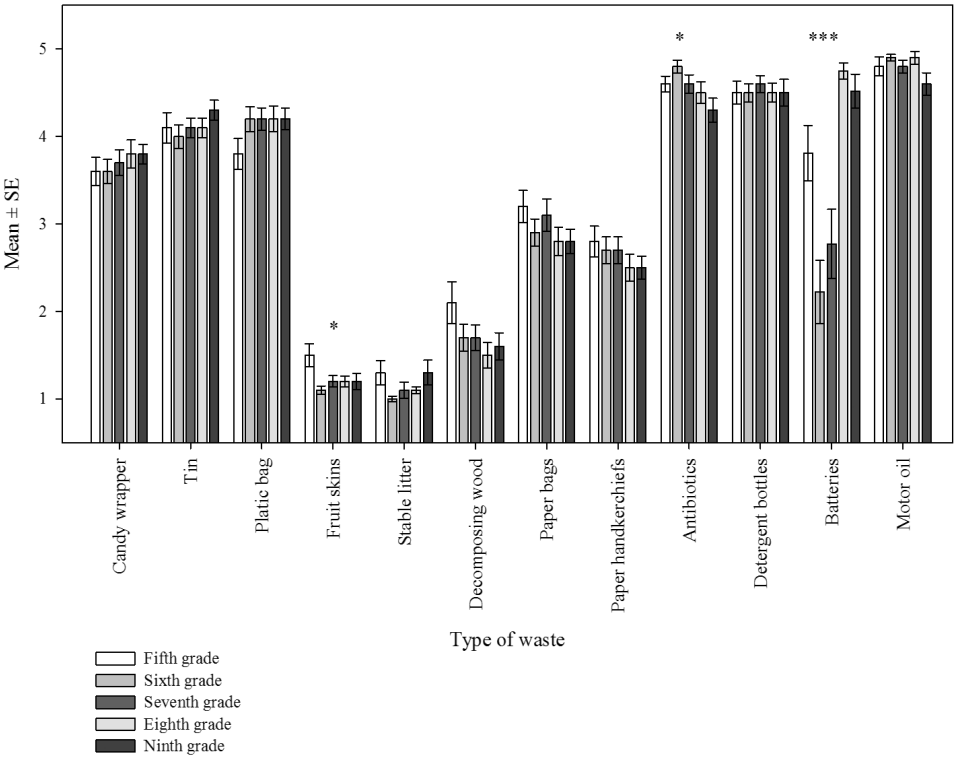


Figure 1: Pupils' ratings of waste hazardousness.
Slika 1: Ocene učencev o nevarnosti odpadkov.

	Boys			Girls			Mann-Whitney U	
Waste	Mean	SD	N	**Mean**	SD	N	Z	p
Paper handkerchiefs	**2.4**	0.952	98	**2.8**	0.900	99	–3.006	0.003
Tins	**4.0**	0.845	99	**4.2**	0.754	100	–2.283	0.022
Plastic bags	**4.0**	0.920	99	**4.3**	0.852	99	–2.477	0.013
Paper bags	**2.7**	1.015	96	**3.2**	0.986	99	–3.235	0.001

Table 1: Perception of waste as an environmental hazard – gender differences.
Tabela 1: Ocenjevanje nevarnosti odpadkov glede na spol učencev.

cup in a proper way is lower, i.e. only 42% of the pupils followed the rules of waste disposal.

The most frequent improper way of disposing of yogurt cups was to put them in a bin for mixed waste (Tab. 2). In addition, data for organic waste show that such waste often ends up in a bin for mixed waste, although the percentage of pupils who stated that they composted organic waste should also be taken into consideration.

We also found that 50% of the pupils from 5th to 9th grades would normally observe the rules for the disposal of motor oil and batteries. With regard to other waste, we found that fewer than 50% of the pupils know how to treat and dispose of waste properly. Also, the percentage of pupils who do not know how to dispose of hazardous waste should not be underestimated (Tab. 2).

Data about the disposal of vegetable oil show that only 14.4% pupils observe disposal recommendations. Other pupils reported that they disposed of oil by putting it in a bin for mixed waste or a compost bin, which is not in accordance with the recommendations. More than 30% of the pupils reported pouring vegetable oil in a drain. Some reported not knowing how they dispose of such waste at home (Tab. 2). Over 30% of the pupils did not know how to dispose of motor oil. On the other hand, almost 50% of them reported that they treated this waste as recommended. We found that pupils follow the rules of used battery disposal, regularly disposing of such items when their local waste collection company organises a hazardous waste collection, or even taking used batteries to a waste collection and treatment centre themselves (Tab. 2). On the other hand, many pupils improperly dispose of tins containing lacquers and varnishes (57%), and bottles of aggressive detergents (61%). This waste often ends up in a bin for mixed waste or in a plastic fraction bin (Tab. 2). With regard to antibiotics, the pupils reported that they put them in a bin for mixed waste (which they should be discouraged from doing), dispose of them when their local waste collection company collects hazardous waste, or even take them to a waste collection and treatment centre (behaviour which should be encouraged) (Tab. 2).

Pupils' role in the environmental protection

We asked the pupils what they do when they come across litter (candy wrappers, paper handkerchiefs, fruit skins, old car tyres, and motor oil) in the nature. According to our results, some of them adopt an proactive approach to environmental protection.

While most pupils will pick up the candy wrapper and put it in a bin (Fig. 2), this behaviour decreases with age. Pupils from the second cycle (grades 5–6) will more readily pick up a discarded wrapper than their colleagues from the third cycle (grades 7–9), with pupils of the 7th grade being an exception. While the percentage of children who would do nothing is not negligible, they mainly come from the last cycle (grades 8–9). Some pupils reported that they feel bad when they see litter lying around.

Figure 3 shows how pupils behave when they see a discarded paper handkerchief. These results are comparable to the results for the candy wrapper. 5th grade pupils are most likely to pick it up and put it in a bin, while 9th and 8th graders are the most likely to ignore it. As many as 33% of 9th and 31% of 6th graders reported that they would do nothing with a discarded handkerchief because it would decompose anyway. The answers

Ways of waste disposal	Nonhazardous waste		Hazardous waste					
	Yoghurt, pudding cups etc.	**Fruit skins**	**Vegetable oil**	**Motor oil**	**Batteries**	**Tins of varnish or coating**	**Bottles of aggressive detergents**	**Antibiotics**
We put waste in a bin for mixed waste.	52.1	40.0	13.5	6.0	9.8	25.1	22.3	25.6
We separate waste, and then put each fraction in an appropriate waste bin.	**42.3**	**1.4**	5.1	7.0	20.5	29.8	35.8	14.9
We dispose of waste when the waste collection company collects hazardous waste.	0.9	0	**8.4**	**26.0**	**40.0**	**23.3**	**22.8**	**25.6**
We do nothing. We leave the waste in the basement.	0.9	0	1.9	6.5	0.5	1.4	1.9	1.4
We put waste in a compost bin.	0.5	**55.3**	14.9	0	0	0.5	0.5	0
We take waste to a waste collection and treatment centre.	**0.5**	0	**6.0**	**20.9**	**24.2**	**10.7**	**7.0**	**18.6**
I don't know how to treat waste.	2.8	2.3	17.7	30.2	5.1	9.3	9.8	13.0
We pour it down the drain.	0	0	32.6	0.9	0	0	0	0
We feed it to the animals.	0	**0.9**	0	0	0	0	0	0
We do not have such waste.				2.3				0.9

The percentage of pupils (N_{ALL} = 215) who opted for a proper way of waste disposal is printed bold.
Odstotek učencev (N_{VSI} = 215), ki je izbral pravilnen način ravnaja z odpadki, je zapisan s krepkim tiskom.

Table 2: Ways of waste disposal for some (non)hazardous waste.
Tabela 2: Načini ravnanja z nekateremi (ne)nevarnimi odpadki.

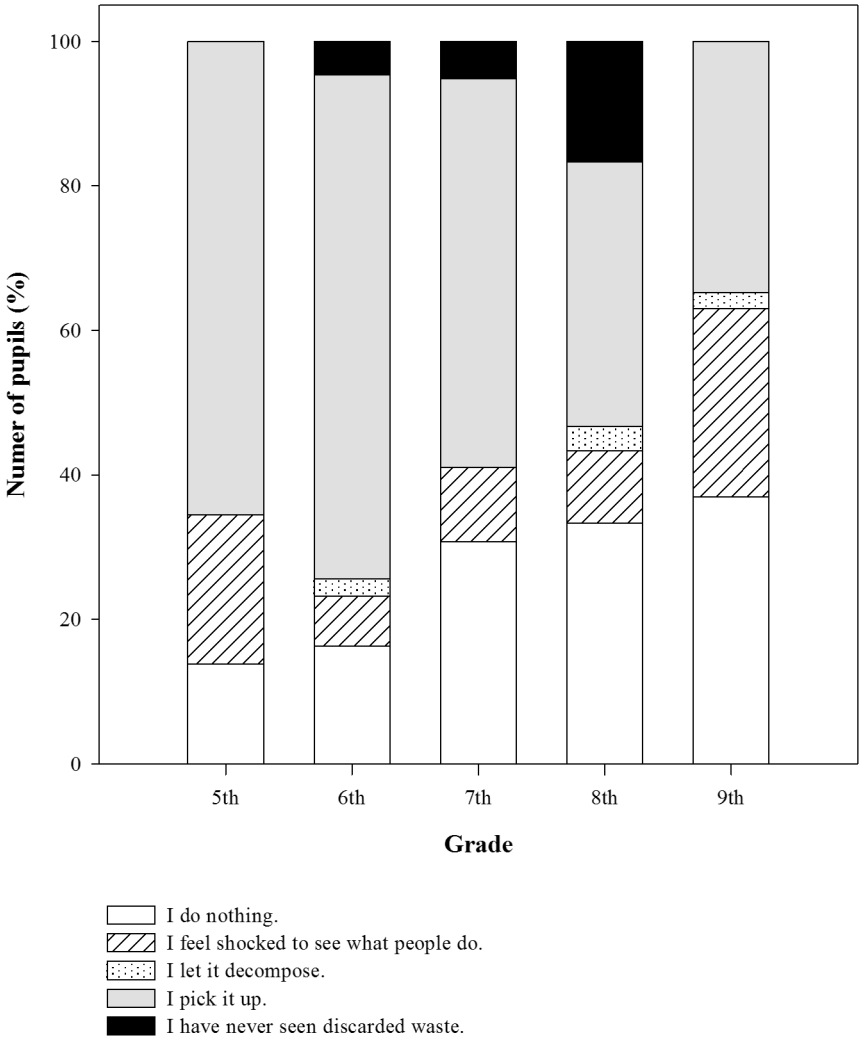


Figure 2: What do children do when they see a discarded candy wrapper outdoors?
Slika 2: Kako ravnajo učenci, ko opazijo zavržen ovitek bonbona na prostem?

of 7th grade pupils are almost equally distributed between "*I do nothing*.", "*I pick it up*." and "*I feel bad about it*."

Figure 4 shows how children react when they come across discarded fruit skins in the street or in the nature. Amost 80% of the 6th graders do nothing, since they correctly assume that the fruit skin will decompose. This result is expected, since these pupils learn about how to prepare compost and which waste can be composted. Pupils from the third cycle should be familiar with composting since they learn about this in the 6th grade. Again, 9th and 8th graders dominate in that they would do nothing if they saw discarded fruit skins, while 5th graders are the most likely to clean up the mess. The percentage of pupils who feel disgusted at the behaviour of the others is less than 15% for each grade.

The data for car tyres show that pupils are aware that disused car tyres should be removed

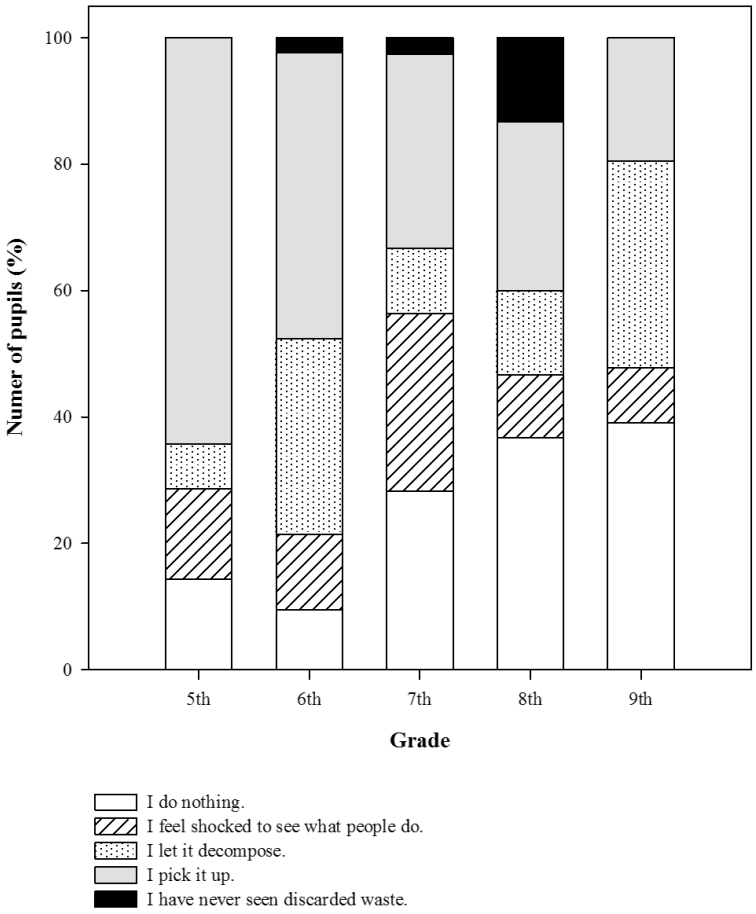


Figure 3: What do children do when they see a discarded paper handkerchief outdoors?
Slika 3: Kako ravnajo učenci, ko opazijo zavržen papirnat robček na prostem?

and disposed of properly (Fig. 5). Only some 5th grade pupils believe that car tyres can decompose by themselves. Also, some 5th graders believe that motor oil decomposes. Data shows that there is a considerable percentage of pupils from the 8th and 9th grades who would not take action to protect the environment. These pupils usually just feel disgusted at what other people do, or simply do nothing. Some pupils would contact the waste disposal company and tell them about the waste, this behaviour decreases with age.

The pupils' source of environmental information

The pupils stated that the major sources of environmental information for them were TV documentaries, their teachers in school, and the internet (Fig. 6). Fewer pupils learn about environmental care from their parents or read about it in books.

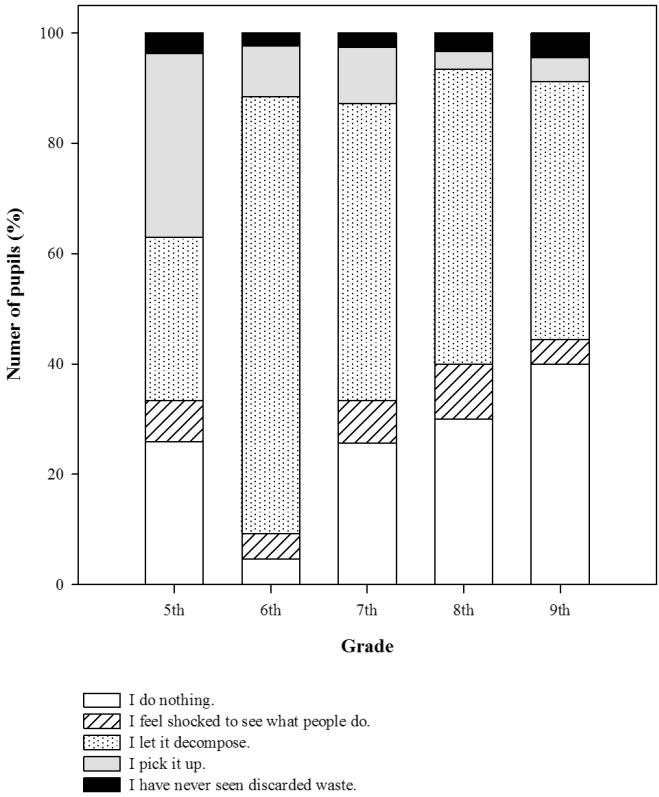


Figure 4: What do children do when they see discarded fruit skins outdoors?
Slika 4: Kako ravnajo učenci, ko opazijo zavržene olupke sadja na prostem?

Discussion

Results of the study show that although pupils know which waste is hazardous their knowledge about the disposal of certain non-hazardous or hazardous waste at home is limited. Waste such as plastic yogurt or pudding cups often ends up in a container for mixed waste. Only 42% pupils state that they actually separate waste, although most of them should do so. These findings could be generalised to include other packaging (meat pâtés, butter, chips, coffee, etc.), which yields itself to the conclusion that children prefer collecting all waste in the mixed-waste container than separating it by fractions, which is easier and faster (Matsumoto 2011).

We find that over 50% of the pupils collect organic waste (e.g. fruit skins) in a compost bin. However, four out of ten pupils will still put such waste in a bin for mixed waste (Tab. 2). Parents play a crucial role in teaching their children about waste treatment at home. We feel that if parents do not separate waste by fractions and do not compost organic waste, children are very unlikely to do this themselves. Although pupils learn in the 6th grade which waste can be composted, they cannot apply this knowledge in their everyday life if there is no support from their parents.

Results also revealed that certain hazardous waste is also treated improperly. Lacquer and varnish tins and detergent bottles are often not perceived and treated as hazardous waste, and disposed of accordingly. They often end up either in the mixed-waste container or in a bin for waste fractions (Tab. 2). Results about the disposal of antibiotics are also rather discouraging, since 26%

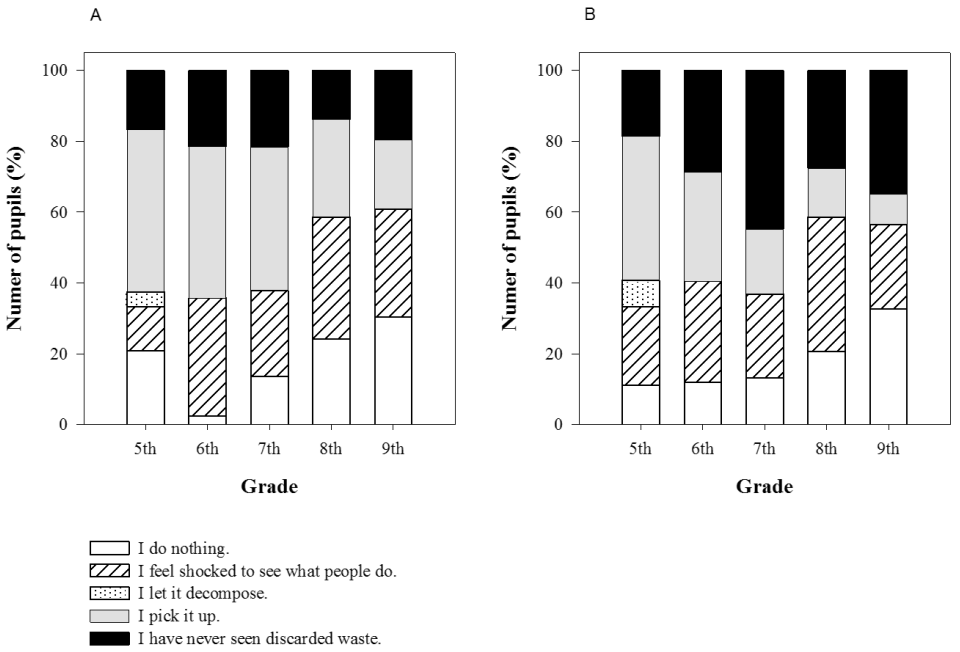


Figure 5: What do children do when they notice discarded car tyres (A) or spilt motor oil (B) outdoors?
Slika 5: Kako ravnajo učenci, ko opazijo zavržene avtomobilske gume (A) ali razlito motorno olje (B) na prostem?

pupils replied that they put antibiotics in a bin for mixed waste (Tab. 2). Furthermore, children treat vegetable oil as nonhazardous waste, and for this reason it is frequently discarded in mixed-waste containers or poured down the drain. Few pupils reported that they take used vegetable oil to a waste collection centre (Tab. 2), even though this would be the proper thing to do.

Data also shows that pupils dispose of used motor oil and batteries as recommended. The positive results regarding used batteries could be attributed to the fact that some schools and many shopping centres make it possible to dispose of old batteries on their premises.

The share of pupils who do not know how to treat certain waste is not insignificant. The reasons for this could be found in a lack of attention to waste management and environmental protection topics within the science and biology curriculum, particularly in the third cycle of the primary school (pupils aged 12–15). Kellert (1985) suggests that the most appropriate age to foster environmental concern and action in students is 13 years. According to our educational system these are pupils of third cycle. Gopurn (2010) also notes that environmental topics in this cycle are discussed in terms of individual subjects, such as biology, and not interdisciplinary. The same author finds that Slovenian pupils possess very limited and occasionally too specific knowledge about environmental issues.

If pupils learned about waste management in the upper grades of compulsory education they would perhaps be more likely to manage waste properly. Different authors point out that schools are an important source of environmental information for pupils (Chan 1998, Rickinson 2001, Kobierska et al. 2007, Shepardson 2007). Lester et al. (2006) provide evidence that students who possess some knowledge of science have greater environmental awareness than those whose knowledge of science topics is poorer, and can even influence their parents to adopt pro-environmental behaviour (Leeming et al. 1997). This is important, particularly since we found that the children rarely mentioned their parents as a

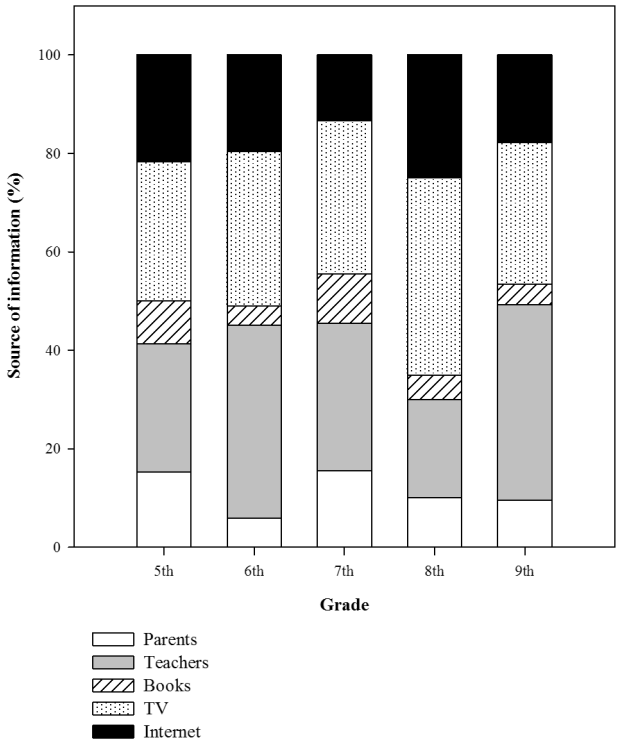


Figure 6: The pupils' source of environmental information.
Slika 6: Viri informacij o vplivih nevarnih odpadkov na okolje.

significant source of information about the impact of hazardous waste on the environment (Fig. 6). From what our results tell us we can speculate that parents also lack sound knowledge about this topic. This is evident in Tab. 2, which shows that proper waste management at home is definitely not an exclusive domain of pupils.

We find that children get most of the information about the impact of hazardous waste on the environment from the TV, and the internet (Fig. 6). These results are supported by the study by Yurttaş and Sülün (2010) and Kobierska et al. (2007). If there were more TV programmes about environmental topics for parents and pupils this would improve the environmental awareness and foster the sensitivity of the public (Yurttaş and Sülün 2010). Children and their parents may thus be willing to take a step toward **reducing their "waste footprint".**

It should be noted that solely the knowledge that the pupils have does not necessarily promote pro-environmental behaviour. The latter can be supported by the study of Kuhlemeier et al. (1999). Also, Kobierska et al. (2007) demonstrates in a study that good environmental knowledge is not always accompanied by pro-environmental behaviour. We saw in this study that pupils could correctly rated waste as hazardous or non-hazardous. However, when we asked them what they do when they see discarded waste in the streets or in the nature we found that pupils from the last cycle mostly do nothing or merely feel disgusted at the actions of others. Pupils from the second cycle frequently reported that they pick up such waste themselves or notify a waste collection company or a waste treatment centre (Figs. 3–5). We could speculate that pupils from the second cycle, at least to some extent, provided the answers that they thought we expected from them. Leeming et

al. (1997), however, notably found that younger pupils show significantly more positive attitudes toward the environment than their colleagues from upper grades, which goes against our speculation. As in the study of Zelezny et al. (2000) also **girls in this study** expressed greater proenvironmental attitudes than boys did.

Kellert (1996) finds that pupils aged 12–15, are the most receptive to learn about environmental issues. They should therefore be engaged in a learning process through which they would improve their knowledge about waste management, and become more willing to take pro-environmental action. A belief that waste and other environmental issues pose a significant problem to society and the self can change intentions toward acting (Barr 2007).

In order to facilitate a change in pupils' behaviour and raise their environmental awareness, we propose that environmental education should be an integral part of the curriculum throughout all three cycles of compulsory education.

Conclusion and Implications

To our knowledge, there exists little or no information about how primary school pupils perceive waste hazardousness and its impact on the environment. This study showed that the knowledge children have about waste management is not necessarily reflected in their actions, as we had expected.

If pupils are to improve their behaviour and environmental awareness, they need continuity in environmental education, which should be provided by the school and at home.

We propose that topics concerning environmental issues be added to the current biology and science curricula. Our findings show that although pupils can correctly identify hazardous waste, they still do not behave environmentally responsibly. We therefore believe that pupils need to be engaged in activities that would help them to improve knowledge on the matter and develop positive attitudes toward the environment. The latter is, however, subject to further research.

Povzetek

Vsebine o okoljskih problemih (npr. ravnanje z odpadki in drugo) so skopo zastopane v učnih načrtih s področja naravoslovja. Vsebine so sicer vključene v različne učne načrte prve in druge triade, vendar so v tretji triadi obravnavane zelo ozko, skopo in ne interdisciplinarno (Gopurn 2010). Učenci tretje triade naj bi bili zelo dovzetni za učenje o okoljskih problemih (Kellert, 1985), kar je bilo očitno pri snovanju učnih načrtov v Sloveniji spregledano.

V raziskavi nas je zanimalo, katere odpadke učenci ocenjujejo kot (ne)nevarne, ali sledijo priporočilom ravnanja z (ne)nevarnimi odpadki doma, kaj naredijo, če naletijo na odpadek zunaj (v naravi) in kje dobijo največ informacij o nevarnosti odpadkov.

Ugotovili smo, da so učenci večino odpadkov pravilno ocenili kot nenevarne (olupki sadja, stelja, razpadajoč les) in nevarne (pločevinke, plastične vrečke, poškodovane plastenke detergentov, antibiotiki, baterije in motorno olje) za okolje in organizme (Slika 1). Učenci petih razredov so ovrednotili olupke sadja kot bolj nevarne v primerjavi z ostalimi učenci. Učenci šestih in sedmih razredov so ovrednotili baterije kot manj nevarne v primerjavi z ostalimi učenci. Devetošolci pa so ovrednotili antibiotike kot manj nevarne v primerjavi z ostalimi učenci. Razlike so bile statistično pomembne. Dekleta so običajno odpadkom pripisale višjo nevarnost kot fantje (Tab. 1).

Pri ravnanju z odpadki doma smo ugotovili, da učenci nekatere odpadke raje kot ločujejo vržejo v zabojnik za mešane odpadke (Tab. 2). Rastlinsko olje zavržejo tako, da ga zlijejo v odtok, antibiotike in pločevinke agresivnih čistil pa pogosto vržejo med mešane odpadke. Učenci so navajali, da za motorno olje in baterije poskrbijo tako, da odpadek odpeljejo ali v zbirni center ali pa oddajo, ko poteka akcija zbiranja nevarnih odpadkov.

Pri zavrženih odpadkih pa se je izkazalo, da so učenci druge triade bolj pripravljeni delovati v smislu odstranjevanja odpadkov iz okolja kot njihovi vrstniki iz tretje triade (Slike 2–4).

Ugotovili smo tudi, da starši svoje znanje o vplivih nevarnih odpadkov na okolje le malokrat posredujejo otrokom. Za učence so tako pomembni

viri informacij o tej temi splet, oddaje na televiziji in učitelji v šoli (Slika 6).

Rezultati raziskave nakazujejo, da bi morali biti učenci vseh triad vključeni v učni proces, preko katerega bi lahko usvojili dodatna znanja o ravnanju z odpadki in bili (bolj) pripravljeni delovati pro-okoljsko. Prav učenci tretje triade so za učenje o okoljskih problemih najbolj dovzetni (Kellert 1985).

Za spreminjanje delovanja učencev, predlagamo, da se okoljske vsebine vključijo v izbrane učne načrte vseh triad.

References

Barr, S., 2007. Factors Influencing Environmental Attitudes and Behaviors. Environment and Behavior, 39 (4), 435–473.

Bogner, F. X., 1999. Empirical evaluation of an educational conservation programme introduced in Swiss secondary schools. International Journal of Science Education, 21 (11), 1169–1185.

COM(2010)235: http://eur-lex.europa.eu/Lex UriServ/LexUriServ.do?uri=COM:2010:0235:FIN:EN:PDF

Chan, K., 1998. Mass communication and pro-environmental behaviour: waste recycling in Hong Kong. Journal of Environmental Management, 52 (4), 317–325.

Chung, S. S., Poon, C. S., 1996. The Attitudinal Differences in Source Separation and Waste Reduction between the General Public and the Housewives in Hong Kong. Journal of Environmental Management, 48 (3), 215–227.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., 2000. Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. Journal of Social Issues, 56 (3), 425–442.

Esa, N., 2010. Environmental knowledge, attitude and practices of student teachers. International Research in Geographical and Environmental Education, 19 (1), 39–50.

Evans, S. M., Gill, M.E., 1996. Schoolchildren as educators: The indirect influence of environmental education in schools on parents' attitudes towards the environment. Journal of Biological Education, 30 (4), 243–249.

Fernández-Manzanal, R., Rodríguez-Barreiro, L., Carrasquer, J., 2007. Evaluation of environmental attitudes: Analysis and results of a scale applied to university students. Science Education, 91 (6), 988–1009.

Gopurn, M., 2010. Okolje in čistilne naprave. Univerza v MAriboru, Fakulteta ua naravoslovje in matematiko, Oddelek za kemijo in oddelek z atehniko, 105 pp.

Hornik, J., Cherian, J., Madansky, M., Narayana, C., 1995. Determinants of recycling behavior: A synthesis of research results. *Journal of Socio-Economics*, *24* (1), 105–127.

Jensen, B. B., 2002. Knowledge, Action and Pro-environmental Behaviour. Environmental Education Research, 8 (3), 325– 334.

Kellert, S. R., 1985. Attitudes toward animals: age-related development among children. Journal of Environmental Education, 16 (3), 29– 39.

Kellert, S. R., 1996. The value of life: biological diversity and human society. Washington: DC, Island Press.

Kobierska, H., Tarabuła-Fiertak, M., Grodzińska-Jurczak, M., 2007. Attitudes to environmental education in Poland. Journal of Biological Education, 42 (1), 12–18.

Kraus, S.J., 1995. Attitudes and the prediction of behavior – a metaanalysis of the empirical literature. Personality and Social Psychology Bulletin, 21 (1), 58–75.

Kuhlemeier, H., Van Den Bergh, H., Lagerweij, N., 1999. Environmental knowledge, attitudes and behavior in Dutch secondary education. Journal of Environmental Education, 30 (2), 4–15.

Leeming, F. C., Dwyer, W. O., Bracken, B. A., 1995. Children's Environmental Attitude and Knowledge Scale: Construction and Validation. Journal of Environmental Education, 26 (3), 22–31.

Leeming, F. C., Porter, B. E., Dwyer, W. O., Cobern, M. K., Oliver, D. P., 1997. Effects of Participation in Class Activities on Children's Environmental Attitudes and Knowledge. Journal of Environmental Education, 28 (2), 33–42.

Lester, B.T., Li, M., Okhee, L., Lambert, J., 2006. Social activism in elementary science education: A science, technology, and

society approach to teach global warming. International Journal of Science Education, 28, 315–39.

Littledyke, M., 2008. Science education for environmental awareness: approaches to integrating cognitive and affective domains. Environmental Education Research, 14 (1),1–17.

Matsumoto, S., 2011. Waste separation at home: Are Japanese municipal curbside recycling policies efficient? Resources, Conservation and Recycling, 55, 325–334.

Rickinson, M., 2001. Learners and Learning in Environmental Education: a critical review of the evidence. Environmental Education Research, 7 (3), 207–320.

Schultz, P. W., 200. Empathizing With Nature: The Effects of Perspective Taking on Concern for Environmental Issues. Journal of Social Issues, 56 (3) 391–406.

Shepardson, D.P., Wee, B., Priddy, M., Harbor, J., 2007. Students' Mental Models of the Environment. Journal of Research in Science Teaching, 44 (2), 327–348.

Učni načrt: program osnovnošolskega izobraževanja, 1998; Učni načrt: Spoznavanje okolja, Naravoslovje in tehnika, Gospodinjstvo, Naravoslovje, Biologija, Kemija.

Uradni list RS, št. 45/2009: Odlok o ravnanju s komunalnimi odpadki v Mestni občini Kranj.

Zelezny, L. C., Schultz, P.W., 2000. Promoting Environmentalism. Journal of Social Issues, 56 (3), 365–371.

Zelezny, L. C., Chua, P., Aldrich C., 2000. Elaborating on Gender Differences in Environmentalism. Journal of Social Issues, 56 (3), 443–457.

Yurttaş, G. D., Sülün, Y., 2010. What are the most important environmental problems according to the second grade primary school students? Procedia Social and Behavioral Sciences, 2, 1605–1609.