10TH ANNIVERSARY ISSUE

Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 11(1): 1522, January 2015 doi: http://dx.doi.org/10.15560/11.1.1522
ISSN 1809-127X

Checklist of benthic macroinvertebrates of high altitude ponds of the Tatra Mountains (Central Europe) with new records of two species for Slovakia

Milan Novikmec[1*], **Marta Veselská**[1], **Peter Bitušík**[2], **Ladislav Hamerlík**[2], **Zuzana Matúšová**[1], **Barbora Reduciendo Klementová**[1] and **Marek Svitok**[1]

1 Faculty of Ecology and Environmental Sciences, Technical University in Zvolen, T. G. Masaryka 24, SK–960 53 Zvolen, Slovakia
2 Faculty of Natural Sciences, Matej Bel University, Tajovského 40, SK–974 01 Banská Bystrica, Slovakia
* Corresponding author. E-mail: novikmec@tuzvo.sk

Abstract: A checklist of benthic macroinvertebrates of ponds of Tatra Mountains is presented. The checklist comprises 122 taxa including the first records of *Derotanypus* cf. *sibiricus* (Kruglova & Chernovskii, 1940) (Diptera: Chironomidae) and *Arctocorisa carinata* (Sahlberg, 1918) (Heteroptera) from Slovakia. The most diverse pond site supported 28 taxa, the minimum number of recorded taxa was 2. The richest group was Chironomidae (Diptera) constituting almost half of the total diversity (58 taxa), followed by Trichoptera with 15 taxa. The other higher taxonomic groups were represented by considerably lower taxa number. Relatively high number of recorded taxa underlines important contribution of small lentic waterbodies to regional biodiversity of high-altitude ecosystems.

Key words: Tatra Mountains, ponds, benthic invertebrates, *Derotanypus*, *Arctocorisa carinata*, regional diversity

INTRODUCTION

High-altitude ponds are a specific category of aquatic ecosystems. These permanent or temporary water bodies of small area and without a developed profundal zone are excellent models for various ecological studies (De Meester *et al.* 2005) but have often been overlooked or considered as smaller equivalents of large lakes (Kownacki *et al.* 2006). Currently, owing to their specific ecological processes and apparent functional distinction from lakes, research interest in ponds is growing (Oertli *et al.* 2008; Hamerlík *et al.* 2014; Ilg and Oertli 2014). Due to their small area, depth, and small catchment area, high altitude ponds are extremely sensitive to external effects of global, regional, and local scale (Kopáček *et al.* 2002). Compared to lakes, ponds tend to be more abundant within a given area, which in combination with their high environmental heterogeneity (substrate types, depth, etc.) leads to high regional diversity of pond dwelling macroinvertebrates (Hamerlík *et al.* 2014).

Among the stagnant waterbodies of the Tatra Mountains, the majority are ponds with an area up to 1 ha and a maximum depth of less than 2 m (Gregor and Pacl 2005). Due to their abundance and concentration within a small area, the Tatra ponds represent an ideal system for studying various aspects of benthic invertebrate diversity of high altitude ponds. A high number of both ponds and lakes situated in the same altitudinal belts offer a great possibility of comparison between those aquatic ecosystems. However, for a thorough understanding of the processes governing the diversity of benthic organisms in high altitudes, a good and detailed knowledge of the regional fauna is essential (Fjellheim *et al.* 2000). Because responses of communities to various gradients and environmental factors are different at different latitudes (Astorga *et al.* 2011), sound knowledge of regional species pool is necessary.

In the Tatra Mountains, high altitude lakes have been studied intensively over the last decades both in terms of their biota and physico-chemical patterns (for details see Bitušík *et al.* 2006a). In contrast, pond ecosystems of the region are virtually unknown and the detailed information on taxonomic composition of pond benthic communities is lacking (cf. Hamerlík *et al.* 2014). In this paper, we present the first comprehensive checklist of benthic macroinvertebrates of ponds of the Tatra Mountains. We believe that these data will be useful either for the gradually rising number of studies dedicated to the biodiversity of high altitude ponds or studies dealing with complex description of diversity of high altitude ecosystems.

MATERIAL AND METHODS

Study area and sampling sites

The Tatra Mountains are situated at the border between Slovakia and Poland (the West Carpathians; 49°10′ N, 020°10′ E; Figure 1). They experience rapid changes in temperature (0.6°C per 100 m; Konček and Orlicz 1974) and precipitation along an altitudinal gradient. Comprehensive general description of the relevant hydrology, soil and vegetation attributes of the Tatra Mountains can be found in Bitušík *et al.* (2006a).

Littoral benthic communities of Tatra lakes and ponds are continuously sampled in order to study their recovery from acidification (Kopáček *et al.* 2002) and their diversity patterns

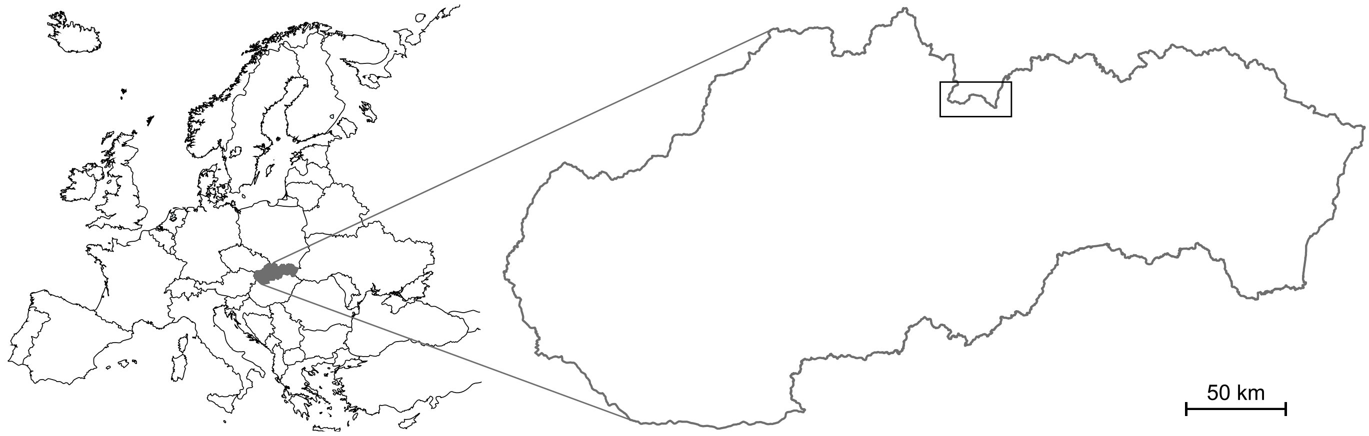

Figure 1. Map showing location of the studied area.

(Hamerlík *et al.* 2014). The dataset presented in this study is based on intensive sampling of lakes and ponds from both Slovak and Polish parts of the Tatra Mountains performed by authors during 2000–2013 (always in September). For purposes of this study, we defined a pond as a water body with an area ≤ 2 ha and maximum depth of 8 m, according to ecological threshold proposed for classification of ponds and lakes (Oertli *et al.* 2000; Hamerlík *et al.* 2014). Based on this criterion, we present data for 66 ponds (Table 1). Some ponds were sampled only in one occasion, but many were more or less regularly sampled in two or three year intervals through the study period. All of the surveyed ponds are of glacial origin, located in altitude range 1,089–2,201 m. Soft-water and oligotrophic ponds as well as dystrophic ponds are represented in the data set.

Data collection

Samples of benthic macroinvertebrate communities were taken by kicking technique using D-shaped hand net (Frost *et al.* 1971) in each sampling occasion. Dominant substrate types were sampled, considering the relative dominance of the different substrate types, and the total amount of sampling effort was equal in all the sites (3 min). Collected material was preserved with 4% formaldehyde and stored in plastic bottles. In the laboratory, organisms were hand sorted and identified (except Oligochaeta, Hirudinea and Hydracarina) to the lowest possible taxonomic level. The identification and nomenclature is based on Rozkošný (1980), Wiederholm (1983), Savage (1999), Bitušík (2000), Hanel and Zelený (2000), Bauernfeind and Humpesch (2001), Kohl (2003), Stur and Ekrem (2006), Tempelman and von Haaren (2009), Waringer and Graf (2011), Krno (2013). Chironomid pupae obtained by kick sampling were determined following the key Langton (1991). All the identified material is deposited in permanent scientific collections open to public of either permanent slide collections (Chironomidae; University of Matej Bel, Banská Bystrica) or alcohol preserved samples (all material excluding Chironomidae; Technical University in Zvolen).

RESULTS AND DISCUSSION

Almost 90,000 individuals of aquatic invertebrates were collected from the studied ponds in period of 2000–2013 and 122 taxa were identified (Table 2). The most diverse pond site supported 28 taxa; the minimum number of recorded taxa was 2, and the mean diversity was 10.7 taxa per pond. Forty-two taxa (32%) occurred only in a single pond. Oligochaeta (indeterminate) were collected from majority of the ponds (80%). The richest group was Chironomidae (Diptera) with 58 taxa, constituting almost half of the total diversity, followed by Trichoptera with 15 taxa. The remaining taxonomic groups were represented by considerably lower number of taxa.

The predominance of chironomids is a common pattern in European high altitude stagnant water bodies (Fjellheim *et al.* 2009) and has also been found in surveys of the benthic macroinvertebrates of the Tatra Mountains (Kownacki *et al.* 2000; Čiamporová-Zaťovičová *et al.* 2010).

The most frequent species of the Tatra ponds is the chironomid *Heterotrissocladius marcidus*, recorded from almost half of the ponds studied. *Heterotrissocladius marcidus* is a eurytopic species with Holarctic distribution pattern that can be found in the littoral to profundal zone of oligotrophic lakes, streams, springs, rivers and ponds (Cranston *et al.* 1983) and belongs to the most common species in the Tatra lakes (Bitušík *et al.* 2006b).

One chironomid species (*Derotanypus* cf. *sibiricus*; Figure 2) and aquatic bug *Arctocorisa carinata* represent new records for Slovakia. The only European species of *Derotanypus* is *D. sibiricus* (Saether and Spies 2013), so the larvae found in a small, permanent pond in Račkova dolina valley (1,717 m a.s.l.

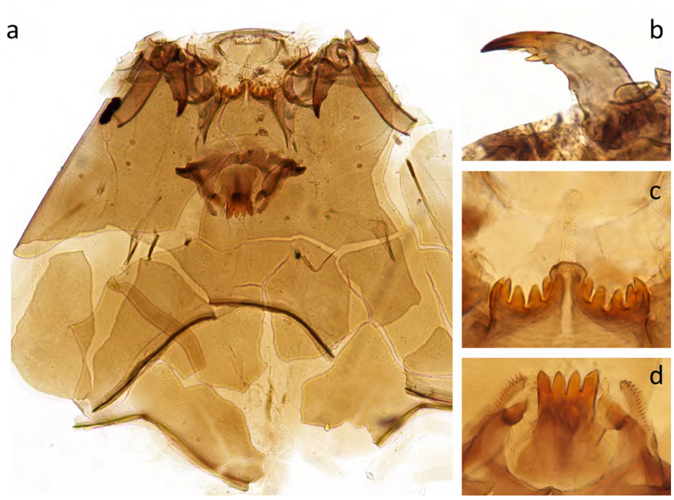

Figure 2. The head capsule (a), mandible (b), mentum (c) and ligula (d) of *Derotanypus* larva. (Photo L. Hamerlík).

Table 1. The list of sampling sites with geographic coordinates.

Number	Pond name	N	E
1.	Tretie Roháčske pleso	49.20889°	19.73667°
2.	Vyšné Jamnicke pleso	49.20250°	19.76350°
3.	Prostredné Račkovo pleso	49.19922°	19.80662°
4.	Nameless pond	49.19863°	19.80907°
5.	Wyżni Siwy Stawek	49.20417°	19.83504°
6.	Niżni Siwy Stawek	49.20452°	19.83548°
7.	Nameless pond	49.20452°	19.83552°
8.	Smreczyński Staw	49.22250°	19.86444°
9.	Vyšné Tomanovo pleso	49.21737°	19.91019°
10.	Jedyniak	49.23972°	19.99917°
11.	Kurtkowiec	49.22944°	20.00389°
12.	Zadni Staw Gąsienicowy	49.22417°	20.01083°
13.	Jamské pleso	49.13306°	20.01250°
14.	Kobylie pleso	49.20029°	20.01417°
15.	Vyšné Terianske pleso	49.16778°	20.02083°
16.	Zmarzły Staw Gąsienicowy	49.22444°	20.02278°
17.	Vyšné Rakytovské pleso	49.12639°	20.02444°
18.	Nižné Rakytovské pleso	49.12500°	20.02583°
19.	Nameless pond	49.15076°	20.02791°
20.	Nižné Furkotské pleso	49.14052°	20.02959°
21.	Vyšné Furkotské pleso	49.14351°	20.03004°
22.	Toporowy Staw Niżny	49.28333°	20.03111°
23.	Nižné Kozie pleso	49.16361°	20.04361°
24.	Vyšné Kozie pleso	49.16833°	20.04528°
25.	Wyżni Mnichowy Stawek II	49.19469°	20.05301°
26.	Wyżni Mnichowy Stawek IX.	49.19416°	20.05358°
27.	Nižné Satanie pleso	49.17251°	20.06088°
28.	Vyšné Satanie pleso	49.17009°	20.06099°
29.	Vyšné Rumanovo pleso	49.17193°	20.10068°
30.	Nižné Rumanovo pleso	49.16991°	20.10182°
31.	Vyšné Žabie pleso	49.18496°	20.10314°
32.	Malé Batizovské pleso	49.15028°	20.12694°
33.	Hrubé pleso	49.18129°	20.13362°
34.	Nameless pond	49.17687°	20.13648°
35.	Horné Velické pliesko I	49.17234°	20.13712°
36.	Dlhé Velické	49.16544°	20.14419°
37.	Malé Žabie Javorové pleso	49.20222°	20.14944°
38.	Pusté pleso	49.18222°	20.15389°
39.	Malé Pusté pleso	49.18332°	20.15495°
40.	Nameless pond	49.18344°	20.16204°
41.	Szontághovo pleso	49.16645°	20.16358°
42.	Nameless pond	49.17860°	20.16471°
43.	Nameless pond	49.17822°	20.16471°
44.	Starolesnianske pleso	49.17916°	20.16556°
45.	Vyšné Sesterské pleso	49.17746°	20.16679°
46.	Nameless pond	49.18248°	20.16832°
47.	Nameless pond	49.18481°	20.17468°
48.	Nameless pond	49.18303°	20.17510°
49.	Prostredné Sivé pleso	49.18396°	20.17524°
50.	Nižné Strelecké pleso	49.18389°	20.17528
51.	Studené pleso I.	49.17979°	20.17605°
52.	Studené pleso II.	49.17901°	20.17779°
53.	Nameless pond	49.18544°	20.17854°
54.	Nameless pond	49.18657°	20.17883°
55.	Nameless pond	49.18414°	20.18138°
56.	Nameless pond	49.18432°	20.18196°
57.	Slavkovské pleso	49.15250°	20.18333°
58.	Modré pleso	49.19219°	20.18562°
59.	Kolové pleso	49.21972°	20.19111°
60.	Pond Vyšné Spišské pleso	49.19449°	20.19700°
61.	Prostredné Spišské pleso	49.18806°	20.19833°
62.	Belasé pleso	49.21495°	20.21131°
63.	Maličké Čierne pleso	49.20780°	20.22315°
64.	Malé Čierne pleso	49.20889°	20.22361°
65.	Čierne pleso	49.20760°	20.22460°
66.	Veľké Biele pleso	49.22183°	20.22987°

[above sea level]) most likely belong to that species; however, species-level determination of larvae is impossible. Larvae of *Derotanypus* are known to inhabit cold lotic and lentic waters and have northern or mountain distribution (Fittkau and Roback 1983). Interestingly, *D. sibiricus* has only been recorded in a few countries, such as Sweden, Estonia, Germany, Austria and Russia (Saether and Spies 2013), and it is not clear whether it is a result of its rare distribution pattern or special habitat preferences. *Arctocorisa carinata* is boreomontane species widespread in some European countries (*e.g.*, Štys 1976; Jansson 1995). According to Jansson (1979) this species occurs in a wide range of habitats from small periodic rocky ponds to permanent, relatively large and deep lakes. Our record comes from Vyšné Tomanovské pleso (1,597 m a.s.l.), dystrophic pond with thick accumulation of plant detritus.

The macroinvertebrate fauna of studied ponds consisted mostly of cold stenothermic taxa typical for high mountain lentic ecosystems of Europe (Kownacki *et al.* 2000; Krno *et al.* 2006). However, great environmental variability of studied ponds is mirrored in occurrence of taxa with various ecological requirements. Lower altitude, dystrophic ponds supported diverse communities with caddisflies (*Oligotricha striata, Phryganea bipunctata, Limnephilus rhombicus*), aquatic bugs (*Hesperocorixa sahlbergi*), and odonate species (*Aeshna cyanea, Aeshna juncea*) with preferences to biotopes rich in aquatic vegetation. Our study set contained also ponds with inflows and outflows, as well as small, shallow ponds with fluctuating water level. This enabled occurrence of lotic taxa inhabiting cold mountain springs and brooks (*e.g., Stilocladius montanus, Parorthocladius* sp.), and taxa dwelling in semi-terrestrial and hygropetric habitats (*e.g., Pseudosmittia* sp., *Smittia* sp., *Metriocnemus hygropetricus* group). Due to the strong atmospheric acidification of some waterbodies in the past (Bitušík *et al.* 2006b), pond communities also contained taxa that are able to tolerate low pH (*e.g., Limnephilus coenosus, Zalutschia tatrica* gr.).

Conservation value of high altitude ponds is often stressed (*e.g.,* Oertli *et al.* 2008). From this point of view, records of rare odonate species listed in the Slovak national red list, *Aeshna juncea* and *Sympetrum danae*, are interesting. These species are tyrphophilous, preferring mountain peat bogs. Though being overall rare, *A. juncea* is assessed as abundant in Tatra area (Šácha *et al.* 2011). Surprisingly, the damselfly *Platycnemis pennipes* was recorded in Wyżni Mnichowy Stawek IX at 1,870 m a.s.l. The reported upper altitudinal threshold for this species is about 700 m in Central Europe with exceptional records above 1,000 m (Dolný and Bárta 2007). Such a dramatic shift in distribution is probably a consequence of accidental oviposition by female transported by wind. However, establishment of viable population is unlikely at this site.

Up to now, the most comprehensive checklist of benthic macroinvertebrates of the Tatra lakes (including several ponds) was presented by Krno *et al.* (2006). Based on intensive sampling in 2000, they listed 93 taxa from 45 lakes, including 17 taxa of Oligochaeta. In our study, the higher number of taxa (even without Oligochaeta) results from considerably greater number of waterbodies studied, but probably also from the heterogeneous community composition mirrored in higher β diversity of ponds, when compared to lakes (cf. Hamerlík *et al.* 2014).

Table 2 (sites 1–33; see p. 7 for sites 34–66). Checklist of benthic macroinvertebrates recorded in ponds of Tatra Mts. in our study. Plus sign indicates presence of taxa at sampling sites. Number of sampling site refers to Table 1.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
TURBELLARIA																																	
Crenobia alpina (Dana, 1766)					+		+					+				+							+								+	+	
BIVALVIA																																	
Pisidium cf. *casertanum* (Poli, 1791)		+				+			+											+													+
OLIGOCHAETA																																	
Oligochaeta indet.	+	+			+	+			+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+		+		+	+	+	+
HIRUDINEA																																	
Hirudinea indet.	+																																
ARACHNIDA																																	
Hydracarina indet.																																	
MALACOSTRACA																																	
Gammarus sp.																																	
EPHEMEROPTERA																																	
Ameletus innopinatus Eaton, 1887																															+	+	
Baetis alpinus (Leach, 1815)	+																																
ODONATA																																	
Platycnemis pennipes (Pallas, 1771)																										+							
Pyrrhosoma nymphula (Sulzer, 1776)								+																									
Coenagrionidae spp. juv.																	+																
Aeshna cyanea (Muller, 1764)																	+					+											
Aeshna juncea (Linnaeus, 1758)								+					+				+	+															
Aeshna spp. juv.								+												+													
Somatochlora metallica (Vander Linden, 1825)																						+											
Somatochlora sp.													+																				
Sympetrum danae (Sulzer, 1776)																																	
PLECOPTERA																																	
Nemoura cinerea (Retzius, 1783)								+	+																								
Nemurella pictetii (Klapálek, 1900)											+			+		+										+	+	+			+		
Capnia vidua (Klapálek 1904)												+				+							+										
Leuctra nigra (Olivier, 1811)																							+								+		
Leuctra cf. *rosinae* Kempny, 1900							+																										
Arcynopteryx compacta (McLachlan, 1872)																																	
Diura bicaudata (Linnaeus, 1758)	+																						+								+		
HETEROPTERA																																	
Arctocorisa carinata (C. R. Sahlberg,1918)									+																								
Hesperocorixa castanea (Thomson, 1869) / *moesta* (Fieber, 1848)									+	+																	+						
Hesperocorixa sahlbergi (Fieber, 1948)										+																							
Corixinae indet.																																	
Gerris spp.																																	
MEGALOPTERA																																	
Sialis lutaria (Linnaeus, 1758)	+												+				+	+				+					+	+			+		

Table 2 (sites 1–33). Continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
COLEOPTERA																																	
Acilius sulcatus (Linnaeus, 1758)																	+																
Agabus bipustulatus (Linnaeus, 1767)				+				+		+	+																				+		+
Agabus sturmii (Gyllenhal, 1808)																	+																
Agabus sp.	+	+	+			+					+		+	+		+	+	+		+					+	+		+					
Hydroporus melanarius Sturm, 1835				+						+																							
Hydroporus palustris (Linnaeus, 1761)						+					+						+																
Hydroporus sp.																									+			+			+		
Hygrotus sp.																																+	
Ilybius obscurus (Marsham 1802)																																+	
Dytiscidae indet.																+																	
Limnius perrisi (Dufour, 1843)						+																											
TRICHOPTERA																																	
Rhyacophila sp.		+																															
Holocentropous dubius (Rambur, 1842)								+									+	+															
Plectrocnemia conspersa (Curtis, 1834)	+																														+		
Agrypnia obsoleta (Hagen, 1864)								+																									
Oligotricha striata (Linneaus, 1758)								+		+			+				+					+											
Phryganea bipunctata Retzius, 1783								+										+				+											
Apatania fimbriata (Pictet 1834)											+																				+		
Drusus cf. *annulatus* (Stephens, 1837)																																	
Limnephilus rhombicus (Linnaeus, 1758)																	+	+															
Limnephilus coenosus Curtis, 1834				+	+	+			+	+										+	+					+	+	+				+	
Chaetopteryx sp.											+																				+		
Pseudopsilopteryx zimmeri (McLachlan, 1876)																																	
Acrophylax sp.							+									+							+										
Allogamus starmachi Szczęsny, 1967																+							+										
Limnephilidae indet. juv.																				+													
DIPTERA																																	
Pedicia rivosa (Linnaeus, 1758)																															+		
Pedicia sp.																																	
Dicranota sp.																															+		
Tipula (S.) rufina (Meigen, 1818)																															+		
Chaoborus obscuripes (van der Wulp 1804)																																	
Chaoborus crystallinus (De Geer, 1776)								+		+			+				+	+				+											
Limoniidae indet.																																	
Ceratopogonidae indet.		+																															
Ablabesmyia monilis agg. (Linnaeus, 1758)																	+					+											
Derotanypus cf. *sibiricus* (Kruglova & Chernovskii 1940)				+																													
Macropelopia cf. *nebulosa* (Meigen, 1804)		+			+						+					+				+						+		+			+	+	
Procladius (Holotanypus) spp.		+			+	+		+	+	+			+	+			+	+		+		+											+
Zavrelimyia sp.	+	+							+		+	+		+		+				+								+			+	+	

Table 2 (sites 1–33). Continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Diamesa tonsa (Haliday, 1856)/ *cinerella* Meigen, 1835/ *vaillanti* Serra-Tosio, 1972																																	
Pseudodiamesa branickii (Nowicki, 1873)											+	+				+			+	+											+		
Pseudodiamesa nivosa (Goetghebuer, 1928)							+			+		+			+				+		+		+						+	+	+		
Pseudokiefferiella parva (Edwards, 1932)																																	
Prodiamesa olivacea (Meigen, 1818)		+																			+			+									
Chaetocladius piger group												+							+										+				
Corynoneura scutellata group	+	+							+		+			+		+	+			+						+	+	+			+		
Cricotopus (s. str.) *tremulus* group																																	
Cricotopus (*Isocladius*) cf. *perniger* (Zetterstedt, 1850)																															+		
Cricotopus (*Isocladius*) *sylvestris* group						+			+											+													
Cricotopus spp.					+																										+		
Diplocladius cultriger (Kieffer 1908)																																	
Eukiefferiella minor (Edwards, 1929)/ *fittkaui* Lehmann, 1972																+																	
Eukiefferiella spp.																+																	
Heterotrissocladius marcidus (Walker, 1856)	+	+			+		+				+	+			+	+					+			+		+		+			+	+	
Hydrobaenus conformis (Holmgren, 1869)																																	
Limnophyes spp.				+																													
Metriocnemus hygropetricus group																				+				+									
Orthocladius (Euorthocladius) sp.																																	
Orthocladius (*Mesorthocladius*) *frigidus* (Zetterstedt, 1838)																																	
Parachaetocladius sp.					+																												
Paratrichocladius skirwithensis (Edwards, 1929)																																	
Parorthocladius sp.																																	
Psectrocladius (s. str.) *barbatipes* (Kieffer, 1923)	+																																
Psectrocladius (s. str.) *limbatellus* group														+						+													
Psectrocladius (s. str.) *octomaculatus* Wülker, 1956	+	+			+				+		+			+																	+		
Psectrocladius (s. str.) *sordidellus* group	+	+				+																									+		
Psectrocladius (Allopsectrocladius) sp.																				+													
Pseudosmittia sp.																																	
Smittia sp.															+																		
Stilocladius montanus (Rossaro, 1979)																					+												
Tokunagaia rectangularis group																											+						
Tvetenia bavarica (Goetghebuer, 1934)															+																		
Zalutschia tatrica (Pagast, 1935)										+										+		+			+	+	+	+					
Zalutschia tornetraeskenis group																																	
Chironomus spp.	+		+	+					+	+			+				+					+			+		+	+					
Cladopelma laccophila group									+																								
Microtendipes pedellus group	+																																
Omisus caledonicus (Edwards, 1932)								+														+											
Phaenopsectra sp.																																	
Polypedilum (s. str.) spp.								+									+																
Synendotendipes sp.								+		+							+	+				+			+	+							

Table 2 (sites 1–33). Continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Micropsectra apposita (Walker, 1856)																																	
Micropsectra atrofasciata (Kieffer, 1911)	+																																
Micropsectra junci (Meigen, 1818)	+																															+	
Micropsectra lindrothi Goetghebuer, 1931		+			+	+						+																				+	
Micropsectra notescens (Walker, 1856)																																	
Micropsectra radialis Goetghebuer, 1939										+		+				+							+										
Micropsectra spp.		+			+				+			+											+			+					+		
Paratanytarsus austriacus (Kieffer, 1924)	+	+									+	+					+		+		+	+									+	+	+
Tanytarsus gregarius group cf. *gregarious* Kieffer, 1909																										+		+					
Tanytarsus lugens group cf. *bathophilus* Kieffer, 1911	+	+			+	+			+																						+		
Tanytarsus spp.								+		+												+					+						+

Table 2 (continued; sites 34–66).

Taxa	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
TURBELLARIA																																	
Crenobia alpina (Dana, 1766)			+	+	+								+	+								+	+		+	+		+					
BIVALVIA																																	
Pisidium cf. *casertanum* (Poli, 1791)				+																						+						+	+
OLIGOCHAETA																																	
Oligochaeta indet.		+	+	+	+		+	+	+	+	+	+	+	+	+	+	+			+	+	+	+	+		+	+	+	+		+	+	+
HIRUDINEA																																	
Hirudinea indet.																																	
ARACHNIDA																																	
Hydracarina indet.				+																												+	+
MALACOSTRACA																																	
Gammarus sp.																														+			
EPHEMEROPTERA																																	
Ameletus innopinatus Eaton, 1887					+	+																											+
Baetis alpinus (Leach, 1815)																																	
ODONATA																																	
Platycnemis pennipes (Pallas, 1771)																																	
Pyrrhosoma nymphula (Sulzer, 1776)																																	
Coenagrionidae spp. juv.																																	
Aeshna cyanea (Muller, 1764)																																	
Aeshna juncea (Linnaeus, 1758)																																	
Aeshna spp. juv.																														+	+		+
Somatochlora metallica (Vander Linden, 1825)																																	
Somatochlora sp.																																	
Sympetrum danae (Sulzer, 1776)																															+		

Table 2 (continued; sites 34–66).

Taxa	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
PLECOPTERA																																	
Nemoura cinerea (Retzius, 1783)																										+						+	
Nemurella pictetii (Klapálek, 1900)				+							+	+						+						+		+						+	+
Capnia vidua (Klapálek 1904)			+	+																													
Leuctra nigra (Olivier, 1811)																																	
Leuctra cf. *rosinae* Kempny, 1900					+	+																							+				
Arcynopteryx compacta (McLachlan, 1872)					+																												
Diura bicaudata (Linnaeus, 1758)					+																												+
HETEROPTERA																																	
Arctocorisa carinata (C. R. Sahlberg,1918)																								+									
Hesperocorixa castanea (Thomson, 1869) / *moesta* (Fieber, 1848)																																	
Hesperocorixa sahlbergi (Fieber, 1948)																																	
Corixinae indet.	+																														+		
Gerris spp.	+																																
MEGALOPTERA																																	
Sialis lutaria (Linnaeus, 1758)																								+									+
COLEOPTERA																																	
Acilius sulcatus (Linnaeus, 1758)																																	
Agabus bipustulatus (Linnaeus, 1767)														+			+														+		
Agabus sturmii (Gyllenhal, 1808)																																	
Agabus sp.										+	+					+		+	+					+		+		+		+		+	+
Hydroporus melanarius Sturm, 1835																																	
Hydroporus palustris (Linnaeus, 1761)																																	
Hydroporus sp.	+								+	+	+							+	+					+			+						
Hygrotus sp.												+				+										+							
Ilybius obscurus (Marsham 1802)																																	
Dytiscidae indet.																																	
Limnius perrisi (Dufour, 1843)																																	
TRICHOPTERA																																	
Rhyacophila sp.																																	
Holocentropous dubius (Rambur, 1842)																																	
Plectrocnemia conspersa (Curtis, 1834)												+																					
Agrypnia obsoleta (Hagen, 1864)																																	
Oligotricha striata (Linneaus, 1758)																														+	+		
Phryganea bipunctata Retzius, 1783																																	
Apatania fimbriata (Pictet 1834)					+																					+							
Drusus cf. *annulatus* (Stephens, 1837)																						+											
Limnephilus rhombicus (Linnaeus, 1758)																																	
Limnephilus coenosus Curtis, 1834	+								+	+	+	+	+					+	+					+	+		+			+			
Chaetopteryx sp.																										+						+	+
Pseudopsilopteryx zimmeri (McLachlan, 1876)																							+										
Acrophylax sp.								+							+																	+	
Allogamus starmachi Szczęsny, 1967			+	+	+		+	+								+				+	+	+						+	+				+

Table 2 (continued; sites 34–66).

Taxa	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Limnephilidae indet. juv.																																+	
DIPTERA																																	
Pedicia rivosa (Linnaeus, 1758)																																	
Pedicia sp.													+									+	+										
Dicranota sp.																							+					+					
Tipula (S.) rufina (Meigen, 1818)																																	
Chaoborus obscuripes (van der Wulp 1804)																								+									
Chaoborus crystallinus (De Geer, 1776)																															+		
Limoniidae indet.																														+			
Ceratopogonidae indet.																															+		
Ablabesmyia monilis agg. (Linnaeus, 1758)																														+	+		
Derotanypus cf. *sibiricus* (Kruglova & Chernovskii 1940)																																	
Macropelopia cf. *nebulosa* (Meigen, 1804)				+								+				+	+	+						+		+						+	+
Procladius (Holotanypus) spp.	+				+						+	+					+	+						+						+	+		
Zavrelimyia sp.				+																				+		+						+	+
Diamesa tonsa (Haliday, 1856)/ *cinerella* Meigen, 1835/ *vaillanti* Serra-Tosio, 1972							+						+	+						+													
Pseudodiamesa branickii (Nowicki, 1873)				+									+	+	+													+	+			+	
Pseudodiamesa nivosa (Goetghebuer, 1928)		+	+		+	+	+	+								+						+	+		+	+			+				
Pseudokiefferiella parva (Edwards, 1932)														+	+	+				+	+								+				
Prodiamesa olivacea (Meigen, 1818)				+																						+							+
Chaetocladius piger group		+											+							+			+										
Corynoneura scutellata group					+				+	+	+	+		+	+		+	+						+		+		+			+		
Cricotopus (s. str.) *tremulus* group									+					+	+			+															
Cricotopus (*Isocladius*) cf. *perniger* (Zetterstedt, 1850)																																	
Cricotopus (*Isocladius*) *sylvestris* group											+																						
Cricotopus spp.																	+									+							
Diplocladius cultriger (Kieffer 1908)				+																													
Eukiefferiella minor (Edwards, 1929)/ *fittkaui* Lehmann, 1972				+																													
Eukiefferiella spp.																																	
Heterotrissocladius marcidus (Walker, 1856)	+			+	+	+					+	+		+	+	+	+		+							+		+		+	+	+	+
Hydrobaenus conformis (Holmgren, 1869)											+																						
Limnophyes spp.							+						+	+	+			+	+	+	+	+	+				+						
Metriocnemus hygropetricus group					+												+	+															+
Orthocladius (Euorthocladius) sp.																						+	+										
Orthocladius (*Mesorthocladius*) *frigidus* (Zetterstedt, 1838)																										+							
Parachaetocladius sp.																																	
Paratrichocladius skirwithensis (Edwards, 1929)				+																													
Parorthocladius sp.				+																													
Psectrocladius (s. str.) *barbatipes* (Kieffer, 1923)																																	
Psectrocladius (s. str.) *limbatellus* group												+														+							+
Psectrocladius (s. str.) *octomaculatus* Wülker, 1956											+																						
Psectrocladius (s. str.) *sordidellus* group												+																					

Table 2 (continued; sites 34–66).

Taxa	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Psectrocladius (Allopsectrocladius) sp.																																	
Pseudosmittia sp.																+							+										
Smittia sp.					+									+							+				+				+				
Stilocladius montanus (Rossaro, 1979)				+																						+							
Tokunagaia rectangularis group														+																			
Tvetenia bavarica (Goetghebuer, 1934)																																	
Zalutschia tatrica (Pagast, 1935)	+								+	+	+	+					+	+	+					+							+		
Zalutschia tornetraeskenis group																															+		
Chironomus spp.	+					+			+									+	+								+			+			
Cladopelma laccophila group																																	
Microtendipes pedellus group																																	
Omisus caledonicus (Edwards, 1932)																																	
Phaenopsectra sp.																															+		+
Polypedilum (s. str.) spp.																																	
Synendotendipes sp.	+					+																		+						+	+		
Micropsectra apposita (Walker, 1856)																																	+
Micropsectra atrofasciata (Kieffer, 1911)					+																												
Micropsectra junci (Meigen, 1818)																																	
Micropsectra lindrothi Goetghebuer, 1931																																	
Micropsectra notescens (Walker, 1856)																										+						+	+
Micropsectra radialis Goetghebuer, 1939				+		+		+							+	+	+												+				
Micropsectra spp.					+																							+		+			
Paratanytarsus austriacus (Kieffer, 1924)	+			+			+		+	+	+	+	+	+	+		+	+				+	+		+	+							+
Tanytarsus gregarius group cf. *gregarious* Kieffer, 1909											+													+									
Tanytarsus lugens group cf. *bathophilus* Kieffer, 1911																		+															+
Tanytarsus spp.	+					+			+									+												+	+		

In this study, we have shown that high altitude ponds of the Tatra Mountains harbour relatively rich taxa pool of benthic macroinvertebrates. Considering the extensive sampling scheme (66 ponds over many years), the results provided here can be useful as a good baseline data for estimation of pond macroinvertebrate diversity of the Central European high-altitude ponds. We believe that the checklist presented here underlines the role of ponds in maintaining regional biodiversity of high-altitude ecosystems.

ACKNOWLEDGMENTS

We thank our colleagues and students, namely Dana Fidlerová, Zuzana Hládeková, Dana Lempochnerová, Renáta Gelienová, Jana Jurčová, Veronika Palicová, Martina Mancalová, Miroslav Očadlík, participating in laboratory processing and Zuzana Čiamporová-Zaťovičová helping with determination of Coleoptera. This work was supported by the Slovak Research and Development Agency under the contract number APVV-0059-11. This study was also partially funded by the Slovak Scientific Grant Agency (VEGA, projects numbers 2/0081/13 and 1/0180/12).

LITERATURE CITED

Astorga, A., J. Heino, M. Luoto and T. Muotka. 2011. Freshwater biodiversity at regional extent: determinants of macroinvertebrate taxonomic richness in headwater streams. *Ecography* 34(5): 705–713 (doi: 10.1111/j.1600-0587.2010.06427.x).

Bauernfeind, E. and U.H. Humpesch. 2001. *Die Eintagsfliegen Zentraleuropas (Insecta: Ephemeroptera): Bestimmung und Ökologie*. Wien: Naturhistorisches Museum. 239 pp.

Bitušík, P. 2000. *Príručka na určovanie lariev pakomárov (Diptera: Chironomidae) Slovenska. Časť I. Buchonomyinae, Diamesinae, Prodiamesinae a Orthocladiinae*. Zvolen: Vyd. Tech. Univerzity vo Zvolene. 133 pp.

Bitušík, P., J. Kopáček, E. Stuchlík and F. Šporka (eds.). 2006a. Limnology of Lakes in the Tatra Mountains. *Biologia*, *Bratislava* 61 (Supplement 18): 222 pp.

Bitušík, P., M. Svitok, P. Kološta and M. Hubková. 2006b. Classification of the Tatra Mountains lakes (Slovakia) using chironomids (Diptera, Chironomidae); pp. 191–201, in: P. Bitušík, J. Kopáček, E. Stuchlík and F. Šporka (eds.). Limnology of lakes in the Tatra Mountains. *Biologia* (Bratislava) 61 (Supplement 18): S191–S201 (doi: 10.2478/s11756-006-0131-8).

Cranston, P.S., D.R. Oliver and O.A. Saether. 1983. 9. The larvae of Orthocladiinae (Diptera: Chironomidae) of the Holarctic region–keys and diagnosis; pp. 149–291, in: T. Wiederholm (ed.). *Entomologica Scandinavica*, Supplement 19.

Čiamporová-Zaťovičová, Z., L. Hamerlík, F. Šporka and P. Bitušík. 2010. Littoral benthic macroinvertebrates of alpine lakes (Tatra Mts) along an altitudinal gradient: a basis for climate change assessment. *Hydrobiologia* 648(1): 19–34. (doi: 10.1007/s10750-010-0139-5).

De Meester, L., S. Declerck, R. Stoks, G. Louette, F. Van De Meutter, T. De Bie, E. Michels and L. Brendonck. 2005. Ponds and pools as model systems in conservation biology, ecology and evolutionary biology. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15(6): 715–725. (doi: 10.1002/aqc.748)

Dolný, A. and D. Bárta. 2007. *Vážky ČR: Ekologie, ochrana a rozšíření*. Vlašim: Český svaz ochránců přírody. 642 pp.

Fittkau, E.J. and S.S. Roback. 1983. 5. The larvae of Tanypodinae (Diptera: Chironomidae) of the Holarctic region — keys and diagnosis; pp. 33–110, in: T. Wiederholm (ed.). *Entomologica Scandinavica*, Supplement 19.

Fjellheim, A., A. Boggero, G.A. Halvorsen, A.M. Nocentini, M. Riedervall, G.G. Raddum and O.A. Schnell. 2000. Distribution of benthic invertebrates in relation to environmental factors. A study of European remote alpine lake ecosystems. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie* 27: 484–488.

Fjellheim, A., G.G. Raddum, V. Vandvik, D. Cogalniceanu, A. Boggero, A. Brancelj, J. Galas, F. Šporka, Y. Vidinova, P. Bitušík, E. Dumnicka, N. Gâldean, A. Kownacki, I. Krno, E. Preda, G. Rîsnoveanu and E. Stuchlík. 2009. Diversity and distribution patterns of benthic invertebrates along alpine gradients. A study of remote European freshwater lakes. *Advances in Limnology* 62: 159–176 (doi:10.1127/advlim/62/2009/167).

Frost, S., A. Huni and W.E. Kershaw. 1971. Evaluation of a kicking technique for sampling stream bottom fauna. *Canadian Journal of Zoology* 49(2): 167–173 (doi: 10.1139/z71-026).

Gregor, V. and J. Pacl. 2005. Hydrology of the Tatra mountain lakes. *Acta Hydrologica Slovaca* 6(1): 161–187.

Hamerlík, L., M. Svitok, M. Novikmec, M. Očadlík and P. Bitušík. 2014. Among-site and regional diversity patterns of benthic macroinvertebrates in high altitude waterbodies: do ponds differ from lakes? *Hydrobiologia* 723(1): 41–52 (doi: 10.1007/s10750-013-1621-7).

Hanel, L. and J. Zelený. 2000. *Vážky (Odonata): výzkum a ochrana*. Vlašim: Český svaz ochránců přírody, základní organizace Vlašim. 240 pp.

Ilg, Ch. and B. Oertli. 2014. How can we conserve cold stenotherm communities in warming Alpine ponds? *Hydrobiologia* 723(1): 53–62 (doi: 10.1007/s10750-013-1538-1).

Jansson, A. 1979. Reproductive isolation and experimental hybridization between *Arctocorisa carinata* and *A. germani* (Heteroptera: Corixidae). *Annales Zoologici Fennici* 16(2): 86–104.

Jansson, A. 1995. Family Corixidae Leach 1815–water boatmam, pp. 26–56, in: B. Aukena and Ch. Rieger (eds.). *Catalogue of the Heteroptera of Palaearctic Region. Vol. 1. Enicocephalomorpha, Dipsocoromorpha, Nepomorpha, Gerromorpha and Leptodopomorpha*. Amsterdam: The Netherlands Entomological Society.

Kohl, S. 2003. *Určovací klíč exuvií evropských druhů vážek (Odonata) podřádu Anisoptera. Příloha metodiky Českého svazu ochránců přírody Vlašim č. 9 (Vážky, výzkum a ochrana)*. Vlašim: Český svaz ochránců přírody. 30 pp.

Konček, M. and M. Orlicz. 1974. Teplotné pomery; pp. 89–179, in: M. Konček (ed.). *Klíma Tatier*. Bratislava: Veda.

Kopáček, J., E. Stuchlík, J. Veselý, J. Schaumburg, I.C. Anderson, J. Fott, J. Hejzlar and J. Vrba. 2002. Hysteresis in reversal of Central European mountain lakes from atmospheric acidification. *Water, Air and Soil Pollution: Focus* 2(2): 91–114 (doi: 10.1023/A:1020190205652).

Kownacki, A., J. Galas, E. Dumnicka and S. Mielewczyk. 2000. Invertebrate communities in permanent and temporary high mountain lakes (Tatra Mts.). *Annales de Limnologie—International Journal of Limnology* 36(3): 181–188 (doi: 10.1051/limn/2000016).

Kownacki, A., E. Dunmicka, J. Kwandrans, J. Galas and M. Ollik. 2006. Benthic communities in relation to environmental factors in small high mountain ponds threatened by air pollutants. *Boreal Environment Research* 11(6): 481–492 (http://www.borenv.net/BER/pdfs/ber11/ber11-481.pdf).

Krno, I. 2013. *Determinačný kľúč pre hydrobiológov. Časť II. Pošvatky (Plecoptera)*. Bratislava: Výskumný ústav vodného hospodárstva. 64 pp.

Krno, I., F. Šporka, J. Galas, L. Hamerlík, Z. Zaťovičová and P. Bitušík. 2006. Littoral benthic macroinvertebrates of mountain lakes in the Tatra Mountains (Slovakia, Poland); pp. 147–166, in: P. Bitušík, J. Kopáček, E. Stuchlík and F. Šporka (eds.). Limnology of lakes in the Tatra Mountains. *Biologia* (Bratislava) 61 (Supplement 18) (doi: 10.2478/s11756-006-0127-4).

Langton, P.H. 1991. *A Key to Pupal Exuviae of West Palaearctic Chironomidae*. Cambridgeshire: privately published by P.H. Langton. 386 pp.

Oertli, B., D. Auderset Joye, E. Castella, R. Juge and J.-B. Lachavanne.

2000. *Diversité Biologique et Typologie Écologique des Étangs et Petits Lacs de Suisse.* University of Geneva, Geneva, Swiss Agency for the Environment, Forests and Landscape, Laboratory of Ecology and Aquatic Biology. 340 pp. Accessible at http://leba.unige.ch/PLOCH/rapport/ploch1234.htm. Captured on 22 December 2013.

Oertli, B., N. Indermuehle, S. Angelibert, H. Hinden and A. Stoll. 2008. Macroinvertebrate assemblages in 25 high alpine ponds of the Swiss National Park (Cirque of Macun) and relation to environmental variables. *Hydrobiologia* 597(1): 29–41 (doi: 10.1007/s10750-007-9218-7).

Rozkošný, R. (ed.). 1980. *Klíč vodních larev hmyzu.* Praha: Academia. 521 pp.

Savage A.A. 1999. *A Key to the Larvae of British Corixidae*. Ambleside, UK: The Freshwater Biological Association. 56 pp.

Saether, O.A. and M. Spies. 2013. Fauna Europaea: Chironomidae, in: Beuk, P., T. Pape and Y.S.D.M. de Jong (eds.). *Fauna Europaea: Diptera, Nematocera.* Fauna Europaea version 2.6. Accessible at http://www.faunaeur.org. Captured on 22 December 2013.

Šácha, D., S. David, E. Bulánková, I. Jakab and I. Konvitt. 2011: *Vážky Slovenskej republiky.* Accessible at http://www.vazky.sk/. Captured on 26 July 2014.

Stur, E. and T. Ekrem. 2006: A revision of Western Palaearctic species of the *Micropsectra atrofasciata* species group (Diptera: Chironomidae). *Zoological Journal of the Linnean Society* 146(4): 165–225 (doi: 10.1111/j.1096-3642.2006.00230.x).

Štys, P. 1976. Faunistic records from Czechoslovakia. Heteroptera: Corixidae: *Arctocorisa carinata carinata*, Tingidae: *Agrama (Serenthiella) minuta*, Aradidae: *Aradus kuthyi*, *Aradus brevicollis*, *Aradus brenskei*. *Acta Entomologica Bohemoslovaca* 73: 61.

Tempelman D. and T. von Haaren 2009. *Water–en Oppervlaktewantsen van Nederland*. Utrecht: Jeugdbondsuitgeverij. 116 pp.

Waringer, J. and W. Graf. 2011. *Atlas der mitteleuropäischen Köcherfliegenlarven–Atlas of Central European Trichoptera Larvae*. Dinkelscherben: Erik Mauch Verlag. 468 pp.

Wiederholm, T. 1983. *Chironomidae of the Holarctic Region Keys and Diagnoses. Part I: Larvae*. Lund: Entomological Society of Lund, Sweden. 457 pp.

Authors' contribution statement: MN and MS collected the data, wrote the text and identified selected groups of benthic macroinvertebrates, MS prepared the map. MV collected part of the data and summarized all the data. PB and LH collected data and identified Chironomidae, LH wrote part of the text. ZM and BRK identified selected groups and wrote part of the text.

Received: August 2014
Accepted: December 2014
Editorial responsibility: Luiz Carlos de Pinho