BOREAL ENVIRONMENT RESEARCH 17: 252–262
ISSN 1239-6095 (print) ISSN 1797-2469 (online)

Helsinki 29 June 2012

Temporal changes in oligochaete fauna of three alpine ponds in the Tatra Mountains (Poland)

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Received 11 Feb. 2011, final version received 7 Nov. 2011, accepted 15 July 2011

Dumnicka, E. & Galas, J. 2012: Temporal changes in oligochaete fauna of three alpine ponds in the Tatra Mountains (Poland). *Boreal Env. Res.* 17: 252–262.

In our long-term (10-, 8- and 6-year) studies we assessed the richness of oligochaete species and changes in the composition of their taxocens as well as the density of the prevailing species over successive years in three ponds situated above the tree line in the Tatra Mts., Poland. In addition, abiotic parameters of the ponds were recorded. In two ponds, characterised by significant fluctuations in the water level and a slightly acidic pH, Enchytraeidae prevailed, represented by the genera *Cognettia* and *Cernosvitoviella*. In the third pond, with slightly warmer water and an almost stable water level, Naididae (*Nais variabilis*, *Spirosperma ferox* and *Tubifex montanus*) were the most numerous. A total of 26 oligochaete species were found. The number of species in particular ponds ranged from 13 to 15, but the number of species determined during all the years of studies was very low. The number of species found in particular years in each of the studied ponds was not stable. It varied from 3 in Czerwony Pańszczycki to 10 in Długi Gąsienicowy and Siwy Wyżni.

Introduction

Alpine waterbodies are considered to be habitats colonized by a small number of species, very well adapted to extreme environmental conditions. They include common, eurytopic species as well as rare ones (Krno *et al*. 2006, Dumnicka and Boggero 2007). It is assumed that they form stable biotic communities year to year. In studies of high-mountain lakes, plankton and littoral benthos were usually sampled once a year, at the end of summer (e.g. Hořická *et al*. 2006), i.e. before the end of the vegetation season, when many macroinvertebrates achieve their maximum biomass and/or sexual maturity. Such a procedure was used in several pan-European research projects, such as AL:PE2 (Acidification of mountain Lakes: Paleolimnology and Ecology) and EMERGE (European Mountain lake Ecosystems: Regionalization, diaGnostics & socio-economic Evaluation) carried out in ca. 350 alpine lakes situated in various mountain ranges. Already Kowalewski (1914) and Hrabě (1942) sampled oligochaete fauna in lakes and ponds of the Tatra Mts. in summer. Previous studies were made during one or two years, so they did not make it possible to analyze probable temporal changes in the composition and density of benthic fauna in alpine waterbodies. Only long-term studies can provide this information.

Editor in charge of this article: Johanna Mattila

The need for long-term studies in freshwater ecology has been emphasized for years, e.g. by Elliott (1990). Many such studies were conducted in various lotic and lenitic waters (Vinson 2001, Resh *et al*. 2005, Jackson and Füreder 2006, Bêche *et al*. 2006), but only sporadically in alpine waterbodies (Ravera 1966).

Our investigations concerned three ponds sampled once a year in late summer for 10, 8 or 6 years. In two of them, some abiotic conditions are subject to distinct year-to-year fluctuations, which may affect oligochaete structure and composition. In the third pond, environmental conditions are more stable. High-mountain waterbodies are usually oligotrophic, and their planktonic communities are limited by food availability (Camarero *et al*. 1999, Fott *et al*. 1999), that is why we decided to investigate whether the availability of organic matter determines oligochaete density.

In this paper we used th data collected by us as part of AL:PE2, MOLAR (Mountain Lake Research) and EMERGE projects, as well as data gathered in summer during statutory studies of the Institute of Nature Conservation PAS, Kraków. The aims of our study were (i) to establish whether there are changes in the composition and structure of oligochaete taxocens from year to year, (ii) to ascertain if organic matter content affects the density of oligochaete fauna, and (iii) to test which method of sampling (kick method or quantitative sampler) is the most effective for determining the presence of oligochaete species.

Study area

We investigated three waterbodies of different sizes (Table 1). The ponds are situated above the tree line in the Tatra Mountains (southern Poland) (Fig. 1). Długi Gąsienicowy and Czerwony Pańszczycki are located on a granitic bedrock covered by postglacial rock debris. The third pond, Siwy Wyżni, is situated on metamorphic rock covered by postglacial sediments.

The three ponds are fed by precipitation and melting snow but Długi Gąsienicowy and Czerwony Pańszczycki also have permanent inlets. In the bottom of Czerwony Pańszczycki and Siwy Wyżni (Table 1) there are springs, which are additional sources of water. All these ponds have outlets, but we observed distinct fluctuations of the water level only in Długi Gąsienicowy and Czerwony Pańszczycki, which depended on the amount of rain and the length of winter.

Material and methods

We took water and benthic samples from each pond in August, when environmental factors are the most stable, and invertebrates the most abundant.

We measured pH and conductivity of the water samples with a portable instrument (Elmetron pHmeter CX-742), and carried out ion determination (Ca, Mg, Cl, SO_4, NH_4, NO_3) by ion chromatography (The Molar Water

Table 1. Morphometric characteristics of the ponds.

Ponds	Altitude (m)	Area (ha)	Max depth	Bottom*	Pond surroundings
Długi Gąsienicowy	1784	1.59	10.6	Stones (90%), patchy mud with fragments of plants (10%)	Boulders, stones (90%), dwarf pine (5%), alpine meadow (5%)
Siwy Wyżni	1718	0.037	1.2	Mud (80%), stones and pebbles (20%)	Alpine meadow (100%)
Czerwony Pańszczycki	1654	0.3	1.5	Stones (80%), patchy mud with fragments of plants (15%), sand and pebbles (5%)	Boulders, stones (50%), dwarf pine (35%), alpine meadow (15%)

* Bottom character is that of the shallow, sampled part of a pond.

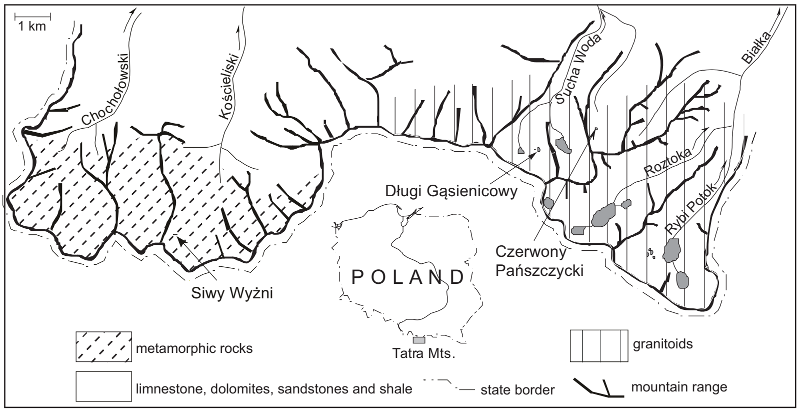


Fig. 1. Locations of the studied ponds in the Polish Tatra Mts.

Chemistry Group 1999) and standard protocols (Anon. 1992). Water pH in Siwy Wyżni and Czerwony Pańszczycki was nearly neutral, whereas in Długi Gąsienicowy it was slightly acidic (5.94), but this parameter changed considerably (Table 2). Water conductivity of all ponds, despite differences in the geology of their catchments, was low: between 14 and 47 μS cm^{-1}. Ca and Mg concentrations were also low, except for Siwy Wyżni, where they were slightly higher. In Czerwony Pańszczycki, the concentration of nitrates reached 1.53 mg l^{-1}, in the other ponds it was lower (< 1 mg l^{-1}). For most chemical parameters in the study period, we found small value ranges, except for the concentrations of chloride in Czerwony Pańszczycki and sulphate in Długi Gąsienicowy, which changed distinctly.

Lake surface-water temperatures (LSWT) were measured with miniature thermistors (the sampling interval was one hour) in Długi Gąsienicowy and Siwy Wyżni in 2000; in the other years and in Czerwony Pańszczycki, LSWT were measured with a mercury thermometer at noon. The average water temperature in August was low, ranging from 9.9 °C in Siwy Wyżni to 5.2 °C in Długi Gąsienicowy (Table 2). According to an average of thousands of measurements in the year 2000, water temperature in Siwy Wyżni was only 1 °C higher than in Długi Gąsienicowy (Fig. 2). Summer tempera-

Table 2. Hydrochemical characteristics (range) and lake surface-water temperatures (LSWT) in the ponds studied.

Parameters	Długi Gąsienicowy[1]	Siwy Wyżni	Czerwony Pańszczycki
pH	4.3–6.6	6.3–7.2	6.2–7.0
Oxygen saturation (%)	73.4–96.42	71.5–108.4	87.3–100.4
Calcium (mg l^{-1})	1.0–3.4	2.5–4.1	2.1–3.6
Magnesium (mg l^{-1})	0.1–0.2	1.1–2.1	0.5–0.7
Chloride (mg l^{-1})	0.1–0.5	0.6–0.7	0.13–2.8
Sulphate (mg l^{-1})	0.7–4.6	2.9–4.1	1.1–2.1
Ammonia (mg l^{-1})	0.01–0.21	0.17–0.37	0.24–0.66
Nitrate (mg l^{-1})	0.28–0.98	0.06–0.52	0.34–1.53
Conductivity (μS cm^{-1})	13.9–43.8	27.3–44.6	22.7–46.7
LSWT (°C)			
Mean August sampling	7.6[2]	9.9	5.2
10 Oct. 2000	3.4[2]	4.2	3.5
10 June 2001	4.1[2]	5.8	4.2
Aug. 1994	11.3[3]	–	8.0[3]

[1] Water chemistry parameters from 1993–1998 after Kownacki *et al.* (2000).
[2] Šporka *et al.* (2006).
[3] Lange *et al.* (2000).

tures in Czerwony Pańszczycki did not reflect its elevation: in spite of the lowest elevation the maximum temperature was also the lowest among the three waterbodies. Other authors (e.g. Šporka *et al*. 2006, Lange *et al*. 2000), also observed this relationship, but it was based on single measurements. The oxygen content in surface water was measured using the Winkler method. Water oxygenation was sufficient, but in Długi Gąsienicowy and Siwy Wyżni the minimum value was as low as 70%, and in Długi Gąsienicowy it did not exceed 100%.

In all three ponds, benthic samples were collected from their shallow parts, down to 1-m depth, which in the case of Siwy Wyżni and Czerwony Pańszczycki constitute almost the whole bottom area. In Długi Gąsienicowy, we collected only qualitative benthic kick-samples (Frost *et al*. 1971) according to the "Protocol for the sampling of contemporary invertebrates" recommended for the multi-national projects: AL:PE2, MOLAR and EMERGE (http://www.mountain-lakes.org/). During 1992–2002, we took two or three samples from Długi Gąsienicowy each time (Table 3).

From Siwy Wyżni and Czerwony Pańszczycki, we collected two types of quantitative benthic samples: from fine and coarse sediments. In 1998–2005 from Siwy Wyżni, where fine sediment prevailed (Table 1), we collected samples with a corer (area 12.56 cm^2), which was pushed into the substratum to the depth of 5 cm. We took only a few samples from the stony substrate (Table 3) with a hand scraper (15 × 15 cm frame with a 0.2 mm size mesh). From Czerwony Pańszczycki, almost the same number of samples were taken from the fine bottom and from the coarse bottom. We studied this pond from 2000 to 2005. To obtain benthic-fauna data representative of the whole pond, we took samples from various bottom points of Siwy and Czerwony Pańszczycki.

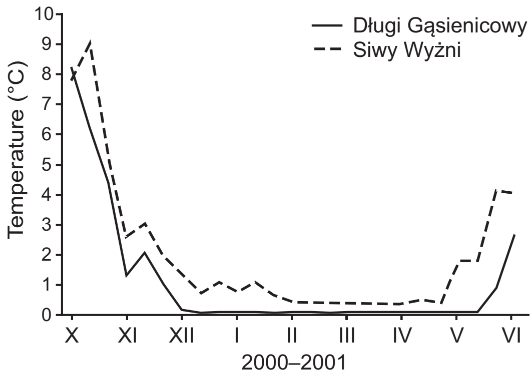


Fig. 2. Water temperatures in Długi Gąsienicowy and Siwy Wyżni ponds (10 days mean) measured at 0.05 m depth.

In a laboratory, we removed invertebrates from sediments under a stereoscopic microscope. We preserved these specimens in 4% formaldehyde and prepared solid slides in Canada balsam. We identified Oligochaeta to the species or genus level. After removing the invertebrates, we dried the remaining sediment, collected with a corer, at 105 °C for 4 hours in order to determine the ash-free dry mass (AFDM) expressed as a percentage of the organic matter. We calculated the densities of Oligochaeta in Siwy Wyżni and Czerwony Pańszczycki, as well as the absolute number of individuals caught in Długi Gąsienicowy. Owing to a non-normal distribution of our data, non-parametric tests were used for statistical analyses. Spearman's correlations

Table 3. Sampling details.

Ponds	Years of sampling	Project	Total number of samples		
			Fine sediments	Coarse sediments	Kick method
Długi Gąsienicowy	1992–2002	AL:PE2 MOLAR EMERGE	–	–	39
Siwy Wyżni	1998–2005	EMERGE Statutory studies	96	5	–
Czerwony Pańszczycki	2000–2005	Statutory studies	28	24	–

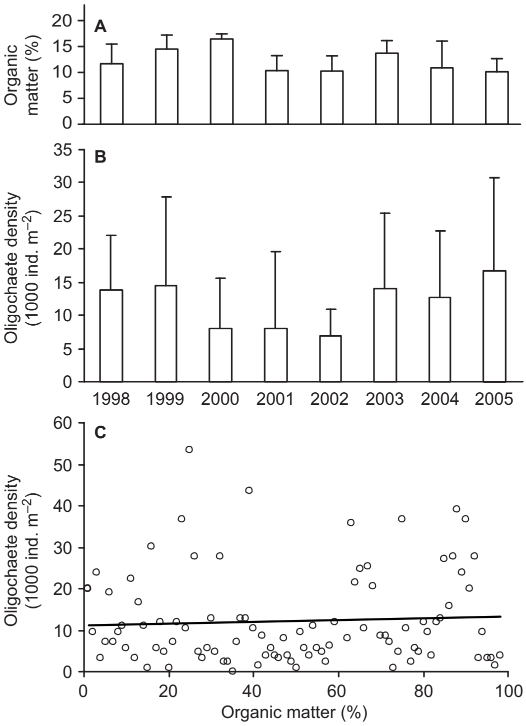


Fig. 3. (**A**) Percentage of organic matter in the sediments, and (**B**) oligochaete densities in successive years in Siwy Wyżni pond; shown are mean + SD. (**C**) Correlation between organic matter content and oligochaete densities in corer samples.

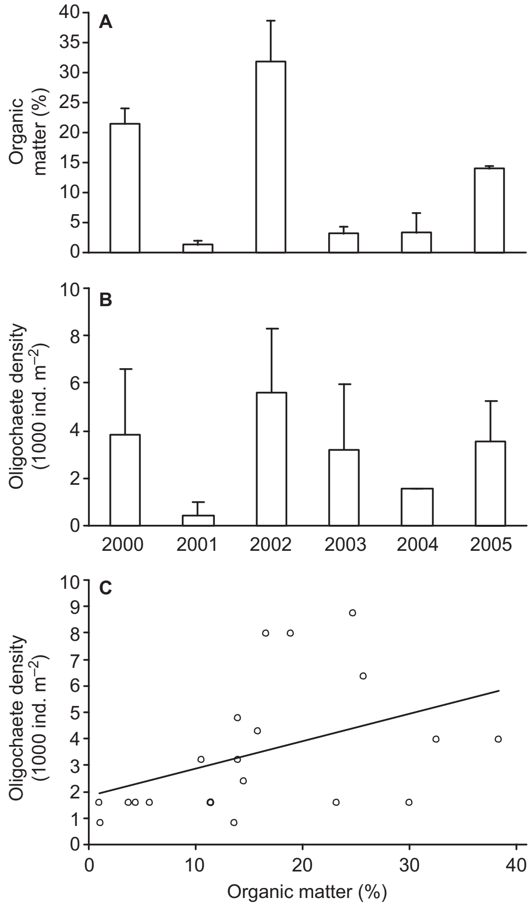


Fig. 4. (**A**) Organic matter contents in the sediments (%), (**B**) Oligochaete densities in successive years in Czerwony Pańszczycki pond; shown are mean + SD. (**C**) Correlation between organic matter content and oligochaete densities in corer samples.

between organic matter content in sediments and oligochete densities as well as the frequency and densities of selected species were calculated. In order to compare the structure of oligochaete taxocens, we calculated the relative abundance (%) of each taxon for the study period (average value) and for each year. The changes in density of the prevailing taxa in Czerwony Pańszczycki and Siwy Wyżni was tested with a non-parametric Kruskal-Wallis test. For data from Długi Gąsienicowy we constructed a Generalized Linear Model (GLM) with repeated measures (dependent variable: measurement I and II, i.e. kick sample I and kick sample II; grouping variables). Calculations were performed with STATISTICA 5.0.

Results

The content of organic matter in sediments in Siwy Wyżni fluctuated from year to year in a narrow range, whereas oligochaete densities changed more distinctly (Fig. 3A and B), however the correlation between these two variables was not significant ($r_S = –0.073$, $p = 0.49$; Fig. 3C). By contrast in Czerwony Pańszczycki, changes in these two variables were more pronounced (Fig. 4A and B), and the correlation between them was significant ($r_S = 0.430$, $p = 0.025$; Fig. 4C).

The number of species found in particular years in each of the studied ponds was not stable. It varied from 3 to 8 in Czerwony Pańszczycki, 4 to 10 in Długi Gąsienicowy and 5 to 10 in Siwy Wyżni. Only in the latter, we did find a substantial number of juvenile Enchytraeidae, which could not be determined to the species level.

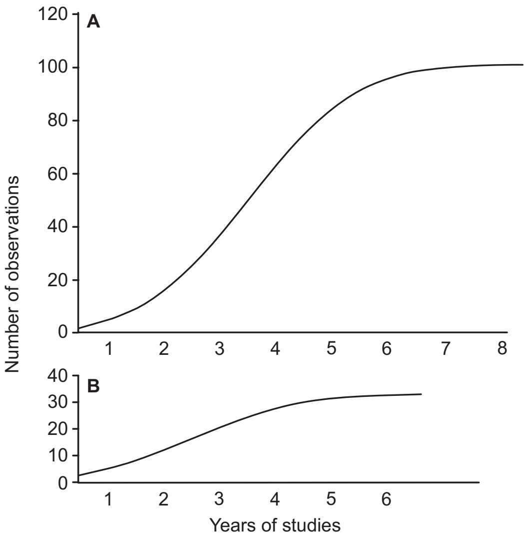


Fig. 5. Species accumulation curve for oligochaete taxa in (**A**) Siwy Wyżni and (**B**) Czerwony Pańszczycki.

According to cumulative curves calculated for Siwy Wyżni, we probably caught representatives of all resident species, whereas in Czerwony Pańszczycki this result was not so obvious (Fig. 5).

Changes in the relative abundance of oligochaetes in Długi Gąsienicowy in particular years (expressed as the absolute number of individuals caught) also fluctuated strongly, and these differences were statistically significant (according to GLM; Table 4). The lowest number of individuals caught in two kick-samples was 11, and the highest 415 (Fig. 6). The differences between the oligocheate numbers obtained from two kick-samples for selected taxons and in particular years were not significant (Table 4).

Table 4. GLM for Długi Gąsienicowy; R1 = the difference between kick samples I and II.

Effect	MS	*F*	*p*
Intercept	13152.71	20.01	< 0.0001
Species	2363.12	3.59	< 0.0001
Year	1577.72	2.4	0.0142
Error	657.21		
R1	31.21	0.2	0.6480
R1 × Species	196.68	1.31	0.1881
R1 × Year	63.64	0.42	0.9193
Error	149.23		

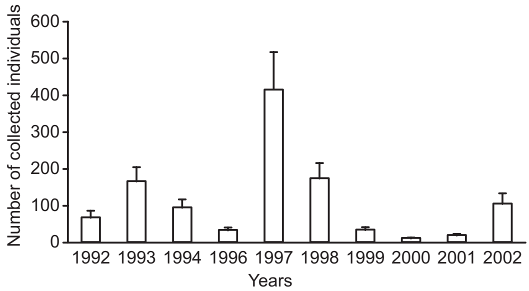


Fig. 6. The number (+ SD) of oligochaetes collected in studied years in Długi Gąsienicowy.

We found 13 oligochaete taxa in Czerwony Pańszczycki, studied for six years, and 15 in Długi Gąsienicowy (Table 5), which we studied the longest, although in consecutive years this number fluctuated from 3 to 9. Species representing the family Enchytraeidae were the most numerous (from 10 in Długi Gąsienicowy to 8 in Czerwony Pańszczycki). We found 2–4 species from the family Naididae and only single species from Haplotaxidae, Lumbriculidae and Lumbricidae.

Only in Siwy Wyżni, the relative abundance of naidids was high, whereas in the other ponds, enchytraeids were the most numerous (Table 5). In two of the ponds, the genera *Cernosvitoviella* and *Cognettia* prevailed. The genus *Cernosvitoviella* was represented by three species in each pond, whereas in Długi Gąsienicowy and Czerwony Pańszczycki we found, respectively, five and three species of the genus *Cognettia*. Naididae, represented by *Nais variabilis*, *Spirosperma ferox* and *Tubifex montanus,* predominated in Siwy Wyżni, constituting on average 73.4% of the whole taxocen.

The number of species that were always found in a given pond was very low: one in Czerwony Pańszczycki, and two in Długi Gąsienicowy and Siwy Wyżni (Table 5). The number of species present in more than 50% of sampled years in Długi Gąsienicowy and Czerwony Pańszczycki was also low: one and two species, respectively; whereas in Siwy Wyżni there were four such species. Exceptionally high number of taxa was found only once during the whole study period from Długi Gąsienicowy (Table 5).

Substantial density changes in dominating species from year to year were not always noted

(Fig. 7), nevertheless in Siwy Wyżni significant differences in densities (Kruskal-Wallis test) were found for six taxa: *Nais variabilis* (χ^2 = 16.45, df = 7, p = 0.020), *Cernosvitoviella* spp. juv. (χ^2_7 = 21.92, p = 0.003), *C. tatrensis* (χ^2_7 = 23.89, p = 0.001), *Marionina argentea* (χ^2_7 = 18.35, p = 0.010), *M. riparia* (χ^2_7 = 16.27, p = 0.030) and *Cognettia* spp. juv. (χ^2_7 = 17.64, p = 0.013). In Czerwony Pańszczycki, such differences were found only for *Cognettia sphagnetorum* (χ^2_4 = 11.10, p = 0.025). A high density of a particular species was not always correlated with its high frequency in successive years. We found such a correlation only for *Haplotaxis gordioides* (r_S = 0.919, p = 0.001, *Tubifex montanus* (r_S = 0.877, p = 0.004), *Marionina riparia* (r_S = 0.902, p = 0.002) in Siwy Wyżni (Fig. 7) and *Henlea perpusilla* (r_S = 0.949, p = 0.004) in Czerwony Pańszczycki (Fig. 7). Among less abundant taxa, we found few species with high frequencies (*Haplotaxis gordioides*, *Marionina riparia*) as well as species found sporadically (*Pristina amphibiotica*, *Aulodrilus pluriseta*).

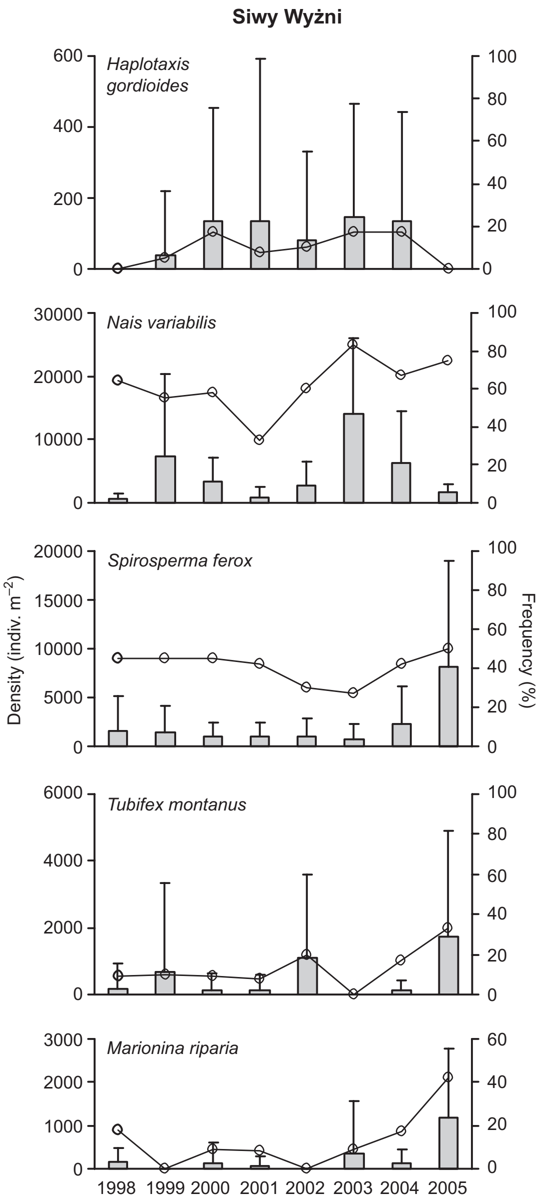
Discussion

In running, stagnant and subterranean waterbodies of the Polish Tatra Mountains, we found circa 60 species of oligochaetes (Dumnicka and

Table 5. Taxa collected from the ponds.

Species	Długi Gąsienicowy (number of individuals)	Siwy Wyżni (indiv. m^{-2})	Czerwony Pańszczycki (indiv. m^{-2})
Cognettia spp. juv.	1357	97	1061
Cognettia sphagnetorum	630**	24	260
Cognettia glandulosa	146	25	288**
Cernosvitoviella spp. juv.	921	178	153
Cernosvitoviella tatrensis	486*	171	246
Nais variabilis	4	4668**	2
Mesenchytraeus armatus	3	16	171*
Cognettia lapponica	50	–	18
Cernosvitoviella atrata	14	–	16
Cernosvitoviella carpatica	1	–	16
Stylodrilus spp. juv.	28	–	29
Marionina argentea	2	596*	–
Cognettia cognetti	1	–	–
Cognettia anomala	1	–	–
Achaeta sp. juv.	1	–	–
Nais pseudobtusa	1	–	–
Stylodrilus parvus	1	–	–
Eiseniella tetraedra	1	–	–
Spirosperma ferox	–	2179**	–
Tubifex montanus	–	531*	–
Marionina riparia	–	241*	–
Haplotaxis gordioides	–	80*	–
Buchholzia falax	–	38	–
Buchholzia sp. juv.	–	40	–
Pristina amphibiotica	–	8	–
Enchytraeus buchholzi	–	121	1
Henlea spp. juv.	–	8	16
Henlea perpusilla	–	–	143*
Tubifex tubifex	–	–	32
Aulodrilus pluriseta	–	–	16
Stylodrilus heringianus	–	–	1
Enchytraeidae gen. spp. juv.	7	1295	170
Tubificinae gen. spp. juv.	–	869	59

** species present in all years of the study.
* species present for more than 50% of the study period.



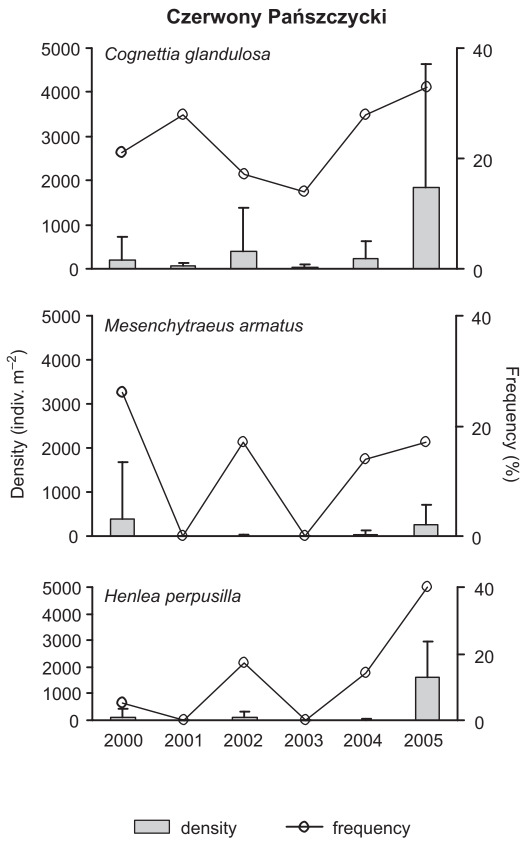


Fig. 7. Density and frequency changes for selected species in successive years of the study in Siwy Wyżni and Czerwony Pańszczycki.

Galas 2010), whereas in 29 ponds and lakes studied until now, there were only 33 species. In the three ponds under investigation, we noted as many as 26 oligochaete species. This proves the uniformity of oligochaete fauna composition in stagnant waterbodies of the Tatra Mts. Such low diversity is typical of high-mountain environments, e.g. Uzunov and Varadinova (2000) found 22 species in 28 lakes of the Rila Mountains, and Collado and de Mendoza (2009) identified 40 species in 82 Pyrenean lakes.

The results of the previous studies of the waterbodies located in the alpine zone of the Tatra Mts. (Table 6) show that in ponds, as well as in the littoral of lakes, few species prevailed. *Nais variabilis* seems to prefer non-acidified ponds (Šporka 1992) and lake littoral zones (Krno *et al*. 2006, Dumnicka and Boggero 2007) whereas the genera *Cernosvitoviella* and *Cognettia* appear to dominate in small, shallow ponds with a lower water pH (Table 6).

In each of the studied ponds, only a few species were found during the whole study period. Perhaps higher number of species lived permanently in these ponds but the absence of mature specimens from the genera *Cernosvitoviella* and *Cognettia* in the samples did not allow for the assembly of the complete list of species. The number of species caught in particular years varied strongly that does not necessarily mean that the number of species living there also changed so considerably given that with only single sampling a year some taxa could be overlooked. Among species occurring for a short time or in one pond only, are those typical of lowland waters (*Pristina amphibiotica*, *Aulodrilus pluriseta* and *Nais pseudobtusa*), soil species (*Buchholzia falax, Henlea perpusilla*) (Timm 2009) and rare species that could only be identified from mature specimens (*Cognettia cognetti*, *C. anomala*, *C. lapponica*, *Stylodrilus parvus*) (Kahl and Pilipiuk 2004). We wish to point out that a single year's sampling shows only dominating species, whereas long-term studies make it possible to determine almost the entire species composition, as well as its natural or anthropogenic changes. Another way to find the maximum number of species living in high-mountain waterbodies is to study a large number of lakes once a year (Uzunov and Varadinova 2000, Dumnicka and Boggero 2007, Collado and de Mendoza 2009). The fact that rare species

Table 6. Dominating oligochaete species in various Tatra ponds and lakes.

Dominating species	Ponds/lake littoral	pH	References
Cernosvitoviella spp. mainly *C. tatrensis*	Dwoisty Staw Wschodni & Zachodni	4.3–6.5	Kownacki *et al.* (2000) Dumnicka and Boggero (2007)
Cernosvitoviella tatrensis, *Cernosvitoviella* sp.	Mnichowy Staw I, II, IX	4.8–5.2	Dumnicka and Galas (2002), Kownacki *et al.* (2006)
Cognettia spp., *Cernosvitoviella tatrensis*	Mnichowy Staw V	4.8	Dumnicka and Galas (2002)
Cernosvitoviella atrata	Vyšné Terianske pleso	5.01	Krno *et al.* (2006)
Cernosvitoviella atrata	Okrúhle pleso	5.8	Krno *et al.* (2006)
Tubifex montanus, *Mesenchytraeus armatus*	Niżny Siwy Staw	7.0–7.7	Dumnicka and Galas (2002)
Nais variabilis, *Cernosvitoviella* spp. juv.	Zmarzły Staw Gąsienicowy	5.9**	Dumnicka and Boggero (2007)
Cognettia spp., *Nais variabilis*	Vyšné Račkove pleso	6.0	Šporka (1992), Krno *et al.* (2006)
Spirosperma ferox	Stredné Račkove pleso	–	Šporka (1992)
Nais variabilis	Velké Bystré pleso	7.28	Krno *et al.* (2006)
Spirosperma ferox, Tubifex tubifex	Druhé Roháčske pleso	6.7*	Šporka (1992)
Stylodrilus heringianus	Štvrté Roháčske pleso	6.1	Krno *et al.* (2006)
Nais variabilis	Zielony Staw Gąsienicowy	5.9–7.1	Kownacki *et al.* (2000)
Nais variabilis	Czarny Staw Gąsienicowy	6.2**	Dumnicka and Boggero (2007)
Nais variabilis	Zadni Staw Polski	6.1**	Dumnicka and Boggero (2007)
Nais variabilis	Nižné Terianske pleso	6.73	Krno *et al.* (2006) Čiamporová-Zat'ovičová *et al.* (2010)
Nais variabilis, *Cernosvitoviella tatrensis*	Czarny Staw pod Rysami	6.8**	Dumnicka and Boggero (2007)
Nais variabilis	Velké Hincovo pleso	6.85	Krno *et al.* (2006)
Nais variabilis	Velké Žabie pleso	6.49	Krno *et al.* (2006)
Cernosvitoviella atrata	Capie pleso	6.31	Krno *et al.* (2006)
Stylodrilus heringianus	Vyšne Wahlenbergovo pleso	6.26	Krno *et al.*(2006) Čiamporová-Zat'ovičová *et. al.* (2010)
Stylodrilus heringianus	Vyšné Temnosmrečinské pleso	7.19	Krno *et al.* (2006), Čiamporová-Zat'ovičová *et al.* (2010)

* mean water pH in 1978–1996 after Hořická *et al.* (2006)
** water pH after Stuchlik *et al.* (2006).

may be found in one or two lakes proves their presence in waters of a given mountain range.

Although abiotic conditions in high-mountain lakes are considered to be the most stable in late summer (Hořická *et al*. 2006), we found variations in water chemistry components: terrigenous (pH value, calcium and magnesium content) as well as anthropogenic ones (chloride, nitrate) from year to year. The values of these parameters seem to be affected by the amount of precipitation preceding the sampling date or the intensity of tourist activity (for Czerwony Pańszczycki). We assumed that the sum of water flowing into the ponds influenced not only the pond water level (mainly in Czerwony Pańszczycki and Długi Gąsienicowy) but also the organic matter content. In ultra-oligotrophic alpine lakes and ponds, organic matter is almost entirely of allochthonous origin (Dumnicka and Galas 2002, Galas and Gòrniak 2006). In Czerwony Pańszczycki, a significant correlation found between oligochaete densities (mainly belonging to the genus *Cognettia*) and the amount of organic matter suggests that oligochaetes might also have migrated (or could be washed) from the soil. This fact may have affected temporary changes in oligochaete density. We often observed individuals that reproduced by architomy (fragmentation and regeneration of one or both ends of the body), what is typical for low-temperature habitats (Chalupský 1992). In Siwy Wyżni, where the water level and sediment organic matter content fluctuated insignificantly, and where changes in oligochaete densities were not correlated with these two parameters, other factors influenced such changes in particular years. Another parameter which may affect the density of the *Nais variabilis* population is water temperature. In Siwy Wyżni, water temperature was the highest, this factor facilitates multiple asexual reproductions by paratomy (budding). In Czerwony Pańszczycki and Długi Gąsienicowy, where the temperature was low, we found *N. variabilis* sporadically. Its presence for only few years proves that the attempts to colonize these two ponds were unsuccessful. This species dominated in Pyrenean lakes, where temperature limited its occurrence as well as that of other Naidinae (Collado and de Mendoza 2009). Moreover, *N. variabilis* seems to prefer relatively stable environmental conditions, as do *Spirosperma ferox* and *Tubifex montanus*, which were usually found in stable conditions of deep parts of Tatra lakes (Hrabě 1939, Šporka 1992) and which numerously occurred in Siwy Wyżni.

Despite various sampling methods applied, the composition of oligochaete fauna and the prevailing species in each pond could be sufficiently identified. Taking two littoral samples with the kick method, as recommended in the "Protocol", seems to be somewhat dangerous for benthic fauna because it disturbed most of the littoral part of Długi Gąsienicowy, the largest of the three waterbodies studied. Moreover, our study did not reveal significant differences between data obtained with different methods. This method is more invasive than others and may decrease oligochaete populations in small waterbodies. Additionally, data from such qualitative samples cannot be used in certain statistic calculations, e.g. cumulative curves. We found that small corer samples taken in various part of the littoral gave better results without disturbing the habitat.

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