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Aquatic entomocoenosis in lotic ecosystems of the upper Vydra basin (Šumava National Park, Czech Republic)

Společenstvo vodního hmyzu v lotických ekosystémech povodí horní Vydry (Národní park Šumava, Česká republika)

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Abstract

Aquatic entomocoenosis in the upper Vydra basin (the Šumava National Park, Bohemian Forest) was studied. In the course of the season of 1997, at 10 sampling sites of the brooks Roklanský and Modravský, an extensive material of aquatic insects (more than 17 000 specimens) was collected and almost 60 insect taxa, including some rare species (e.g. *Rhitrogena loyolaea, Ecdyonurus submontanus, Amphinemura triangularis, Nemoura mortoni, Rhabdiopteryx neglecta, Siphonoperla montana* and *Chaetopteryx major*), were identified. A similar structure of the aquatic insect communities dominated by *Plecoptera*, *Trichoptera* and *Diptera* was observed in both streams investigated. The biodiversity and pH in the brooks Roklanský and Modravský ranged between D = 1.8-2.8, pH = 5.5-6.6 and D = 2.2-2.7, pH = 5.7-5.9, respectively. The biodiversity of aquatic insects of the brook Roklanský is highly correlated with pH values and both parameters generally increase towards downstream. A reverse development of biodiversity was observed in the brook Modravský. Some changes of the aquatic insect biodiversity and other biological characteristics at sampling sites, affected by the deforestation due to the bark beetle calamity are described. The results of previous biomonitoring of the aquatic entomocoenosis in the area studied are characterized and long-term changes in acidified aquatic biotopes are discussed.

Key words: aquatic insects, biodiversity, lotic ecosystems, acidification, deforestation

Introduction

The Šumava National Park, together with the Bavarian Forest, form an extensive Central European complex of international importance with high natural value (water sources, peatbogs, lakes of glacial origin, climax spruce forests). The Bohemian Forest is a very valuable refuge from the standpoint of the aquatic insect biodiversity. Soldán & al. (1996) consider altogether 337 species of aquatic insects in this area representing about 64% of the Czech Republic fauna and almost 40% of the Central European one. A number of aquatic insects belong to rare or endangered species and endemites of the Alps and Bohemian Forest.

Aquatic ecosystems are integral parts of the landscape and they sensitively react to methods of its exploitation. In the basin of certain surface water sources at higher elevations of the Bohemian Forest, the forests decline due to the bark beetle calamity and subsequent deforestation is observed. The part of the Bohemian Forest adjacent to the borderline is considerably affected (Skuhravý 1998). The disturbance of the natural biological function of the forest is manifested by a number of changes (in hydrology, biogeochemistry, energetics as

well as ecology) in the terrestrial and subsequently also in aquatic environment (Bormann & Likens 1979, Likens & Bormann 1995). Thus, it is possible to assume that the effect of deforestation will also be indirectly manifested in aquatic ecosystems by changes of the biota.

Material and methods

Samples were taken at 7 sampling sites of the brook Roklanský and at 3 sampling sites of the brook Modravský in the spring (May 20–24), summer (July 28–31) and autumn seasons (September 16–18) of 1997 by semiquantitative method (kicking technique) at the stream line as well as at sides of the streams investigated. Species and higher taxa of aquatic insects in question were determined according to keys by Rozkošný & al. (1980) and biodiversity was measured according to Shannon & Weaver 1963 (in Klem & al. 1990). Principal complementing physico-chemical analysis was conducted (temperature, pH and conductivity), however, pH values were measured only in the spring and summer seasons.

Description of study area

The brooks Modravský and Roklanský are situated in the source area of the river Vydra (river Otava watershed). The water basin investigated is situated at altitudes from 990–1200 m and it is characterized by the presence of numerous peatbogs and wet spruce forests. The river basin of both streams lies in the core zone and in the rest zone of the National Park and currently being affected by the forest decline and both direct and indirect effects of the deforestation. The last bark beetle calamity in the area of the Bohemian Forest was observed in 1992, and as large area as 2600 ha of the forest was already invaded by the bark beetle in 1997. In accordance to data by the Forest Administration Modrava maximum forest clear cutting was observed in 1996 (81 000 m^3 exploited).

The brook Roklanský (number of hydrological order 1-08-01-06 (IV), length of 13.8 km, average discharge 1.66 $m^3.s^{-1}$, see e.g. Vlček 1984) has its source in peatbogs on slopes of the Blatný Mt. and it conducts water from the complex of Modravské slatě. Almost the whole catchment area is unaccessible except for a part between Modrava and Javoří Pila. Altogether seven sampling sites (1–7) were selected on this stream (Fig.1): Roklanská hájenka, Roklanská slať, confluence with the brook Rokytka, confluence with the brook Novohuťský, confluence with the brook Javoří, Rybárna and Modrava. The stream bed average width ranges towards downstream between 1 and 6 m and average depth ranges between 0.3 and 1 m. The bottom is mostly stony (estimated substrate roughness – cobbles 90 %, boulders 5 %, sand and clay 5 %), except for the upper and two lower sampling sites, the substrate of which is formed by gravel (estimated substrate roughness – pebbles 95 %, boulders 3 %, sand and clay 2 %). Clear cutting of forest is implemented in the vicinity of the sampling sites Roklanská slať and Novohuťský, where a large-scale deforestation occurs at present. At certain sampling sites, there are islets of decaying forests, which already do not fulfill their biological role.

The brook Modravský (length of 8 km) is situated in the upper basin of the river Vydra (number of hydrological order 1-08-01-001 (III), length of 22.5 km, average discharge 4.13 $m^3.s^{-1}$ – Vlček 1984). This brook arises by a confluency of the brooks Březnický and Luzenský under Březník. The whole basin of the stream is accessible. Three sampling sites (8–10) were selected (Fig.1) in this stream. These are indirectly affected by clear cutting of the bark beetle infested wood (transport, storage): Březník, confluency with the brook Černohorský and Modrava. The bed width ranges between 2.5 and 5 m and the water depth ranges between 0.5 and 1 m. The mass decay of forest stands and subsequent large-area deforestation was

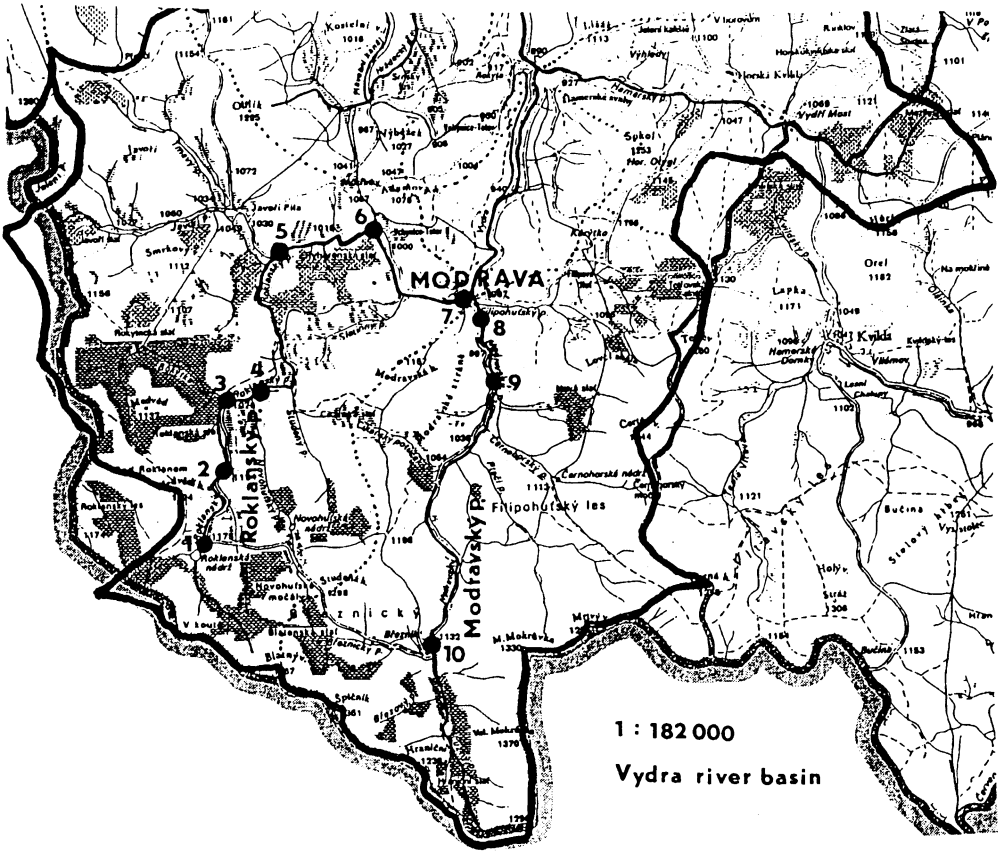

Fig. 1. – Schematic map of selected localities in the brooks Roklanský and Modravský.

observed particularly in the area Malá Mokrůvka and Černá Hora. In the vicinity of Březník, there was no considerable intervention in the non-functioning forest stands in the period of investigation.

Results and discussion

Seasonal aspects of the aquatic insects development in the streams

Aquatic insects (the orders Plecoptera, Ephemeroptera, Trichoptera, Diptera, and Coleoptera) represents dominant group of macrozoobentos taken at all the sampling sites of the brooks Roklanský and Modravský. Further representatives of the macrozoobentos (*Crenobia alpina*, *Gammarus fossarum*, *Niphargus aquilex*, *Pisidium* sp. and Oligochaeta) do not exhibit important abundance in the lotic ecosystems investigated.

At seven sampling sites of the brook Roklanský, total number of 12,507 individuals of aquatic insects were collected (Table 1), more than 50% of them being found during the spring season. From the standpoint of the number of individuals, the locality Javoří was the

Table 1. – Selected characteristics of aquatic insects in the brooks Roklanský and Modravský.

	total number of individuals	total number of taxa	average number of taxa
brook Roklanský			
hájenka	1 907	22	14
slať	2 026	19	11
Rokytka	2 013	26	17
Novohuťský	1 460	19	13
Javoří	2 601	25	18
Rybárna	1 197	22	16
Modrava	1 303	27	17
brook Modravský			
Březník	1 151	23	16
Černohorský	1 700	24	16
Modrava	1 834	24	14

richest one and, on the contrary, the locality Rybárna was the poorest one. Most taxa (prevalently genera) of aquatic insects were recorded at the downstream locality of the Modrava (27 taxa) and the lowest number (19 taxa) were found, on the contrary, at localities situated directly in the deforested areas (Roklanská slať and Novohuťský). Throughout the period investigated, Plecoptera form 45% and Diptera with Trichoptera 44% of the aquatic insects quantitative presentation (Fig. 2).

From the standpoint of seasonal occurrence of aquatic insects in the brook Roklanský (Fig. 2), it is obvious that in the spring, Plecoptera are dominant reaching up to 75% of the entomocoenosis. This group is particularly represented by the genus *Leuctra* forming particularly at upstream localities (Roklanská hájenka, Roklanská slať, Rokytka) about 50–60 % of the community. Similarly *Brachyptera seticornis* reaches almost 60% of individuals taken in the brook Novohuťský. At most of localities, subrecedent quantitative presentation of the genera *Siphonoperla* and *Protonemura* was observed. Principally, rather rare *Diura bicaudata* and the genera *Nemoura* and *Nemurella* occure, only at upstream localities, while *Amphinemura* sp. and *Rhabdiopteryx neglecta* were found mostly at middle localities. The latter species occurs quite rarely and only in this season. The second most numerous order Trichoptera is represented by the subfamily Drusinae (*Anomalopterygella* sp., *Drusus* sp., *Ecclisopteryx* sp.), occurring at all the profiles although being most frequent downstream. The subfamily Limnephilinae occurs at most localities and the genus *Apatania* is encountered at the locality Roklanská hájenka only in spring period. At most localities, Diptera are exceptionally represented by the genus *Dicranota* and by representatives of the families Simuliidae and Chironomidae. The presentation of the species *Atherix ibis* increases downstream. Of the Ephemeroptera, *Ameletus inopinatus* occurs at certain profiles. In summer, dominance of the Plecoptera disappears showing essential reduction or even elimination of main representatives of the whole entomocoenosis (including the genus *Brachyptera*). The Diptera dominate in summer and autumn, reaching about 50% of quantitative presentation. Of them, the Chironomidae occur most frequently and they form more than a half of the total number of the aquatic insects at certain upstream localities (Rokytka, Roklanská slať). In this period, the quantitative portion of the Ephemeroptera is considerably enhanced (27%), particularly represented by the genus *Baetis* (contrary to the genus *Ameletus* in spring), importance of which

particularly increases at middle and downstream localities. The genera *Siphlonurus, Ecdyonurus* and *Ephemerella* occur for the first time (the latter only at locality Modrava). In the autumn, the Diptera are still dominant, the Chironomidae showing a considerable portion of the total macrozoobentos quantitative presentation, particularly at upstream and middle localities of the brook Roklanský. The Ephemeroptera are replaced by the order Trichoptera, which is similarly taxonomically represented as in the earlier seasons. The Plecoptera remains still reduced, however, in addition to the genus *Leuctra*, *Brachyptera seticornis* starts to occur more frequently and the species *Perlodes microcephalus* appears for the first time.

At three localities of the brook Modravský, total of 4685 specimens of aquatic insects (Ta-

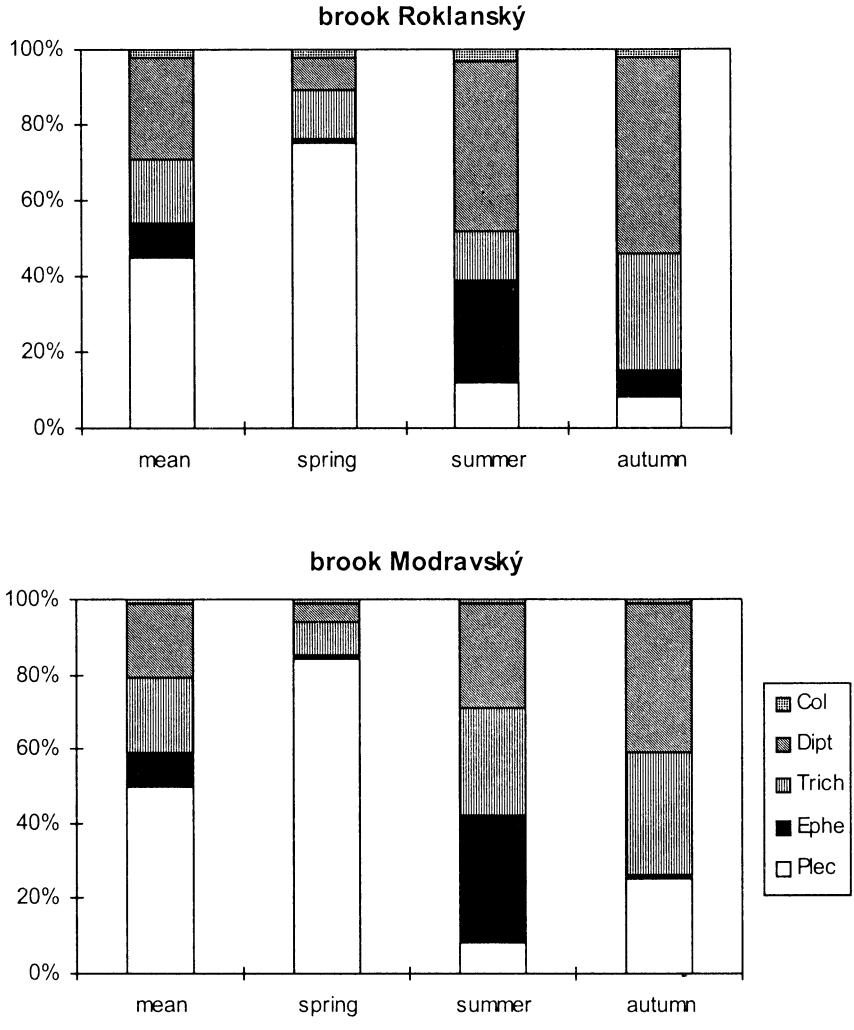

Fig. 2. – Structure of aquatic insect community in the brooks Roklanský and Modravský in different seasonal aspects. (Plec = *Plecoptera*, Ephe = *Ephemeroptera*, Trich = *Trichoptera*, Dipt = *Diptera*, Col = *Coleoptera*).

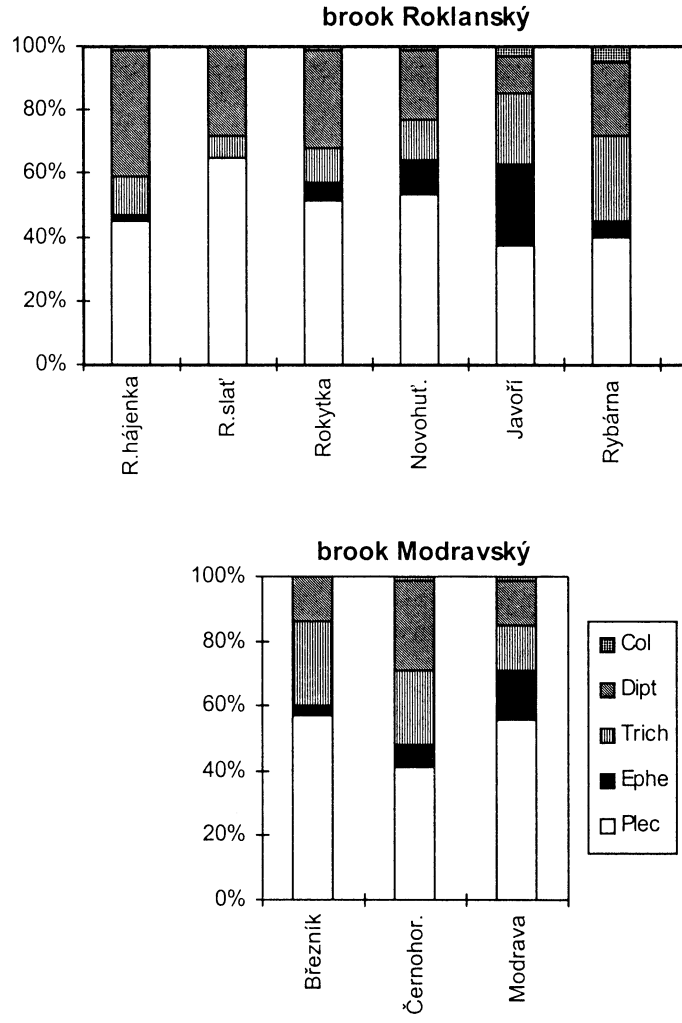

Fig. 3. – Structure of aquatic insect community in the brooks Roklanský and Modravský at different sampling sites. (Plec = *Plecoptera*, Ephe = *Ephemeroptera*, Trich = *Trichoptera*, Dipt = *Diptera*, Col = *Coleoptera*).

ble 1) were collected, a half of this number being taken in the spring. The downstream locality was the richest one and the upstream locality was the poorest one. At all localities, there is a similar number of taxa (23 to 24, mostly genera). The principal structure of the main groups of aquatic insects (Fig. 2) and numbers of the genera are, with a few exceptions, comparable to the brook Roklanský.

The Plecoptera are dominant reaching up to 84% of the entomocoenosis of the brook Modravský in the spring season (Fig. 2) with similar composition as in the brook Roklanský, however, the genera *Amphinemura*, *Nemurella* and *Rhabdiopteryx* were missing. The dominance of Diptera was already no more considerable, when in the summer season, they form, together with Trichoptera and Ephemeroptera, each order about 1/3 of the aquatic insects

quantitative presentation. The importance of the Plecoptera increases in the autumn (contrary to the brook Roklanský).

When investigating differences in the quantitative presentation of the aquatic insects in the brook Roklanský (Fig. 3), it is possible to see that Plecoptera become important in upstream and middle parts of the stream with reaching over 50% of the entomocoenosis in the sampling sites Roklanská slať, Rokytka and Novohuťský. Towards downstream, the percentage of Trichoptera and Coleoptera increases and in middle parts (the sampling sites Novohuťský and Javoří), it is possible to see an increase of the Ephemeroptera. In the general structure of particular localities of the brook Modravský (Fig. 3), towards downstream, it is possible to observe a percent increase of the Ephemeroptera and, on the contrary, decrease in the group Trichoptera. When comparing both streams, it is further possible to note a similar quantitative presentation of the aquatic insects with a dominance of the orders Plecoptera, Diptera and Trichoptera. The Ephemeroptera are represented relatively less frequently and they occur more significantly only in the summer. Differences between the two streams can, however, be observed, when comparing the development of particular groups of insects in different seasons of the year. In the summer and autumn, in the brook Roklanský, there is a decrease of the originally dominant spring order Plecoptera, whereas in the brook Modravský, this group becomes of importance in the autumn. In both streams, at most localities, the Plecop-

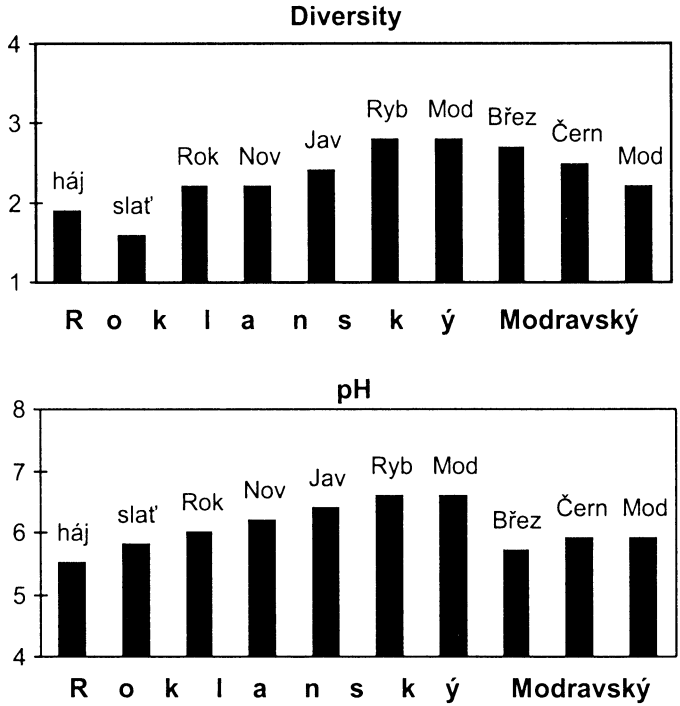

Fig. 4. – Average values of diversity of aquatic insects and pH on selected localities of the brooks Roklanský and Modravský. (sampling sites in the Roklanský stream – háj = Roklanská hájenka, slať = Roklanská slať, Rok = confluence with the brook Rokytka, Nov = confluence with the brook Novohuťský, Jav = confluence with the brook Javoří, Ryb = Rybárna, Mod = Modrava, sampling sites in the Modravský stream – Březˇ = Březník, Černˇ = confluence with the brook Černohorský, Mod = Modrava)

tera are richly represented by the genera and species *Brachyptera seticornis*, *Leuctra* sp., *Protonemura* sp. and *Perlodes microcephalus*. Further groups of aquatic insects are richly represented by the genus *Baetis* in both streams, representatives of the subfamilies Drusinae and Limnephilinae and further by representatives of the families Chironomidae, Simuliidae, *Atherix ibis* and *Dicranota* sp.

The diversity of the aquatic insects in the streams

The mean diversity of the aquatic insects at particular localities of the brook Roklanský ranges between 1.6 and 2.8, the average pH value being of 5.5 to 6.6 (Fig. 4). These two parameters principally increase towards downstream. At localities more affected by the deforestation, there is, however, a decrease of the insects biodiversity (Roklanská slať) or possibly a stagnation of this biological parameter (the sampling site Novohuťský). These two localities are also manifested by the lowest total and average numbers of taxa (Table 1).

The correlation between the aquatic insects diversity or possibly of the macrozoobentos diversity and pH values (Fig. 5) is significant in the brook Roklanský ($r = 0.898$ or 0.920, respectively, both relationships significant at a level < 0.001). No analogous relationship was recorded between the biota and conductivity, since the average values of this parameter varied within a very narrow range (C = 18 to 20 $\mu S.cm^{-1}$). The earlier investigations demonstrated significant relationships between the biodiversity of insects and pH as well as conductivity values in particular streams of the Vydra and Křemelná water basin (Růžičková & al. 1997, Růžičková 1998). This research, however, included selected streams with a considerable diverse conductivity and pH values, respectively (C = 17 to 41 $\mu S.cm^{-1}$ and pH 4.9 to 6.3).

In the brook Modravský, the average diversity of the aquatic insects at particular localities ranges between 2.2 to 2.7 and the pH values are in a narrow range of 5.7 to 5.9 (Fig. 4). There is a decrease of the diversity towards downstream. The conductivity values are similar to those in the preceding stream. The total as well as average numbers of taxa recorded (Table 1) are relatively similar at all localities, which is probably also associated with a relative uniformity of biotopes of this stream.

When comparing the aquatic insects diversity in the two streams, it is obvious that the brook Roklanský differs from the brook Modravský by larger differences in the biodiversity of particular localities and lower average diversity (D = 2.3 against 2.5). The average pH values are, however, higher in this stream than in the brook Modravský (pH 6.2 against 5.8). In spite of this, the total as well as average number of taxa of aquatic insects in both streams are comparable. In particular seasons, the general diversity and the mean number of taxa in each stream are characterized by similar values, however, with larger or smaller deviations at particular localities.

The diversity of the aquatic insects is a suitable parameter when considering long-term changes of biotopes (Landa & al. 1997). In the earlier research in 1994 to 1996 (Růžičková & al. 1997, Růžičková 1998), in the brooks Modravský as well as Roklanský (locality Modrava), a lower average diversity (D = 2.0 and 2.2, respectively) than in the other streams of the Vydra basin was found. The diversity values established at the locality Modrava in 1997 in both streams were, however, higher than in the preceding years (D = 2.2 and 2.8, respectively). This difference may also be, in addition to interannual variations, affected by the sampling method in 1997 when the sampling procedure was also implemented, in addition to the stream line, in the zone adjacent to the stream side flowing more slowly. In spite of the fact that the general diversity in the brook Roklanský was lower than that in the brook Modravský in 1997, the situation at the downstream locality Modrava was opposite, which is essentially associated with the increase of the diversity and pH towards downstream in the brook

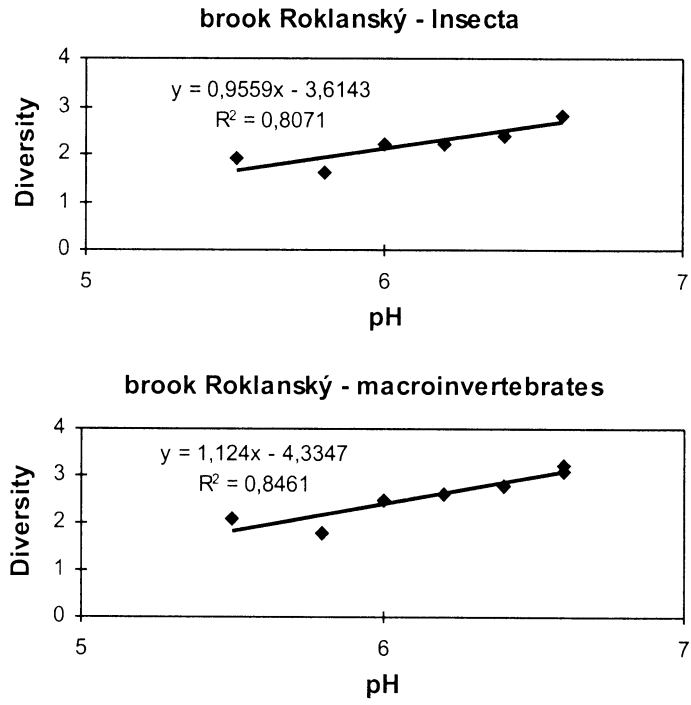

Fig. 5. – Relationship between diversity and pH in the brook Roklanský (linear regression, r = 0.898, sig. < 0.001 and r = 0.920, sig. < 0.001).

Roklanský and with an opposite trend of the biodiversity development in the brook Modravský.

The species composition of the aquatic insects

The aquatic entomocoenosis is very rich in the area of the Bohemian Forest. According to Soldán & al. (1996) the richest are the Trichoptera (156 species of the 220 species known from the Czech Republic). The orders Ephemeroptera (91 species in the Czech Republic) and Plecoptera (108 species in the Czech Republic) are each represented more than 60 species in the Bohemian Forest. Most species occur just in the territory of the Šumava National Park.

In the course of the research carried out in 1997, based on identification prevalently to species or genera, almost 60 taxa of aquatic insects were found (Table 2), 37 of them being identical for both streams. The taxonomically richest were Trichoptera and Plecoptera. The brook Roklanský was richer in species represented in particular groups of aquatic insects (13 Plecoptera, 8 Ephemeroptera, 16 Trichoptera, 10 Diptera and 8 Coleoptera). In the brook Modravský, there is an obvious reduction of representatives in almost all the groups (10 Plecoptera, 4 Ephemeroptera, 12 Trichoptera, 10 Diptera and 4 Coleoptera) which is probably associated with a relative uniformity of the localities investigated as well as long-term lower pH values in this stream.

In the brook Modravský, total of 40 taxa of aquatic insects were found, and the rare findings of *Rhitrogena loyolaea* (Ephemeroptera), *Plectrocnemia conspersa* (Trichoptera) and

Table 2. – Taxonomic review of aquatic insects in the brooks Roklanský and Modravský.

PLECOPTERA	TRICHOPTERA	DIPTERA
Amphinemura sulcicollis	*Allogamus auricollis*	*Acanthocnema glaucescens*
Amphinemura triangularis	*Anomalopterygella chauviniana* *	*Atherix ibis* *
Brachyptera seticornis *	*Apatania fimbriata* *	Ceratopogonidae *
Diura bicaudata *	*Brachycentrus montanus* *	*Dicranota* sp.
Leuctra nigra *	*Drusus discolor* *	Chironomidae *
Leuctra sp. *	*Drusus annulatus* *	*Limnophila submarmorata*
Nemoura mortoní *	Drusinae juv.	*Pedicia rivosa*
Nemoura sp. *	*Ecclisopteryx madida* *	*Pericoma* sp.
Nemurella pictetí *	*Halesus* sp. *	Simuliidae *
Perlodes microcephalus *	*Chaetopterygopsis maclachlani*	*Tipula saginata*
Protonemura sp. *	*Chaetopteryx* cf. *major*	*Tipula* sp. *
Rhabdiopteryx neglecta	*Chaetopteryx villosa*	
Siphonoperla montana	*Plectrocnemia conspersa* *	
	Potamophylax cf. *latipennis*	
EPHEMEROPTERA	*Potamophylax* sp. *	COLEOPTERA
Ameletus inopinatus	*Rhyacophila* sp. *	*Elmis* sp. *
Baetis alpinus *	*Silo pallipes*	*Hydrovatus cuspidatus*
Baetis vernus		*Hydrobius fuscipes*
Baetis sp. *		*Ilybius* sp.
Ecdyonurus submontanus		*Limnius perrisi perrisi* *
Ephemerella ignita *		*Oreodytes sanmarkii*
Ephemerella sp.		*Scirtes* sp.
Rhitrogena loyolaea		*Stictotarsus* sp.
Siphlonurus lacustris		

Note: * also Bavarian Forest (BAUER & al.1988).

Pericoma sp. (Diptera) were encountered only in this stream. In the brook Roklanský, total of 55 taxa of aquatic insects were determined and the species *Amphinemura triangularis*, rarely also *Nemurella picteti* and *Rhabdiopteryx neglecta* (Plecoptera); furthermore *Baetis alpinus, Ephemerella* sp., rarely *Ecdyonurus submontanus* and *Ephemerella ignita* (Ephemeroptera); and furthermore *Chaetopteryx* cf. *major, Potamophylax* cf. *latipennis, Silo pallipes* (Trichoptera); rarely *Acanthocnema glaucescens* (Diptera); *Limnius perrisi perrisi* and rarely *Hydrobius fuscipes, Scirtes* sp. and *Stictotarsus duodecimpustulatus* (Coleoptera) occurred only there.

In addition to representatives of the Plecoptera specified in Table 2, the species *Capnia vidua, Chloroperla tripunctata* and the Hercynian endemite *Isoperla goertzii* were also recorded in both streams at the locality Modrava in the past (RŮŽIČKOVÁ 1998). SOLDÁN (1996) also documents the former species from the stream Modravský as a current finding and also the occurrence of last species was recently (in the 1980's) reported from the Vydra basin. Further species from Ephemeroptera and Plecoptera recorded in 1997 are almost all reported by SOLDÁN & al. (1998) for the Otava basin during the last years. On the contrary, some species have not been long demonstrated. This is particularly *Amphinemura triangularis* (the brook Roklanský) which was reported from the area of the Modrava in the course of the 1920's and

furthermore the rare species *Nemoura mortoni* (both streams) and the Alpine endemite *Siphonoperla montana* (currently all the localities of both streams). These two species have been last recorded in the 1960's in the Bohemian Forest (SOLDÁN 1996). The occurrence of the species *Rhabdiopteryx neglecta* (the brook Roklanský) has not yet been documented from the area of the Bohemian Forest (SOLDÁN & al. 1998). Also the species *Chaetopteryx major* (Trichoptera) has been last observed in the 1920's (SOLDÁN & al. 1998). Further unique findings in 1997 in both streams are *Siphlonurus lacustris, Apatania fimbriata* and *Pericoma* sp.

SOLDÁN (1996) presents as common species in the Bohemian Forest area *Brachyptera seticornis, Leuctra nigra, Perlodes microcephalus, Nemurella picteti, Amphinemura sulcicollis* and, on the contrary, as a rare species *Diura bicaudata*. On the other hand, in 1997, the *N. picteti* was relatively rare and *D. bicaudata* occurred relatively frequently. From localities at an altitude above ~1000 m a.s.l., which are partially comparable with the streams studied in our work (the brooks Filipohuťský – Filipova Huť and Hamerský – Horská Kvilda), SOLDÁN & al. (1998) present the occurrence of 18 and 30 species, respectively, of the Plecoptera and 4 and 18 species, respectively, of the Ephemeroptera. Our findings agree e.g. in the species *Amphinemura sulcicollis, Ameletus inopinatus, Baetis alpinus* and *Baetis vernus, Leuctra alpina, Ephemerella ignita*. NOVÁK (1996), based on collecting imagines of the Trichoptera, presents from the Vydra basin almost all the species found in the present study (except for the *Chaetopteryx major*). Common species in the Bohemian Forest area are *Apatania fimbriata, Chaetopteryx villosa, Allogamus auricollis, Ecclisopteryx guttulata, Odontocerum albicorne, Micrasema longulum* and 3 species of the genus *Rhyacophila*. In the area of Modrava (the river Vydra and the brook Filipohuťský), the author documents 9 species (*Allogamus auricollis, Chaetopteryx villosa, Chaetopterygopsis maclachlani, Drusus annulatus, Drusus discolor, Anomalopterygella chauviniana, Ecclisopteryx madida, Apatania fimbriata, Silo pallipes*) which agree with our findings. In the past, the species *Notidobia ciliaris* and *Odontocerum albicorne* were also recorded in the Vydra basin (RŮŽIČKOVÁ 1998).

The taxonomic structure of the aquatic insects (Plecoptera, Ephemeroptera, Trichoptera, Diptera and Coleoptera) in both streams of the area of the Šumava National Park (Table 2) can be compared with BAUER & al. (1988), who implemented a similar research in the area of the Bavarian Forest. Total of 28 identical taxa were recorded for the two areas, 27 taxa did not occur in the Bavarian Forest (Table 2). The agreement was achieved in 9 species of the Ephemeroptera (3 identical), 11 species of the Diptera (5 identical) and 8 species of the Coleoptera (only 2 identical). Of the Plecoptera, we recorded 13 representatives against 20 (9 identical) and of the Trichoptera 16 representatives against 33 (10 identical).

From the chorological standpoint according to SOLDÁN & al. (1996) and SOLDÁN & al. (1998), we observed certain species of South-Central European origin (*Rhabdiopteryx neglecta, Siphonoperla montana, Amphinemura triangularis, Brachyptera seticornis*, in 1998 also *B. trifasciata*) and of Atlantic-mediterranean origin (*Anomalopterygella chauviniana* and *Ecclisopteryx guttulata*). Findings of the species *Isoperla goertzii* (a hercynian endemite) and *Siphonoperla montana* (an Alpine species) have high importance.

The effect of abiotic and biotic conditions in the streams on the aquatic entomocoenosis

In the past, both streams, in comparison with the other streams in the Vydra basin, demonstrated considerably lower average pH values (RŮŽIČKOVÁ 1998). During the spring snow melting, decreases of pH values down to < 4.5 were observed. These episodic decreases of pH are, in addition to temperature, a considerable environmental factor determining the occurrence and emerging of the acidotolerant overwintering population of the aquatic insects.

The aluminium concentration in water of streams in the spring season can be even as high as 700 $\mu g.l^{-1}$ (Růžičková & al. 1997). During more frequent or long-term decreases of pH values, enhanced concentrations of dissolved aluminium can exert a toxic influence on the aquatic biota. A similar decrease of pH was also exceptionally observed in the autumn after strong rain precipitations.

The acidification considerably affects the structure of the aquatic insects with changes in the dominance of particular groups. In both streams, representatives of Plecoptera, Diptera and Trichoptera are most abundant and Ephemeroptera are reduced. The differences can also be observed in streams with different degrees of the acidification, where the abundance of the Ephemeroptera furthermore decrease and that of the Diptera, on the contrary, increase. There is also a typical reduction of the number of taxa and decrease of the aquatic insects biodiversity (Růžičková 1998). Some representatives of aquatic insects, however, exert a certain tolerance of the spring episodic pH decreases, as e.g. *Brachyptera seticornis, Leuctra alpina, Isoperla goertzii* and some species of the genus *Protonemura,* relatively acidotolerant species being e.g. *Siphonurus lacustris, Ameletus inopinatus*, *Diura bicaudata* and also certain species of the genus *Amphinemura*. Landa & al. (1997) consider the acidification as one of important factors in the extinction of the Plecoptera. In streams of certain mountainous areas, it is the main factor saving the biodiversity of this group of aquatic insects (Soldán & al. 1998).

The two investigated streams are also different from the other streams of the Vydra basin, in addition to low pH and conductivity values, by lower contents of basic cations, chlorides, sulfates, zinc and cadmium and, on the contrary, by higher COD_{Mn} and, particularly in the brook Modravský, also by concentrations of nitrates and aluminium (Růžičková & al. 1999, Růžičková & al. 2000). Low values of the alkalinity and hardness are also typical for both streams. For example in 1996 to 1998, in both streams (locality Modrava), the mean values of the conductivity, nitrate concentrations and chloride concentrations were at most of 21.1 $\mu S.cm^{-1}$, 2.7 $mg.l^{-1}$ and 0.6 $mg.l^{-1}$, respectively, however, the COD_{Mn} were as high as 8.3 $mg.l^{-1}$ and those of phosphates were of 0.03 $mg.l^{-1}$ (particularly in the brook Roklanský). Sulfate values determined in 1998, do not exceed in average 2.1 $mg.l^{-1}$ and concentrations of basic cations do not exceed 2.5 $mg.l^{-1}$. Both streams are unpolluted or only weakly polluted by biodegradable organic matter and are characterized by oligosaprobic conditions (average saprobic indices do not exceed S = 1.4).

Autochthonous food resources for macroinvertebrate consumers in both streams include periphyton, detritus and other animals. Consumers can be assigned to feeding guilds or functional groups. Functional analysis of invertebrate feeding is based on morphobehavioral mechanisms of food acquisition. If the functional feeding groups concept (Allan 1995, Hodovský & al. 1999) is applied in investigated lotic ecosystems, then we can observe that the Plecoptera and Trichoptera were represented in all functional feeding groups with prevalence of shredders (coarse particulate organic matter consumers) and grazers (periphyton feeders). Predators and collectors (fine particulate organic matter consumers) occurred less frequently. All representatives of the Ephemeroptera were collectors-gatherer and grazers. Determined species and genera of the Diptera were represented prevalently by predators (with some exceptions). The Coleoptera had two different feeding strategies – grazers and predators. Functional approach mentioned above has some limitations (e.g. food availability, flexibility of many taxa in their feeding strategy, feeding changes in different age and size).

Fishes are the major vertebrate predators in food webs of many aquatic ecosystems. *Salmo trutta* was recorded only in less acidified brook Roklanský (locality Modrava).

Within the scope of a regular biomonitoring program in 1996 to 1998, which is implemented every year in three seasons, an increase of average values of pH in both streams was ob-

served (the brook Modravský: 4.7 – 5.4 – 5.6, and the brook Roklanský: 5.5 – 6.2 – 6.4). A similar increase was also observed in further streams of the Vydra basin. In the mountainous area of the Bohemian Forest, these are probably consequences of simultaneous action of several environmental factors (decrease of the atmospheric deposition, consequences of the bark beetle calamity and deforestation, increasing loading particularly of downstream localities by recreational activities). For example in the brook Roklanský, at downstream localities, very high phosphate concentrations were determined during summer sampling in 1998, which exceeded the value of 0.10 mg.l^{-1} (Růžičková & al. 1999, Růžičková & al. 2000). The bottom of this stream is, in contrast to the brook Modravský, richly covered with mosses and algae. From the point of view of the diversity of primary producents, the brook Roklanský is, however, rather poor (Zahrádková 1996, Mánek 1998).

It is of a high probability that in the short-term, however, also long-term future, the above mentioned environmental factors will considerably affect the development of the biota in both streams.

Conclusion

Based on the results of the research it can be stated that the aquatic entomocoenosis is an important indicator of the integrity of aquatic and also adjacent terrestrial environment. The structure and diversity of aquatic insects are suitable parameters in considering short-term as well as long-term, natural as well as antropogenously caused changes of aquatic biotopes. With respect to the unique nature and sensitivity of aquatic ecosystems, the strict protection of aquatic as well as terrestrial ecosystems remains as an important priority of the sustainable development in the Šumava National Park.

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