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STRUCTURE AND POPULATION DYNAMICS OF *PTEROSTICHUS* SPP. BEETLES (*COL. CARABIDAE*) IN THREE TYPES OF WETLAND

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Abstract - This study presents research on communities of *Pterostichus* spp. beetles found in 2001 and 2003 in three types of wetland: elm and ash riparian forest (RF), poplar monoculture (P) and extensively managed meadow (M). All sample plots were located near the city of Bydgoszcz (53°, 9'N18°E) on the Vistula River floodplain. During both years, 11 species of genus *Pterostichus* spp. were found. In 2001, from all sample plots 886 beetles were collected; in 2003, 5 963. In both years, most specimens came from plot RF (636 in 2001 and 3 544 in 2003). From plot P, 1 862 specimens of *Pterostichus* spp. beetles were collected and from plot M, 807 specimens. No statistically significant influences of the marshland habitat type and year of research on communities of *Pterostichus* spp. beetles were revealed.

Key words: Extensively managed meadow, flood plain, poplar monoculture, *Pterostichus*, riparian forest

INTRODUCTION

In Europe, the genus *Pterostichus* comprises 240 species (Trautner and Geigenmüller. 1987), of which 40 are found in Poland, 21 species of which are found in the Wielkopolsko-Kujawska Lowland (Burakowski et al., 1974).

Many species from this genus have high or moderate preferences for humidity (Leśniak. 1987), and therefore these beetles are frequently recorded in the *Carabidae* communities captured on flood plains (Olejniczak, 1998; Huruk, 2003; Sienkiewicz, 2003).

Flood plains are associated with meandering and naturally flowing rivers. Small watercourses are a permanent feature of the landscape in Poland, although large non-engineered rivers are generally rare in Europe today. Human pressure resulting in river engineering has altered most of the riverside ecosystems into farming land, which is less valuable to nature. Today, riparian forests, which in the temperate climate zone are the equivalent of rain forests, cover only 5% of their primary surface area (of this, mature forms of riparian forests account for only 1%) (Tomiałojć and Dyrcz, 1993).

The purpose of this study was to identify seasonal changes in the number of species from the genus *Pterostichus* captured in three types of wetland: elm and ash riparian forest *Ficario-Ulmetum minoris* (RF), poplar monoculture (P), and extensively managed meadow (M).

Study area

The study was conducted in three areas located on the Vistula River flood plain, near Bydgoszcz city (53°9'N, 18°E, Kujawsko-Pomorskie province, Poland): (1) The Wielka Kępa nature reserve (RF)

established in 1953 to protect a fragment of a riparian forest in the lower Vistula valley, on the right riverbank, near Ostromecko village. The nature reserve covers a narrow strip of forest (27.61 ha) that stretches along the Vistula 350-400 m from the riverbed. A considerable section of the reserve on the Vistula side adjoins old riverbeds with planted poplar or poplar and ash industrial forests located between the nature reserve and the riverbed. Patches of industrial forests are separated by unused meadows. On the eastern side, the Wielka Kępa reserve borders an open area, which has been recently converted from heavily used meadows into plowland. The reserve surface is flat with drops not exceeding 1.5 m of relative height. Rich soils (medium-dusty fen soils) of the reserve are covered by elm and ash riparian forest, *Ficario-Ulmetum minoris* Matuszkiewicz (2001). The tree stand of this habitat includes European ash, field elm, the pedunculate oak and an admixture of black alder, fluttering elm, white poplar, the white and crack willow, European pear, crab apple and field maple among others. The understory layer primarily includes the common dogwood, black elder, bird cherry and ash brushwood. The flora of a forest floor is dominated by ground ivy, lesser celandine, ground elder, stinging nettle, and also small balsam, at the end of July. Starting in June, the plants of the forest floor are covered by cleavers.

The poplar monoculture (P) was established on an area of a former riparian forest habitat, which is confirmed by the species composition of the understory and forest floor. This area is located behind the old riverbeds, which separate it from the Wielka Kępa reserve, and it borders the meadows.

The poplar plantation includes a approximately 50-year-old uniform tree stand formed by black poplars with admixtures of other poplar species and their hybrids similar to the North American balsam poplar. The understory layer includes scarce bushes, for example, the common dogwood and common hawthorn; the forest floor is covered by grass and includes the giant fescue, goldenrod, cleavers and stinging nettle.

The extensively managed meadow area (M) is located between the Vistula riverbed and the poplar plantation and includes an open grassy land with scarce willow saplings.

In addition to various grass species, the most common plant species include dewberry, common comfrey, common sorrel, and numerous thistles. During the vegetative season, some of the mentioned species reach the height of 1.5-2 m.

During periods with high water level, particularly in the early spring, a large part of the described area is often flooded with water covering the ground for 12-15 days on average; however, this period, particularly in the case of the Wielka Kępa reserve, may last up to a month.

MATERIALS AND METHODS

The study was carried out in 2001 and 2003 during the vegetation season for 6 months (from May, after the retreat of Vistula floodwaters, to October). In August 2001, no beetles were captured due to flooding. Beetles were captured using one litre glass jars (Barber pitfall traps), without bait or insect preservation liquid. In total 90 traps were placed, 30 on each study site (5 traps on each of the 6 sites). On each site, traps were placed in the ground in one line, with about a 3 m distance between them. When jars were destroyed at a given site, the number of beetles captured in the remaining traps was calculated for the initial number, i.e. 5 traps, and the result was rounded to an integer. When the jars were filled with water after precipitation, the captured material was drained on a sieve to collect even the smallest individuals.

The comparison between the communities of beetles from the genus *Pterostichus* captured in different habitats and study years was carried out using ANOVA variance analysis. We also calculated the dominance index (D %), Renkonen index (Re %), and Shannon-Wiener index (H), as well as alpha, beta and gamma diversity (N) (according to Hill's rule (1973)). To ensure the equality of weight for all captured species we adopted q=1 (Głowacki, 2009).

Table 1. Abundance of *Pterostichus* spp. beetles communities collected in three types of wetland – elm and ash riparian forest (RF), poplar plantation (P), extensively managed meadow (M) – in 2001 and 2003

	2001				2003			
species	RF	P	M	total	RF	P	M	total
Pterostichus cupreus (L.)	0	1	39	**40**	1	0	17	**18**
Pterostichus coerulescens (L.)	0	0	4	**4**	0	0	31	**31**
Pterostichus vernalis (Panz.)	0	1	4	**5**	2	0	9	**11**
Pterostichus oblongopunctatus (Fabr.)	151	55	3	**209**	99	30	1	**130**
Pterostichus niger (Schall.)	174	10	16	**200**	1819	1519	368	**3706**
Pterostichus vulgaris (L.)	262	19	36	**317**	1594	174	197	**1965**
Pterostichus anthracinus (Ill.)	38	6	11	**55**	21	2	14	**37**
Pterostichus minor (Gyll.)	1	0	0	**1**	0	0	0	**0**
Pterostichus nigrita (Fabr.)	1	1	1	**3**	1	1	1	**3**
Pterostichus diligens (Sturm)	0	0	3	**3**	0	0	2	**2**
Pterostichus strenuus (Panz.)	9	28	10	**47**	7	15	38	**60**
total	639	121	129	**889**	3544	1741	678	5963

The value of gamma diversity (N gamma) was obtained using the multiplicative partition with respect to the habitat closest to natural, i.e. *Ficario-Ulmetum minoris*.

RESULTS

The highest number of *Pterostichus* spp. beetles (4 180 individuals) was captured in the ash and elm riparian forest (RF), 1 862 beetles were captured in the poplar monoculture (P), and the lowest number of beetles (807) were found on extensively managed meadows (M) (Table 1).

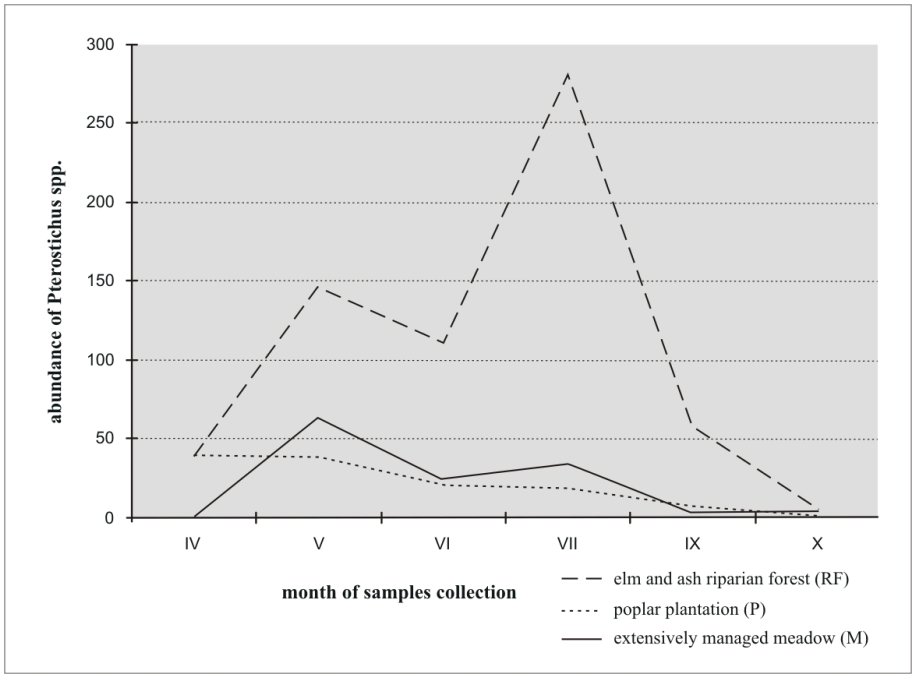
We found no statistically significant effect of habitat type on the number of captured beetles (ANOVA $F_{habitat}$=1.15, p=0.32).

In 2001 the number of captured individuals was almost seven times lower in comparison to 2003 (Table1), but the ANOVA test did not confirm any statistically significant difference between the numbers of beetles captured in these two study years ($F_{study\ year}$=3.34, p=0.07). However, differences were close to the limit of statistical significance.

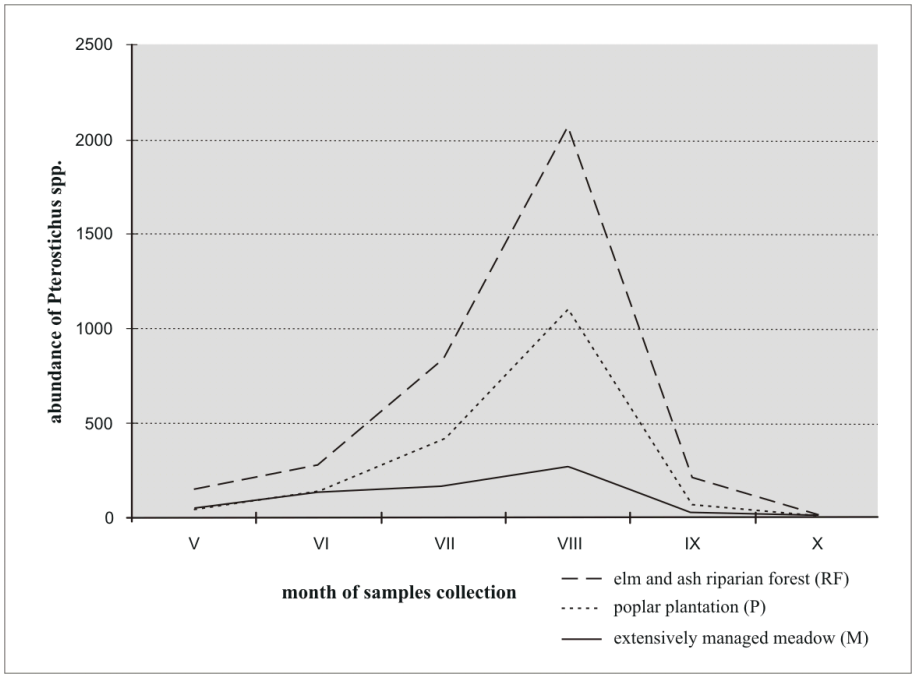
In total, during both study years 11 beetle species from the genus *Pterostichus* were captured in all the study sites. The lowest diversity was found for the material collected in 2003 in the poplar monoculture (6 species), and the highest number of species was recorded on meadows, both in 2001 and 2003 (Table1).

Another diversity pattern was obtained by the comparison of Shannon-Wiener (H), Simpson (D), and alpha diversity (N1alpha) indices calculated for the communities of *Pterostichus* spp. beetles captured in different habitats. The highest values of these indices were obtained for material captured in the poplar monoculture in 2001 (H=1.83; D=0.79; N1alpha=6.23) and in 2003 (H=1.26; D=0.61; N1alpha=3.5). The lowest diversity was recorded in 2001 for the communities of beetles from the riparian forests in the nature reserve (H=1.31, D=0.69; N1alpha=3.7) and in 2003 for beetles captured on the meadows (H=0.47, D=0.23; N1alpha=1.6) (Table 2).

The study material obtained in 2001 was characterized by higher biodiversity than the material cap-



1a. Abundance of *Pterostichus* spp. beetles collected in three types of wetland – elm and ash riparian forest (RF), poplar plantation (P), extensively managed meadow (M) – in 2001



1b. Abundance of *Pterostichus* spp. beetles collected in three types of wetland – elm and ash riparian forest (RF), poplar plantation (P), extensively managed meadow (M) – in 2003

Table. 2 Species diversity indexes – Shannon-Wiener (H) and Simpson (D) and alpha (N1 alpha), beta (N1beta) and gamma (N1gamma) biodiversity calculated for *Pterostichus* spp. communities collected in three types of wetland: elm and ash riparian forest (RF), poplar plantation (P) and extensively managed meadow (M) in 2001 and 2003

2001	H	N1alpha	N1beta	N1gamma	Simpson D
RF	1.31	3.706174			0.696
P	1.83	6.233887			0.795
M	1.47	4.349235			0.707
RF+P+M	1.61		5.002811		
RF(RF+P+M)				18.5	
2003					
RF	0.85	2.339647			0.534
P	1.26	3.525421			0.615
M	0.471	1.601595			0.229
RF+P+M	0.88		2.4109		
RF(RF+P+M)				5.61	
2001+2003					
RF	0.974	2.648517			0.572
P	1.154	4.26738			0.679
M	0.663	1.940605			0.312
RF+P+M	1.053		2.866		
RF(RF+P+M)				3.02	

tured in 2003 (Table 2). In addition, beta diversity, reflecting the species turnover between study sites, and gamma diversity, had higher values in 2003 (Table 2).

Among the captured beetles, *P. niger* and *P. melanarius*, classified by Leśniak (1987) as the Euro-Siberian element of carabids in Poland, were the most numerous species regardless of study site. Both these species together accounted for 90.36% of all captured individuals.

The number of *Pterostichus* spp. beetles changed within the vegetation season. In 2001, the highest number of individuals was captured in May. In June there was a decrease in the population followed by a peak in July, and then the number gradually decreased, reaching minimum level in October (Fig.1a). These changes were very clear in *Ficario-Ulmetum minoris* (RF) and on the meadows (M). A decreasing trend was found in the poplar monoculture (P) and it lasted from May to October. In 2003, the population of *Pterostichus* spp. beetles gradually increased to reach its peak in August, and declined after that, attaining minimum level at the end of the vegetation season (Fig.1b).

The comparison of the communities of beetles from the genus *Pterostichus* living in all study sites revealed a high value of the Renkonen index: 59.42% for RF vs. M, 63.53% for RF vs. P and 61.42% for P vs. M.

The beta diversity (N1beta) reflecting the species turnover between habitats was two times higher in 2001 and accounted for 5 in 2001 and 2.41 in 2003 (Table 2).

DISCUSSION

Fluctuations in the number of *Pterostichus* spp. beetles may be caused by different factors, such as mi-

gration along the humidity gradient, migration between habitats of different size, competition between species preferring similar ecological niches, or high plasticity of the reproductive cycle (Šustek, 1995).

In our study, seasonal changes in the number of *Pterostichus* beetles were mainly determined by the two most frequently captured species, i.e. *P. niger* and *P. melanarius*, which are widely distributed mesophilous carabids, in zoogeographic terms representing the Euro-Siberian element Leśniak (1987).

The very frequent occurrence of *P. niger* and *P. melanarius* in the nature reserve, and their infrequent presence on meadows, could have resulted from the differences between the soil fertility in the studied habitats. As reported by Šustek (1995), *P. niger* is highly dependent on plant cover and humidity level, preferring ecosystems on more fertile soils.

The Wielka Kępa nature reserve is a very humid habitat, as result of factors such as evaporation and infiltration of water from old riverbeds, considerable shade created by canopies, and the presence of a large number of decaying tree stumps also retaining water. Because of this, soils in the nature reserve are very wet, and this is considered the main factor affecting the population size and diversity of *Carabidae* (Šustek, 1994; Skłodowski, 2003). Even species widely regarded as eurytopic, including *P. niger* or *P. melanarius*, migrate along the humidity gradient and choose, whenever possible, wetter habitats (Šustek, 1995). *Pterostichus niger* is classified as a forest species, and this explains its presence in the nature reserve. On the other hand, *Pterostichus melanarius* is classified as an open-area species (Lindroth, 1974), and despite this, a higher number of its individuals were captured in riparian forest and poplar monoculture instead of meadows.

For many years, management and forestry activities have been abandoned in the nature reserve, and hence there is a large amount of organic matter deposited on the forest floor. Dead wood creates a habitat for various groups of invertebrates (Buchholz and Ossowska, 1995; Kaila et al., 1994; Schiegg, 1993), which are a potential source of food for predators, including those representing the *Pterostichus* genus. The two most frequently captured *Carabidae* species belong to the group of large zoophagous insects (Skłodowski, 2003).

Carabidae communities are also influenced by the age of the tree stand in which insects are captured (Holec et al., 2006). Indeed, some trees in the nature reserve are 150 years old (pedunculate oaks, elms) or 250 years old (white and black poplars). In comparison to other habitats, the nature reserve is therefore an enclave attracting many animal species, including carabid beetles (Stachowiak. 1981).

Although the number of individuals captured in the nature reserve was considerably high, the biodiversity indices were at a quite low level. This particularly refers to 2001, when only seven species of *Pterostichus* spp. beetles were captured (including two species represented by single individuals) (Table 1). This can be explained by the fact that riparian forests in the nature reserve are almost homogeneous habitats, hence the ecological diversity of niches is lower and there is a lower biodiversity of captured species.

In addition, floodwaters in the nature reserve on the sites of insect capture remained for the longest time in comparison to other study sites. This probably limited the number of captured species, particularly those represented by very few individuals. In 2001, after the summer rise in water level, we mainly captured representatives of the most numerous species, i.e. *P. niger* and *P. melanarius*.

The nature reserve is adjacent to the poplar monoculture, which was established by planting poplar on a habitat occupied by riparian forest. Poplar monocultures are considered artificial habitats, often with disturbed vertical structure in comparison to riparian forests, and are frequently formed by hybrid or alien species, which have a negative impact on the local flora and fauna (Blab and Kudrna, 1982; Rotach, 2004). However, in our study the material captured in this habitat was characterized by the highest

diversity, as proven by the high values of biodiversity indices (H, N1alpha and D) (Table 2). The monoculture chosen for study is a habitat on fertile soil, very wet, with luxuriant vegetation and dead wood material deposited on the forest floor. The amount of dead wood is lower than in the nature reserve, but it is not removed during forest management activities. This may be a reason for the high diversity of the material collected there, proving the high potential of this habitat.

Interestingly, *P. niger* was found to be a very numerous species, although Šustek (1995) reported it as more demanding in terms of habitat quality than *P. melanarius,* which is less frequently captured in the poplar monoculture (Table1). Our findings indicate that poplar monocultures may play a significant role as potential habitats for invertebrates. For example, Grechkin and Vorontsov (1962) reported that as many as 700 various insect species (including *Carabidae*) are associated with *Populus* sp. alone. In addition, poplar monocultures may be an alternative to natural riparian forests, particularly on sites where these were cut down and their natural restoration is impossible.

On extensively managed meadows, located at the closest distance to the riverbed, we captured the lowest number of *Pterostichus* spp. beetles in both study years. However, in 2001 the number of individuals captured there was comparable to the number of beetles captured in the poplar monoculture (Table1), despite the long-lasting rise in water level in spring (in addition to summer flooding in all study sites), preventing insect collection in April. In the communities of beetles from meadows, we found, apart from eurytopic species, also species characteristic to open areas, such as *P. cupreus* and *P. caerulescens.* However, in contrast to reports by Olejniczak (1998) they were not the major component of the communities, probably because the meadows were adjacent to the forest. The values of biodiversity indices calculated for meadows (M) were quite low (Table2) because most of the captured species were represented by very few individuals (Table1).

In comparison to the other forest sites, meadows are homogeneous habitats without dead wood material. This probably results in the lower number of habitable ecological niches, and explains the lower diversity and number of collected individuals. Despite clear quantitative differences between the communities of *Pterostichus* spp. beetles living in the study sites we found no statistically significant correlation between the type of habitat and population size, and this may be associated with the location of the capture sites. Because all the study sites are adjacent to each other and are characterized by similar water and soil conditions, there is a natural species turnover as beetles can migrate between sites. This results in the high similarity of species composition and the high value of the Re index (%). On the other hand, the correlation between the year of capture and the number of communities of *Pterostichus* spp. beetles was close to the level of statistical significance. Differences in the number of beetles captured in both study years most likely depended on the flooding that took place in 2001, and were reflected by, for example, higher species turnover between study sites expressed in higher value of N1beta. The April flooding, which took place before the spring emergence of *Pterostichus* spp. beetles, probably improved soil fertility in habitats and caused an increase in the number of potential prey for beetles, but was also a reason for their migration from adjacent areas to more fertile habitats. This can probably explain the higher capture rate recorded one month after the retreat of floodwaters (Fig. 1a). In addition, a slight flooding of study sites in August resulted in reduced number of *Pterostichus* spp. beetles, most likely due to such factors as death or escape of part of their population. Therefore, the beetle capture rate was almost seven times lower in comparison to 2003 (Table 1). Flooding in August had a limiting effect, particularly on autumn breeding species, such as *P. melanarius* and *P. niger*, whose population peak falls in the second half of the year. Such fluctuations in the population size concerned the RF and M sites, where floodwaters remained for a longer time. In the poplar monoculture, the number of beetles gradually decreased over the vegetation season, probably because flooding disturbed the natural migration between the studied habitats.

Overall, river flooding, a natural consequence of spring or summer rises in water level, is the key factor ensuring the presence of *Carabidae* communities characteristic of flood plains. However, for many terrestrial insect species periodic flooding is also an abiotic stressor, usually influencing temporal reduction in insect population size (Šustek. 2001; Hering et al., 2004; Šejnohová, 2006).

Our findings can be considered as an introduction to further studies on the effect of periodic flooding on *Carabidae* fauna. Results from this study are promising enough to justify further observations, or to carry out similar research on the flood plains of different rivers in the region.

CONCLUSIONS

The results of this study confirmed that: (1) beetles from the genus *Pterostichus* are a permanent component of waterlogged ecosystems, regardless of their more or less natural character; (2) artificial poplar monocultures can be alternative habitats for species associated with riparian forests, as evidenced by the number of *Pterostichus* spp. beetles captured in this habitat; (3) periodic flooding is one of the factors influencing the presence of *Pterostichus* spp. beetles, and locally it may reduce population size; (4) when flooding occurred before the vegetation season, floodwaters increased habitat fertility, and this probably had an effect on the increased number of *Pterostichus* spp. beetles; (5) no statistically significant correlations were found between the habitat type or study year and the number of *Pterostichus* spp. beetles; (6) although we captured 6 852 individuals representing 21 species it should be emphasized that studies using Barber pitfall traps do not reflect the actual structure of communities. Instead, they offer a combined result of species density and their migration potential in the study area.

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