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The occurrence of *Triaenodes unanimis* McLachlan, 1877 (Insecta: Trichoptera) and other rare species of caddisflies in the Powidz Landscape Park (Poland)

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Abstract: The paper presents the results of studies from 2008, 2009, 2018 and 2021 on the trichopteran fauna of Lake Powidzkie Małe as well as the peatlands of Powidz Landscape Park. The total of 25,091 caddisfly specimens of 47 species were collected. Among them were three species from the Red List of Threatened Animals in Poland – *Triaenodes unanimi*s McLachlan, 1877, *Ceraclea nigronervosa* (Retzius, 1783) and *Oecetis notata* (Rambur, 1842) – and four species rare in the fens of Poland – *Holocentropus stagnalis* (Albarda, 1874) and *Cyrnus insolutus* McLachlan, 1878. *T. unanimis* is rare worldwide, including Poland. This is the fourth known site of *T. unanimis* in Poland and at the same time the most westerly Polish site of this species. The typical habitat of *T. unanimis* is defined on the basis of available habitat data and my own results.

Keywords: Trichoptera, faunistics, peatlands, geographical distribution, the Red List

Introduction

Trichoptera is one of the most abundant orders of insects, with more than 16,000 species described so far (Morse *et al.* 2019). In Poland, over 270 species have been recorded. Trichopterans are an integral component of aquatic ecosystems, which have adapted to most freshwater habitats. The wide geographic distribution and diverse range of ecological traits of caddisflies make them eminently suitable as bioindicator organisms (Jähnig *et al*. 2010, Conti *et al.* 2013).

Freshwater ecosystems offer a rich diversity of caddisfly habitats and species, but the knowledge of the current distribution of many species remains deficient. In Poland, insects account for over 82% of all animal species recorded, but the knowledge of their occurrence, habitat requirements and threats is far from complete (Jażdżewski 1999). Almost 80% of aquatic insect species occurring in Poland have no recognized threat status (Czachorowski & Buczyński 2000). The greatest danger to these insects is posed by changes to their habitats. Small ponds and peat bogs, forming unique ecosystems, are highly sensitive to changes in water conditions. The best way to protect such habitats would seem to be their legal protection, but very often this will not halt ongoing processes, for example, the degradation of peatlands (Ilnicki & Szajdak 2016). The state of knowledge of caddisflies in the existing protected areas is insufficient (Czachorowski & Majewski 2003). Relatively much is known about the caddisfly fauna of some protected areas, e.g. Babia Góra (Szczęsny 1986), Białowieża (Czachorowski 1998a), the Bieszczady (Szczęsny 2000), the Drawa (Czachorowski 1998), Roztocze (Buczyńska 2006), Świętokrzyski (Górecki 2016), the Tatra (Szczęsny 1989) and Wigry (Czachorowski 1998b, Szczęsny & Majecki

2002) National Parks, and Suwałki, (Buczyńska & Buczyński 2014), Nadwieprzański (Buczyńska 2012), Iława Lake Districts (Serafin & Czachorowski 2004), Brudzeń (Abraszewska-Kowalczyk *et al.* 2002), Łódź Uplands (Kowalczyk & Majecki 2002), Janów Forests (Czachorowski *et al*. 2000) and Masurian (Czachorowski 1998b) Landscape Parks. In contrast, the trichopteran fauna of Powidz Landscape Park, as well as of Lake Powidz itself, is very poorly known, the main reason being the lack of planned, long-term studies carried out in that area. So far the data from Lake Powidz have come from single catches of larvae (Jaskowska 1961) and adult insects (Żurawlew *et al.* 2017). The present study should be treated as a preliminary contribution to longer and more extensive studies.

Powidz Landscape Park area has a great study potential, mainly because of its diversity of natural habitats. The main threats to it include an excessive development of recreational tourism and the activities of strip brown coal mines. The effect of the cone of depression created as a result of brown coal mining is particularly visible on lakes Suszewskie and Wilczyńskie (Ilnicki *et al*. 2017a). Between 1965 and 2016, the water level in those lakes fell by 5 and 4.4 m, respectively. The lower water table also affected the adjacent peatlands, especially fens, accelerating the moorshing process and the ultimate disappearance of those very often unique ecosystems. There are over 146 peatlands and 5 gyttjas in Powidz Landscape Park, taking up the total area of 1,250.2 ha, as much as 63% of which consists of small peatlands no larger than 5 ha and particularly susceptible to degradation (Ilnicki *et al*. 2017b).

This paper provides new data on the occurrence of rare caddisfly species in Poland, principally *Triaenodes unanimis* McLachlan, 1877, but also *Ceraclea nigronervosa* (Retzius, 1783), *Oecetis notata* (Rambur, 1842), *Holocentropus stagnalis* (Albarda, 1874) and *Cyrnus insolutus* McLachlan, 1878. The geographic distribution and habitat preferences of *T. unanimis* are analysed in detail. This species is very rarely found, and the parameters of its preferred habitats given in the literature are inaccurate. The best way to protect many species of invertebrates, especially insects, is to conserve their habitats. The larva of *T. unanimis* has not yet been described (Hur 2006). All descriptions to date of potential habitat preferences have been based solely on imagines, mostly caught with light traps.

Study area and methods

The study was carried out in 2008, 2009, 2018 and 2021. The insects were caught using a light trap (250 W and 8W) from May to November in different ecosystems near Lake Powidzkie Małe in Powidz Landscape Park (UTM: YU01) (Fig. 1). The collected material was identified immediately after catching or else preserved dry. For identification, the atlas by Malicky (2004) was used. The habitat preferences of particular trichopteran species were assumed after Czachorowski (1998). Most of the insects were trapped in the north-eastern part of Lake Powidzkie Małe (Fig. 2), while some were caught in a fen in Smolnicki Ditch valley (Fig. 3) and on a small fen by the lake shore. The former of those fens is part of a larger peatland and gyttja over 27 ha in area, situated east of Ostrowo village, between Lake Powidzkie and Lake Powidzkie Małe (Ilnicki *et al*. 2017b). The type of peat in that fen can be described as sedge-woody.

The pH of the water in the lake and ponds on the fen was measured using a portable Hach Sens ion 156 series pH meter.

Powidz Landscape Park (area 24 887.21 ha) was established in 1998 to conserve the young glacial landscape, and in particular, a group of mostly ribbon-like post-glacial lakes, with underwater communities of stonewort (*Chara* spp.) meadows. The entire park is part of Gniezno Lakeland Natura 2000 site

(PLH300026). Lake Powidzkie, a typical ribbon lake, has an area of 1 014.3 ha. Its northern branch was cut off from the main water body in the second half of the 19th century, when a causeway was built to carry a road and a railway line, eventually creating a separate lake – Powidzkie Małe (52 ha). The maximum depth of the latter lake is 7.5 m (av. 3.5 m) (Nowak 2019). Its shores are mostly covered with pine forests, and only in the north-eastern part are there larger areas of emergent vegetation (reed beds). The whole bottom in there, the shallowest part of the lake (1-2 m), is covered mainly with hornwort, pondweed and water milfoil.

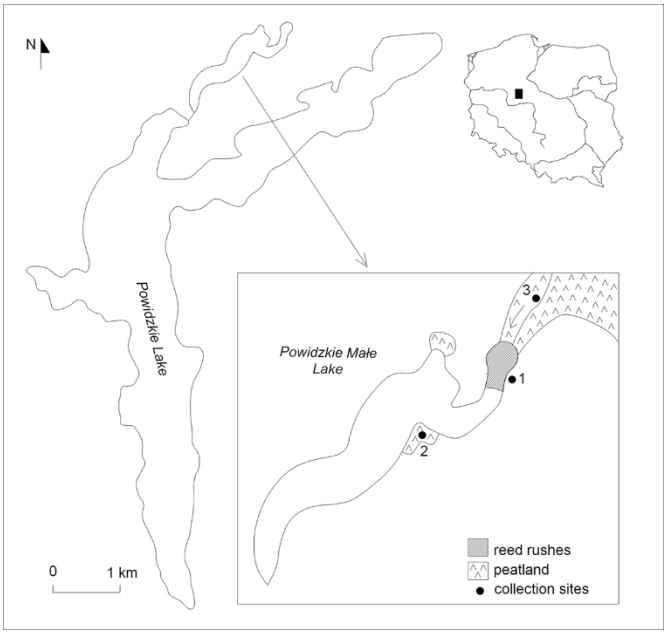

Fig. 1. Positions of the trapping localities on Lake Powidzkie Małe.

Fig. 2. Northern part of Lake Powidzkie Małe with emergent vegetation.

Fig. 3. Fen in the valley of the Smolnicki Ditch.

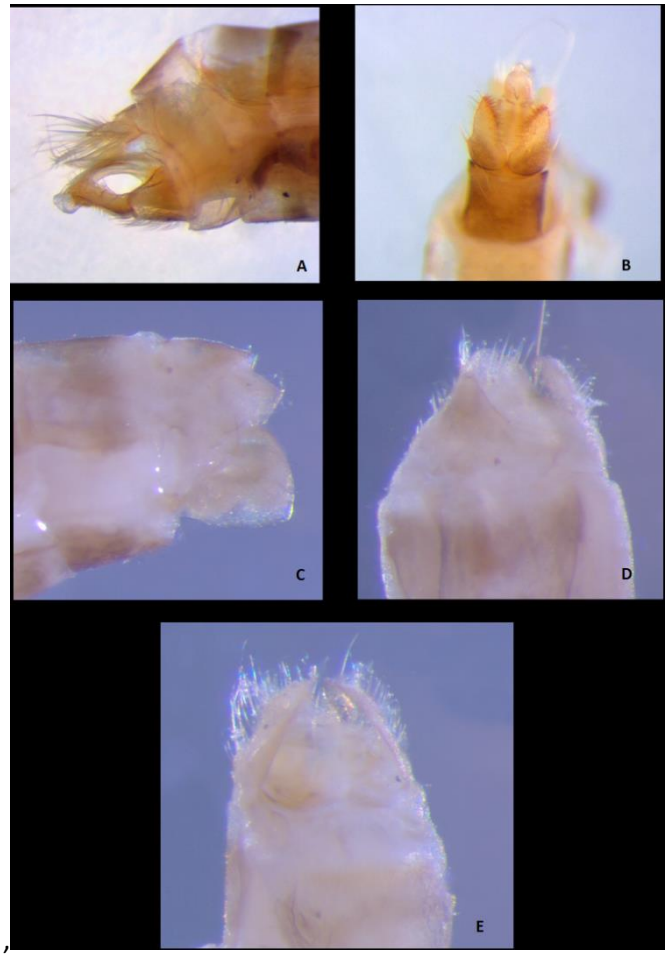

Fig. 4. Genitalia of *Triaenodes unanimis* McLachlan, 1877: A – Male, lateral view; B – Male, ventral view; C – Female, lateral view; D – Female, dorsal view; E – Female, ventral view.

Results

The total of 25,091 caddisflies, belonging to 47 species from 9 families, were caught in Powidz Landscape Park (Tab. 1). Compared with the results of studies from other landscape parks, the number of species caught is satisfactory, given that this is a preliminary study and covers just a small part of this one. More caddisfly species were found in Suwałki Landscape Park – 102 (Buczyńska & Buczyński 2014), Janów Forests Landscape Park – 63 (Czachorowski *et al*. 2000) and the Iława Lakeland Landscape Park – 56 (Buczyńska & Czachorowski 2004). However, in the northern part of Nadwieprzański Landscape Park, Buczyńska (2012) found 35 species, and in a preliminary study for Sieraków Landscape Park, Adamek and Czachorowski (2004) found 14 species. Jaskowska (1961) and Żurawlew et al. (2017), who carried out their study near Przybrodzin on the western shore of Lake Powidzkie, recorded only twelve caddisfly species. One of them, *Goera pilosa* (Fabricius, 1775), reported by Jaskowska (1961), has not been found there again. The larvae of this species prefer sandy and rocky bottoms. But this species was found elsewhere in Wielkopolska Province, as confirmed by Jakubisiakowa's (1933) data from Lake Kierskie and my own studies from the rivers Wrześnica and Goślinka (unpublished data).

The most numerous family was Leptoceridae (23,780 individuals) with 14 species, and the most abundant species caught in all the years of the study was

Leptocerus tineiformis Curtis, 1834 (23 540). The dominance of *L. tineiformis* can be explained with favourable conditions for the development of this species: it prefers the elodeid zone with hornwort (*Ceratophyllum L.*) and water milfoil (*Myriophyllum* L.). L. Though often found in mesotrophic lakes, it also occurs in eutrophic, polytrophic and peatbog lakes in the Masurian Lake District, the Pomeranian Lake District, the Łęczna-Włodawa Lake District and in oxbows in the Biebrza valley (Czachorowski 1998, Buczyńska 2012). In the habitat with hornwort and water milfoil, *L. tineiformis* often co-occurs with *Cyrnus crenaticornis* (Kolenati, 1859), *C. flavidus* McLachlan, *Oxyethira* spp., *Ecnomus tenellus* (Rambur, 1842), *Athripsodes aterrimus* (Stephens, 1836), *Athripsodes cinereus* (Curtis, 1834), and the genera *Mystacides* and *Oecetis* (Czachorowski 1998). All these species and genera, except for *A. cinereus*, were found in the present study (Tab. 1).

Table 1. Caddisflies (Trichoptera) in the Powidz Landscape Park; N – total number collected, D – dominance index [%].

No.	Species	N	D
	Hydropptilidae		
1	*Agraylea sexmaculata* Curtis, 1834	100	0.399
2	*Orthotrichia costalis* (Curtis, 1834)	12	0.048
3	*Oxyethira flavicornis* (Pictet, 1834	3	0.012
	Ecnomidae		
4	*Ecnomus tenellus* (Rambur, 1842)	544	2.168
	Polycentropodidae		
5	*Holocentropus picicornis* (Stephens, 1836)	2	0.008
6	*Holocentropus stagnalis* (Albarda, 1874)	17	0.068
7	*Cyrnus crenaticornis* (Kolenati, 1859)	29	0.116
8	*Cyrnus flavidus* McLachlan, 1864	2	0.008
9	*Cyrnus insolutus* McLachlan, 1878	1	0.004
10	*Cyrnus trimaculatus* (Curtis, 1834)	1	0.004
	Psychomyidae		
11	*Lype phaeopa* (Stephens, 1836)	1	0.004
12	*Tinodes waeneri* (Linnaeus, 1758)	1	0.004
	Hydropsychidae		
13	*Cheumatopsyche lepida* (Pictet, 1834)	2	0.008
14	*Hydropsyche contubernalis* McLachlan, 1865	74	0.295
	Phryganeidea		
15	*Agrypnia pagetana* Curtis, 1835	2	0.008
16	*Agrypnia varia* (Fabricius, 1793)	128	0.510
17	*Trichostegia minor* (Curtis, 1834)	4	0.016
18	*Phryganea grandis* Linnaeus, 1761	149	0.594
	Lepidostomatidae		
19	*Lepidostoma hirtum* (Fabricius, 1781)	1	0.004
	Limnephilidae		
20	*Grammotaulius nigropunctatus* (Retzius, 1783)	1	0.004
21	*Glyphotaelius pellucidus* (Retzius, 1783)	3	0.012
22	*Limnephilus auricula* Curtis, 1834	5	0.020
23	*Limnephilus binotatus* Curtis, 1834	1	0.004
24	*Limnephilus bipunctatus* Curtis, 1834	1	0.004
25	*Limnephilus decipiens* (Kolenati, 1848)	19	0.076
26	*Limnephilus flavicornis* (Fabricius, 1787)	88	0.351
27	*Limnephilus fuscicornis* Rambur, 1842	1	0.004

28	*Limnephilus griseus* (Linnaeus, 1758)	11	0.044
29	*Limnephilus marmoratus* Curtis, 1834	97	0.387
30	*Limnephilus stigma* Curtis, 1834	1	0.004
31	*Limnephilus subcentralis* Brauer, 1857	1	0.004
32	*Limnephilus vittatus* (Fabricius, 1798)	1	0.004
Molannidae			
33	*Molanna angustata* Curtis, 1834	8	0.032
Leptoceridae			
34	*Triaenodes bicolor* (Curtis, 1834)	7	0.028
35	*Triaenodes unanimis* McLachlan, 1877	50	0.199
36	*Mystacides azurea* (Linnaeus, 1761)	2	0.008
37	*Mystacides longicornis* (Linnaeus, 1758)	90	0.359
38	*Mystacides nigra* (Linnaeus, 1758)	3	0.012
39	*Athripsodes aterrimus* (Stephens, 1836)	2	0.008
40	*Ceraclea alboguttata* (Hagen, 1860)	4	0.016
41	*Ceraclea fulva* (Rambur, 1842)	6	0.024
42	*Ceraclea nigronervosa* (Retzius, 1783)	4	0.016
43	*Leptocerus tineiformis* Curtis, 1834	23540	93.819
44	*Oecetis furva* (Rambur, 1842)	13	0.052
45	*Oecetis lacustris* (Pictet, 1834)	2	0.008
46	*Oecetis notata* (Rambur, 1842)	5	0.020
47	*Oecetis ochracea* (Curtis, 1825)	52	0.207
Total		25091	100

This study also revealed the presence of the species associated with riverine habitats, i.e. *Hydropsyche contubernalis* McLachlan, 1865 and *Cheumatopsyche lepida* (Pictet, 1834); the former is found the middle and lower reaches of rivers (Czachorowski and Serafin 2004). Malicky (2008) describes this species as euryoecious, that is, it can live in both small streams and large rivers. *H. contubernalis* is not so demanding in terms of current speed and O_2 deficiency as, for example, *H. pellucidula* (Becker 1987). The coexistence of *H. contubernalis* and *C. lepida* is rather typical for the lower stretches of rivers owing to the large quantities of organic matter that they transport (Tszydel et al. 2003). In the present study area, these two species were associated with small streams: the Smolnicki Ditch flowing into Lake Powidzkie Małe and the Ostrowski Ditch flowing into Lake Powidzkie. Both streams flow through the same fen and their waters are rich in organic matter. These are the only watercourses within the radius of 5 km of Lake Powidzkie Małe, the maximum flight distance of the genus *Hydropsyche* (Arce 2021). Over 40% of the species caught in Powidz Landscape Park prefer the elodeid zone in lakes. Apart from the threatened and rare species described below, this group includes *Agraylea sexmaculata* Curtis, 1834, *Orthotrichia costalis* (Curtis, 1834), *Oxyethira flavicornis* (Pictet, 1834), *Ecnomus tenellus* (Rambur, 1842), *Holocentropus picicornis* (Stephens, 1836), *Cyrnus crenaticornis* (Kolenati, 1859), *C. flavidus* McLachlan, 1864, *Agrypnia pagetana* Curtis, 1835, *Molanna angustata* Curtis, 1834, *Triaenodes bicolor* (Curtis, 1834), *Mystacides azurea* (Linnaeus, 1761), *M. longicornis* (Linnaeus, 1758), *M. nigra* (Linnaeus, 1758), *Leptocerus tineiformis, Oecetis furva* (Rambur, 1842) and *O. ochracea* (Curtis, 1825). More than 25% of the caddisfly species caught are associated with peatlands, the larvae of which very often develop in the elodeid zone: *Oxyethira flavicornis, Ecnomus tenellus, Holocentropus picicornis, Agrypnia pagetana, Agrypnia varia, Limnephilus binotatus* Curtis, 1834, *L. marmoratus* Curtis, 1834, *L. stigma* Curtis, 1834, *L. subcentralis*

Brauer, 1857 and *L. vittatus* (Fabricius, 1798). It can therefore be assumed that more than half of the species were caught close to their larval development habitat. Of course, in order to confirm this hypothesis, a study of the caddisfly larvae of this habitat is necessary. However, the habitats in the northern part of Lake Powidzkie as well as the 27 ha fen situated between Lake Powidzkie Małe and Powidzkie are of a very similar character.

Several species included in the Red List of Threatened Animals and several species rare in the Polish trichopteran fauna were found during the study. The most interesting one found in the Powidz Landscape Park was *T. unanimis* (Fig. 4). The photographs of the genitalia, especially those of the female, included in this paper, may be helpful for the identification of this species. Previous publications by Kumański (1991), Park *et al.* (1999) and Malicky (2006) provide drawings. In the Polish Red List of Threatened Animals, *T. unanimis* is classified as LC (least concern) (Szczęsny 2002). This species is found in the Eastern and Western Palearctic and also in the Oriental Region (Hur 2006). The genus *Triaenodes* McLachlan, 1865 is one of the most numerous in Leptoceridae with over 230 described species. Only three *Triaenodes* species (Malicky 2004) have been found in Europe: *T. bicolor* (Curtis, 1834), *T. unanimis* McLachlan 1877 and *T. ochreellus* McLachlan, 1877 with two subspecies (*T. ochreellus ochreellus* and *T. ochreellus lefkas* Malicki, 1974) (Morse 2022, Malicky 2004). In Europe, *T. unanimis* has been found in Norway, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Poland and Germany (Andersen & Soli 1992, Gullefors 2002, Viidalepp *et al*. 2011, Mey 2020, Morse 2022). The species, until recently reported only from north-eastern Europe, now reaches its south-westerly distribution limit in Saxony (Küttner 2017, Neu *et al*. 2018, Küttner *et al*. 2020). The potential range of this species is very wide, but its occurrence, usually of single individuals, is point-based. In Asia, it has been found in Russia, including southern Buryatia (Ivanov & Melnitsky 2007), the southern Urals (Salokannel *et al*. 2019) and the Sikhote-Alin Biosphere Reserve in the Far East (Potikha 2015), and also in Korea and Japan (Park & Kong 2020). In Japan, the species was first described in 1942 as *Triaenodes yamamotoi* Tsuda, 1942, and in 1991, Kumański considered it a synonym of *T. unanimis* (Kumański 1991). Recent studies of the DNA code of *T. unanimis* indicate that this widely distributed species is composed of different taxa. Kučinić *et al*. (2020) found exceptionally large distances in the phylogenetic tree between specimens from Japan and those from Europe. In most of the countries where it occurs, *T. unanimis* is rare and is included in the Red List of Threatened Animals.

In Poland, *T. unanimis* was first discovered in 1994 in Wigry National Park on the shores of Lake Suchar Wielki (8♂♂, 7♀♀?) (Majecki 1996); later studies using a light trap (1996-2000) confirmed its presence on that lake (Szczęsny & Majecki 2002). Also in north-eastern Poland, one female was trapped at light at Turtul near the river Czarna Hańcza (Buczyńska & Buczyński 2014). In the Łęczna-Włodawa Lake District, eastern Poland, at Lake Skomielno, 4 specimens of *T. unanimis* were caught using a light trap (Buczyńska 2012). On Lake Powidzkie Małe, 50 individuals were caught during the study period (42♂♂, 8♀♀), the highest number of *T. unanimis* specimens ever found in Poland. The species was caught from late May to early August. A particularly high number of *T. unanimis* was caught in early June 2018 (31♂♂, 5♀♀). The timing of catching adults is confirmed by other data from Germany (Vermehren 1977, Mey 1985, Hohmann 2005). In Sweden, the flight period of this species was in the first three weeks of July (Gullefors 2014). The results of the current study shift the range of the species in Poland far to the south-west.

Although *T. unanimis* is regarded as a limnobiont, its larvae, which inhabit mainly

stagnant waters, are also found in streams and small rivers (Graf *et al*. 2008, Botosaneanu & Malicky 1978). In addition, the species has frequently been caught in peat bogs, wetlands and low pH waters (Tjeder 1937, Vermehren 1977, Voigt *et al.* 2019). The pH of the waters in Lake Suchar Wielki, where the first specimens of *T. unanimis* were caught in Poland, varied from 5.0 - 5.5 in the epilimnion to 5.8 near the bottom (Szczęsny & Majecki 2002). However, the waters of Lake Skomielno were slightly alkaline, the pH varying from c. 6.70 to 7.98 (Stępień 2012). In Germany, this species was caught on the Bergwitzsee, a 186-ha artificial lake created in former brown coal workings (Hohmann 2005), and also in a Berlin park on the Hohenzollernkanal (Mey 2020). This shows that it is capable of colonizing artificial water bodies. The presence of *T. unanimis* on the Bergwitzsee may also indicate a high tolerance to the water pH in the habitats where the larvae develop. Over the years, the pH of the water in the Bergwitzsee changed quite significantly, from very low (3.0 – 4.0) in the 1960s to neutral and slightly alkaline (7.0 – 8.1) in 2014 (Malyska *et al*. 1998, https://ms.sachsen-anhalt.de). In Powidz Landscape Park, imagines of *T. unanimis* were caught near the northern, overgrown part of Lake Powidzkie Małe. The entire surface of this part of this lake is covered with elodeids. The lake's waters contain high levels of calcium (69.5 $mg \cdot dm^{-3}$), which leads to quite high pH values, on average 8.3 in the northern part of the lake. Moreover, the numerous fens in the area are lined with calcareous gyttja, which is the reason why the average pH of the fen water is 8.3. This suggests that *T. unanimis* prefers habitats with a large amount of decaying organic matter, those which support aquatic vegetation that is not necessarily acidic. The closely related species *T. bicolor*, as well as *E. tenellus* and *C. flavidus*, are similarly tolerant of pH variations, since they have been recorded in waters with pH <5 as well as in more alkaline ones (Leuven 1987).

Ceraclea nigronervosa and *Oecetis notata* were further Red List species recorded in this study. The former is categorized as LC, the latter used to be regarded as probably extinct (EX?) (Szczęsny 2002). *C. nigronervosa* in Poland was earlier found in the Pomeranian Lake District, the Masurian Lake District and Lower Silesia (Tomaszewski 1965, Buczyńska & Buczyński 2014). On Lake Powidzkie Małe it was caught from late July to early August in 2008 and 2018 (1♂, 3♀). *O. notata* was recorded in the Masurian Lake District, the Pomeranian Lake District, the Łęczna-Włodawa Lake District, the Biebrza Valley and in two unspecified localities in Lower Silesia and Brudzeń Landscape Park (Tomaszewski 1965, Riedel 1972, Abraszewska-Kowalczyk *et al.* 2002, Czachorowski & Graf 2006, Majecki et al. 2007, Buczyńska 2012). In Powidz Landscape Park, five females of this species were caught in early August 2018. Other species rare in Poland that were caught in Powidz Landscape Park include *Holocentropus stagnalis* and *Cyrnus insolutus*. The larvae of these species most readily develop in peatlands and in the elodeid zone.

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