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Dragonflies (Odonata) of sandpits in south-eastern Poland

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Abstract – Dragonflies of sandpits and their succession were studied in 10 sand mines in south-eastern Poland in the years 1996–1998, based mainly on larval communities. 41 species were collected, of which 28 were autochthonous, and 6 probably autochthonous. A rapid succession of larval communities was observed. Many Mediterranean species occurred in the sandpits, of which the most interesting were: *Lestes barbarus* (Fabr.), *Aeshna affinis* (Vand. Lind.), *Hemianax ephippiger* (Burm.), *Anax imperator* Leach, *Sympetrum fonscolombii* (Sél.), and *S. meridionale* (Sél). Dragonflies inhabiting sand- and gravelpits in Central Europe, and the importance of these secondary biotopes for protection of the endangered dragonflies are briefly discussed.

Key words: Odonata, dragonfly larvae, secondary biotopes, succession, southern fauna, endangered species.

1. Introduction

The consequence of industrialization is, among destruction of natural biotopes, the emergence of secondary ones. In the case of stagnant waters, these are, for example, the water bodies that emerge in gravel- and sandpits. These are very interesting environments owing to the dynamic succession of fauna and presence of various numerous rare southern species; moreover, their importance is also significant as a secondary biotope for dragonfly species that are endangered (Bulanková 1997, Schmidt 1995, Tol and Verdonk 1988, Wildermuth 1994, Wildermuth and Krebs 1983*a*). These are the reasons why a considerable number of interesting articles concerning dragonflies have been published (Bilek 1952, Donath 1980, Ohnesorge 1988, Ott 1995, Trockur 1997, Wildermuth and Krebs 1983*b*). Unfortunately, data concerning dragonflies inhabiting this biotope in Poland are very poor. Only Mielewczyk (1972) gives more extensive information, and in some other works some fragmentary data are available (Bernard and Musiał 1995, Buczyński 1995, 1996, 1999).

The materials presented in this work were collected in the course of research on the distribution of some Mediterranean dragonflies in Poland. In the Polish climate it seems that water bodies located in sandpits constitute a particularly convenient environment for their development and, in consequence can be used to determine the range of these species and the changes connected with climate variations. In the course of research the succession was also observed.

2. Study area

The work was carried out in 10 sandpits in south-eastern Poland (50°36'–51°29' N, 22°24'–23°06' E) at (1) Momoty Dolne, (2) Szewce, (3) Tyszowce, (4) Wola Gardzienicka, (5) Dorohucza, (6) Kolonia Jaszczów, (7) Milejów, (8) Malinówka, (9) Nadrybie, and (10) Zienki (Fig. 1). Altogether, there were approximately 50 water bodies.

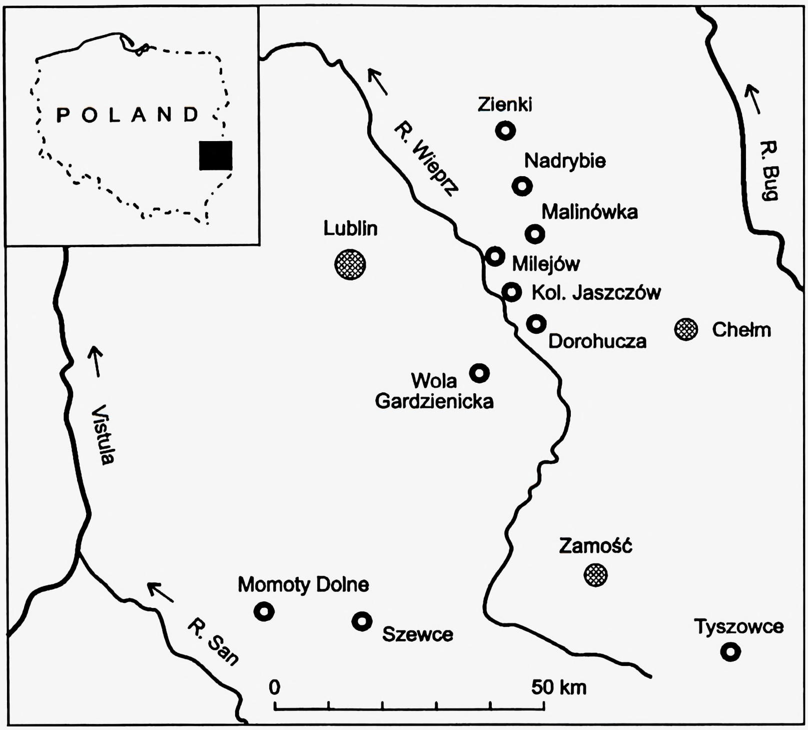

Fig. 1. Location of investigated stations (open circles).

The analysed sandpits were characterised by similar biotope features. They were located in open areas, in river valleys, or in the vicinity of smaller water flows. Their area reached from several hundred square metres up to 1 ha; only the sandpit at Wola Gardzienicka being larger (approximately 3 ha). The waters were rather small (10–200 m^2) and shallow (40–50 cm, rarely up to 1 m). Nevertheless that they did not dry up, which means that they were supported by ground water. The water was transparent, basic: pH 7.76–8.02. Only in Momoty Dolne was the pH lower: 6.92 (the effect of a nearby watercourse carrying acidic humus water), while at Wola Gardzienicka pH was higher: i.e. 9.12. The water temperature reached a maximum of 30 °C (in June and July), and was slightly lower in water bodies overgrown with cattails and reed – approximately 24 °C. The presence of fish (carp) was observed only in water bodies at Momoty Dolne.

The succession of vegetation observed in the water bodies appeared similar. Helophytes dominated; at first these were *Carex* sp., *Juncus* sp., and *Heleocharis* sp., while older water bodies were overgrown by *Phragmites australis* (Cav.) Trin. ex Steud. and *Typha* sp. Often present were *Salix* sp. also. Forms with floating and immersed leaves were not present; there was only *Potamogeton natans* L. in the water body at Tyszowce. The succession of vegetation was very rapid – during one season considerable changes in the spatial structure of the water bodies were observed (e.g. displacement of *Heleocharis palustris* R. Br. by *Typha latifolia* L.). Simultaneously with the succession of vegetation and biomass accumulation, the water body fertility also changed: in newly-emerged water bodies the electric conductivity was 27–88 μS cm^{-1}, and at advanced succession it reached 683 μS cm^{-1}.

For the needs of the analyses, the investigated water bodies were divided into four groups:

I. Newly-emerged, without macrophytes, often with the bottom covered with an algal coating.

II. Two-years old, with sporadic helophytes.

III. Three-years or older, with low helophyte occurrence (*Carex* sp., *Juncus* sp., *H. palustris*).

IV. Advanced succession stages, overgrown with helophytes (*Typha* sp., *P. australis*).

3. Material and methods

The material was collected in the years 1996–1998, the already published materials on Tyszowce from 1995 (Buczyński 1996) being used to some extent. The basic method was half-quantity takes with a hydrobiological scoop. All larvae were taken out of the scoop while the sample surface was determined approximately (thus the presented values of larvae density are approximate in character). Exuviae were collected and imagines set free after identification; only evidence specimens being kept. Emergence of imagines and reproductive behaviour were noted. Altogether, the following were collected: 1436 larvae, 78 exuviae, and 116 imagines. In water bodies at particular succession stages, the following were collected: Group I – 77 larvae and exuviae (12 samples at 3 localities); Group II – 127 (19 samples at 4 localities); Group III – 918 (45 samples at 8 localities); Group IV – 392 (27 samples at 4 localities). The evidencial material is stored in the Zoology Department, Maria Skłodowska-Curie University, in the author's collection.

In the water bodies, the following measurements were taken: temperature – using a Slandi TC204 thermometer, pH – with a Slandi PH204 pH-meter, and electric conductivity of the water – with a Slandi CM204 conductometer.

The age of the water bodies emerged in the course of the study or briefly before it began and was determined empirically (observation, reconnaissance in the area). The remaining water bodies were divided according to the level of the succession of vegetation (part of water bodies from Groups III and IV).

The following categories of dragonflies were determined: species which develop (criterion: presence of larvae, exuviae and/or juvenile imagines), probably developing species (only mature imagines, reproductive behaviour observed), development not confirmed (only mature imagines, reproductive behaviour not evidenced).

4. Results

The collected material represented 41 species of dragonfly, including 28 autochthonous ones and 6 probably autochthonous (Table I). The fauna of particular sandpits was relatively similar; significant differences, however, were observed in the case of water bodies in different stages of succession – even if they were located in the same sandpit.

The quantity of species also differed (Fig. 2): in newly-emerged water bodies, 1 species was present; in two-year water bodies – 7 species; in older water bodies, overgrown with older helophytes – 40 species; in the oldest water bodies, overgrown with cattails and reed – 17 species. Similar changes were observed in the larval density (Fig. 2); in the water bodies of Group I it was 6–9 ind. m^{-2}, the average being 6.7 (only once, on humid mud on the bottom of a dried-out water body, were there 140 ind. m^{-2}); in older water bodies – respectively as follows: Group II – 7–20 ind. m^{-2} (on average: 12.7), Group III – 3–170 ind. m^{-2} (on average: 55.7), Group IV: 8–54 ind. m^{-2} (on average: 33.0). Changes in the percentage share of Anisoptera larvae were reversed for changes in larvae density (Fig. 2).

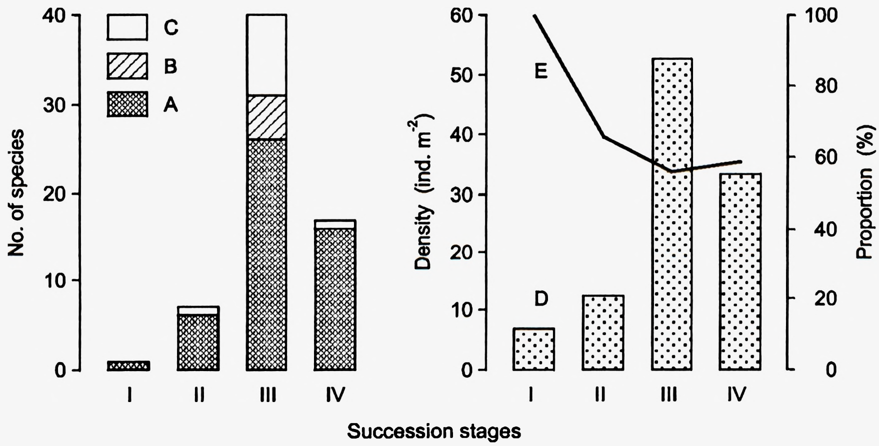

Fig. 2. Dragonflies in particular succession stages of investigated sandpits: A – developing species, B – probably developing species, C – development not observed, D – average larval density, E – percentage share of Anisoptera larvae.

The changes in composition and quantitative structure of the dragonflies were also important (Table I). In young water bodies, pioneer species were dominant. In the first year, 100% of the collected material was *Libellula depressa*, in the second year more than 63%, while the runner-up in terms of abundance was, also pioneering, *Ischnura pumilio*. Among them, eurytopic species emerged: *Lestes sponsa*, *Coenagrion puella*, and *Sympetrum vulgatum*, accompanied by thermophilous *Orthetrum albistylum*. In older water bodies (Group III) the importance of pioneer species decreased, although they were still considerably abundant. *Sympetrum vulgatum* and *Coenagrion puella* were dominant and there were also abundant small water body and low peat bog species. In the oldest water bodies (Group IV) no species was observed – apart from Epitheca bimaculata – which had not appeared earlier. However, many species were missing – both thermophilous and/or those that prefer such areas of water bodies where vegetation is less abundant. *Libellula depressa* was not abundant, being present only at the edges of water bodies.

In the analysed water bodies thermophilous, southern species were abundant. The qualitative ratio of Mediterranean species to Siberian ones (of St Quentin sense, 1960) was 1.06:1, while for the Lublin area it was 0.86:1. This ration changed with the succession of water bodies and reached its quantitative peak in water bodies of Group III and qualitatively in those of Group IV (Fig. 3).

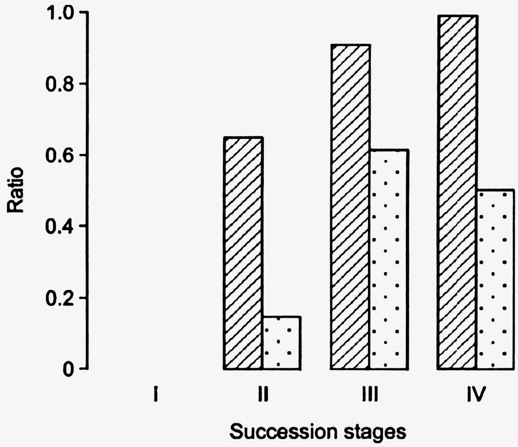

Fig. 3. Mediterranean to Siberian species ratio in number of species (hatched bars) and in number of collected larvae and exuviae (dotted bars) in particular succession stages of investigated sandpits. In water bodies of I succession stage no Mediterranean species were found.

Among the Mediterranean dragonflies that were observed there were many species considered rare, for instance *Lestes barbarus*, *Ischnura pumilio*, *Aeshna affinis*, *Hemianax ephippiger*, *Orthetrum albistylum*, *O. brunneum*, *O. coerulescens*, *Sympetrum depressiusculum*, *S. fonscolombii*, *S. meridionale*, and *S. striolatum*. Their status in the analysed water bodies differed. No data were collected that could confirm the development of *Hemianax ephippiger* and *Orthetrum brunneum*. In the case of *Aeshna affinis* and *Orthetrum coerulescens* reproductive behaviour was observed. *O. coerulescens* is a rheophile, probably connected with streams flowing in the vicinity of a sandpit, and *A. affinis* could be autochthonous in the Tyszowce sandpit – the first data concerning its emergence appeared in 1992, and it was also observed in abundance in 1995 (Buczyński 1995, 1996), the imagines observed being abundant and reproducing intensively. The remaining species were collected in their larval stadium. The most appropriate water bodies for them were those characterized by high insolation. In the first two years of the existence of water bodies, these species were rather infrequent, while in older water bodies (Group III) there were a number of thermophilous species, one of them most typically being *Orthetrum albistylum*, observed at 7 stations.

Table I. Occurrence of dragonflies at investigated stations (● – species develops, ★ – species probably develops, ☆ – development was not confirmed), and their share in the assemblages inhabiting particular reservoir succession stages (percentage of collected larvae and exuviae, + – only imagines, * – juvenile specimens observed, ** – reproductive behaviour observed).

Species	Stations										Succession stages			
	1	2	3	4	5	6	7	8	9	10	I	II	III	IV
Calopteryx splendens (Harr.)					☆								+	
- *virgo* (L.)				☆	☆								+	
Sympecma paedisca (Brau.)	●												0.1	
Lestes barbarus (Fabr.)			☆			●							+	+*
- *dryas* Kirby			★	●		●				●			0.5	2.7
- *sponsa* (Hansem.)	●		●	●	●	●	●		★	●		10.5	6.6	10.0
- *virens* (Charp.)						●	●						0.5	0.9
- *viridis* (Vand.Lind.)			●										+*	
Platycnemis pennipes (Pall.)							☆						+	
Ischnura elegans (Vand.Lind.)	●		●	☆		●		●	●			+	0.5	4.4
- *pumilio* (Charp.)	●		●	●	●	☆	●	●	●			13.2	10.0	
Enallagma cyathigerum (Charp.)	●		●		●		●	☆	☆	●			1.4	+
Coenagrion hastulatum (Charp.)	●			☆	★								4.5	
- *lunulatum* (Charp.)	●					●							0.5	0.3
- *puella* (L.)	●		●	☆	★	●	●	●	●	●		5.7	18.8	19.7
- *pulchellum* (Vand.Lind.)	●		●		★	●	★			●			1.6	2.7
Erythromma najas (Hansem.)			★		★								+	
Brachytron pratense (O.F. Müll.)							☆						+	
Aeshna affinis (Vand.Lind.)			★										+**	
- *cyanea* (O.F. Müll.)	●												0.1	
- *grandis* (L.)	☆								★				+**	
- *mixta* Latr.	●		●		●	●			★				1.1	3.5
Anax imperator Leach	●		●										0.7	
Hemianax ephippiger (Burm.)					☆								+	
Cordulia aenea (L.)			☆										+	
Somatochlora metallica (Vand.Lind.)							★						+	
Epitheca bimaculata (Charp.)						●								0.3

Table I. *continued*

Species	Stations										Succession stages			
	1	2	3	4	5	6	7	8	9	10	I	II	III	IV
Libellula depressa L.	●	●	★	★	●	●	★	●	●		100.0	63.2	10.0	4.1
- *quadrimaculata* L.	●		★		★	●	●		●	●			1.7	2.9
Orthetrum albistylum (Sél.)	●		★	●	●	●	●	●				2.6	1.0	
- *brunneum* (Fonsc.)			☆										+	
- *cancellatum* (L.)				★	★	★		●					0.2	
- *coerulecsens* (Fabr.)			★										+**	
Sympetrum depressiusculum (Sél.)	●												0.2	
- *flaveolum* (L.)	●		●	●	●	●	●		★	●			7.3	7.1
- *fonscolombii* (Sél.)									●	●			0.2	
- *meridionale* (Sél.)	●			●	●	●							0.4	0.6
- *sanguineum* (O.F. Müll.)	●		●	●		●	●		★	●			2.0	8.5
- *striolatum* (Charp.)										●			0.1	
- *vulgatum* (L.)	●		☆	●	●	●	●	☆	●	●		5.3	30.3	32.4
Leucorrhinia pectoralis (Charp.)			★										+**	

5. Discussion

In the results presented the variety of fauna is conspicuous, although the study embraced a relatively small number of objects. A few authors give similar results, such as, e.g., Ott (1995) – 40 species from 33 sand- and gravelpits in the Rhine-Palatinate (Germany), Wildermuth and Krebs (1983*b*) – 39 species from 12 gravelpits in northern Switzerland. More frequently, a smaller number of species was observed, e.g. Königsdorfer (1997) – 33 (145 gravelpits, Bavaria, Southern Germany), Trockur (1997) – 30 (30 gravelpits, Luxembourg). Unfortunately, comparative data from Poland are lacking; only Mielewczyk (1972) presents more comprehensive data about gravelpits in the vicinity of Gniezno, but mentioning only 15 species from the whole fauna.

When taking into account the generally large number of species, the fauna of particular objects was rather poor in terms of quality: a maximum of 23 species, usually below 20. In other works, apart from similar data (e.g. Möckel 1997, Ohnesorge 1988, SGL 1999), can also be found 33 species plus 4 noted in handwriting on the offprint (Bilek 1952), or 32 species (Donath 1980).

This apparent contradiction results from the spatial structure of the water bodies, which was little varied, without deep fragments, and therefore without plants such as *Potamogeton* sp., *Nuphar lutea* (L.) Smith in Sibthorp et Smith, *Nymphaea* sp., *Myriophyllum* sp. The differences between the spatial structure of individual water bodies were considerable, hence the number of species observed.

The qualitative and quantitative changes, clearly correlated with the evolution of the spatial structure of the water bodies, which stemmed from the plant succession, tallied with the general model of succession (Odum 1977); these changes recalled succession in gravelpits in the vicinity of Gniezno (Mielewczyk 1972). The number of species and density of larvae increased with the availability of resources (although the changes in biomass were presumably smaller than densities; in new water bodies the number of Anisoptera larvae was much larger than the number of Zygoptera larvae, with a smaller body mass). The fall in variety in the oldest water bodies might have resulted from the stabilization of environmental conditions – the effect of smaller astaticism (Czachorowski 1997). Succession led through the species communities typical of small water bodies; from "*Orthetrum-Libellula depressa*", characteristic of areas of poor fauna and uncovered bottom, to "*Lestes-Sympetrum-Aeshna mixta*", typical of rushes (Jacob 1969). The medium stage was close to "*Erythromma-Anax imperator*", which was poorer in terms of quantity and quality owing to the lack of species connected with immersed plants and plants with floating leaves. It was very characteristic that these formations followed one another, not co-existing; this was also the result of little spatial variation of water bodies.

The question emerges as to whether, and to what extent, we can determine the common features of dragonflies living in excavations. Generally speaking, it is difficult to present a cohesive model of fauna and its succession. The local factors (the structure of local fauna, the differences in species, and their ecology in different parts of their range, features of microbasin) are too strong and may cause the water bodies to evolve in various ways. Their locality also brings about changes in the course of succession. Therefore the succession of dragonflies would be more of a stochastic rather than deterministic process, and the composition of fauna in water bodies located in different areas is not and cannot be identical. However, a few features common to the water bodies can be mentioned; these features are generally close to those of small natural water bodies. They are: the dominance of eurybionts (a general characteristic of small water bodies, irrespective of their history), abundant presence of thermophilous species, and frequent presence of low-peat species. Moreover, sometimes in the excavations rheophile species can be observed.

The water bodies studied showed the majority of the features enumerated above. The dominance of eurybionts was connected with the instability of environmental conditions. The presence of thermophilous species is obvious owing to the thermal factors of the water bodies. In new ones thermophilous species were not very numerous, which may be due to the fact that they are scattered and therefore the probability of an imago living in a particular water body is relatively small. In the course of time, however, they can be observed in all water bodies. What is interesting is that there were no essential differences in the population of the species on the North-South line which may point to the fact that the area of study lies in their range.

The observation of migrant dragonflies is particularly precious: *Aeshna affinis*, *Hemianax ephippiger*, *Sympetrum fonscolombii*, and *S. meridionale*. These species and their range are regarded as an indicator of a warming up of the climate (Martens and Gasse 1995, Müller et al. 1996, Ott 1996).

In the case of *Aeshna affinis* there is a discussion as to whether in Central Europe it becomes an autochthonous species, with an accompanying warming up of the climate. It is certainly capable of making temporal, unstable populations (Peters 1987, Schorr 1990, Bernard and Samoląg 1995). Recently, however, it has been observed much more frequently, e.g. in Germany its development has been observed since 1992, each year in the Elba valley (Martens and Gasse 1998). The reports from Poland are also more frequent than previously (Bernard and Samoląg 1995, Buczyński 1995, 1996, 1997, 1999). It seems, however, that the issue of autochthony of *Aeshna affinis* is still open and requires further examination.

For the remaining infestation species, each statement is a piece of information about the course and range of their migration. Therefore, the collected data show that south-eastern Poland – at least in the last 3 years – was still within the range of the migration of *Sympetrum fonscolombii* and *S. meridionale* and, in 1998, also *Hemianax ephippiger*.

Here we may risk the statement that the post-exploitation water bodies constitute a novelty in the environment and, thanks to this, the northbound expansion of Mediterranean fauna is facilitated, as compared with the original environment. It seems, however, that these water bodies are to be considered secondary as opposed to flood-land reservoirs of natural river valleys (Wildermuth and Krebs 1983*b*); in this sense, their presence does not introduce any new factors but recalls the original situation.

The presence of low-peat species in post-exploitation water bodies is usually connected with their dystrophication: either autogenous (Mielewczyk 1972) or resulting from the inflow of acid waters from a microbasin. It was also conspicuous in the studied water bodies: low-peat species were most abundant in water bodies in Momoty Dolne – characterized by the lowest pH, located in the vicinity of a *Circaeo-Alnetum* alder swamp with a stream flowing through it.

The present study did not show the development of rheophiles. Their presence in still waters is connected with areas of strong waving, although their presence may simply be due to good water quality, caused either by ground waters or relatively small movements of water made by the wind (Weihrauch 1998). At least one of the conditions – ground water support – was fulfilled by the studied water bodies. It seems, however, that the water temperature was too high and the concentration of oxygen too low. This statement requires further area examination.

A separate question is the importance of water bodies in excavations for endangered dragonflies. In many European countries this is considerable (Wildermut and Krebs 1983*b*, Schmidt 1995, Tol and Verdonk 1988, Trockur 1997, Xylander and Stephan 1998). In south-eastern Poland it is not so important at the present moment. Of 22 species proposed for the Red List of dragonflies in Poland (Łabędzki et al. 1999) only 5 were observed, all from category "I" (Indeterminate). Only two of them (*Sympetrum striolatum* and *Leucorrhinia pectoralis*) were connected with the studied water bodies, and they were caught sporadically and not abundantly; other (*Calopteryx virgo, Orthetrum brunneum, O. coerulescens*) appeared incidentally. This results from the fact that small water body dragonflies, which constitute a major part of the species included in Western European Red Lists (as e.g. in Germany – Ott and Piper 1997) are not endangered in Poland. The only small-pools species which is proposed for the Polish Red List is *Coenagrion armatum* (Łabędzki et al. 1999). However, it requires stability of habitat conditions, and therefore its development in water bodies in sandpits is not very probable because of their strong astatism. Nevertheless, a potential importance of sandpits for protection of dragonflies in Poland is considerable: we are witnessing a distinct fall in the level of ground waters, resulting in a fall in the number of small water bodies. If this process is not stopped, the secondary habitats may soon play first fiddle in the protection of the dragonfly fauna of small water bodies.

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References

Bernard R. and Musiał J. 1995. Observations of an abundant occurrence of *Hemianax ephippiger* (Burmeister, 1839) in western Poland in 1995 (Odonata: Aeshnidae). Opusc. zool. flumin., 138, 1–9.

Bernard R. and Samoląg J. 1995. *Aeshna affinis* (Vander Linden, 1820) in Poland (Odonata: Aeshnidae). Opusc. zool. flumin., 118, 1–7.

Bilek A. 1952. Eine Kiesgrube als Lebensraum für die Hälfte aller mitteleuropäischen Odonaten-Arten. Nachrichtenbl. bayer. Ent., 1, 85–86.

Buczyński P. 1995. Materials to the knowledge of dragonflies (Odonata) of the Lublin region. Part 1. Wiad. entomol., 14, 76–83 [in Polish with English abstract].

Buczyński P. 1996. New records of dragonflies (Odonata) from eastern part of the Lubelska Upland. Wiad. entomol., 15, 5–11 [in Polish with English abstract].

Buczyński P. 1997. Dragonflies (Odonata) of Polesie National Park. Parki Narodowe i Rezerwaty Przyrody, 16, 41–62 [in Polish with English abstract].

Buczyński P. 1999. Libellen von Sandgrubengewässern im südöstlichen Polen. Tagungsband 18. Jahrestagung der GdO, Münster, 19–21 März 1999. Münster, Gesellschaft deutschsprachiger Odonatologen e.V., 13.

Bulanková E. 1997. Dragonflies (Odonata) as bioindicators of environment quality. Biologiá, (Bratislava), 52, 177–180.

Czachorowski S. 1997. Influence of the landscape incontinuity on the amount and numbers of species – a simulation model. In: Puszkar T. and Puszkar L. (eds) Współczesne kierunki ekologii – ekologia behawioralna [Contemporary trends in ecology – behavioural ecology]. Lublin, Wyd. UMCS, 399–412 [in Polish with English abstract].

Donath H. 1980. Eine bemerkenswerte Libellenfauna an einem Kiesgrubenweiher in der Niederlausitz. Entom. Berichte, 24, 65–67.

Jacob U. 1969. Untersuchungen zu den Beziehungen zwischen Ökologie und Verbreitung heimischer Libellen. Faun. Abh. Staatl. Mus. Tierk. Dresden, 24, 197–239.

Königsdorfer M. 1997. Die Bedeutung von Kiesabbaugebieten für den Artenschutz am Beispiel der Libellenfauna im Donauried. Tagungsband 16. Tagung der GdO, Nürnberg, 14–16 März 1997. Nürnberg, Gesellschaft deutschsprachiger Odonatologen e.V., Naturhistorische Gesellschaft Nürnberg e.V., Bayerisches Landesamt für Umweltschutz, Bund Naturschutz in Bayern e.V., 9.

Łabędzki A., Buczyński P. and Tończyk G. 1999. Zagrożenia i ochrona ważek (Odonata) w Polsce [Threats to and protection of dragonflies (Odonata) in Poland]. Proc. Conf. "Ochrona owadów w Polsce – u progu integracji z Unią Europejską" [Protection of insects in Poland on the threshold of integration with the European Union], Kraków, 23–24 September 1999. Poznań-Kraków, Pol. Tow. Entomol., Inst. Ochr. Przyrody PAN, 21–23 [in Polish].

Martens A. and Gasse M. 1995. Die Südliche Mosaikjungfer *Aeshna affinis* in Niedersachsen und Sachsen-Anhalt (Odonata: Aeshnidae). Braunschw. Naturk. Schr., 4, 795–802.

Martens A. and Gasse M. 1998. *Aeshna affinis* in Deutschland. Wie soll man die Funde interpretieren? Tagungsband der 17. Tagung der GdO, Bremen, 20–22 März 1998. Bremen, Bremer Libellengruppe, Naturwissenschaftlicher Verein zu Bremen e.V., Gesselschaft deutschsprachiger Odonatologen e.V., 28.

Mielewczyk S. 1972. Die Libellen (Odonata) der Umgegend von Gniezno. Fragm. faun., 18, 141–162 [in Polish with German summary].

Möckel R. 1997. Die Libellen der Calauer Schweiz mit "angeschlossenen" Teichlandschaften. Natur und Landschaft in der Niederlausitz, 18, 16–36.

Müller J., Schlosser S. and Tiede D. 1996. Südliche Mosaikjungfer (*Aeshna affinis*) – Invasionsart oder Neubürger? Naturschutz im Land Sachsen-Anhalt, 33, 2.

Odum P.E. 1977. Podstawy ekologii [Fundamentals of ecology]. Warszawa, PWRiL, 612 pp. [in Polish].

Ohnesorge D. 1988. Die Libellenfauna (Odonata) der Kiesgrube Barkholz (Kreis Stormarn, Schleswig-Holstein). Seevögel, 9, 17–25.

Ott J. 1995. Die Beeintrachtung von Sand- und Kiesgruben durch intensive Angelnutzung – Auswirkungen auf die Libellenfauna und planerische Lösungssätze. Limnologie aktuell, 7, 155–170.

Ott J. 1996. Zeigt die Ausbreitung der Feuerlibelle in Deutschland eine Klimaveränderung an? Mediterrane Libellen als Indikatoren für Änderungen in Biozönosen. Naturschutz u. Landschaftsplanung, 28, 53–61.

Ott J. and Piper W. 1997. Rote Liste der Libellen (Odonata) (Bearbeitungsstand 1997). Schriftenreihe für Landschaftspflege und Naturschutz, 55, 260–263.

Peters G. 1987. Die Edellibellen Europas (Aeshnidae). Wittenberg Lutherstadt, A. Ziemsen Verlag, 140 pp.

Schmidt E. 1995. A survey of threatened dragonfly habitats in Central Europe, especially bogs, and bog management. In: Corbet P.S. and Dunkle S.W. (eds) Proc. Internat. Symp. "Conservation of dragonflies and their habitats", Kushiro, 13–15 August 1993. Kushiro, Jap. Soc. Preservation of Birds, 45–68.

Schorr M. 1990. Grundlagen zu einem Artenhilsfprogramm Libellen der Bundesrepublik Deutschland. Bilthoven, Ursus Sci. Publ., 512 pp.

SGL (Schutzgemeinschaft Libellen in Baden-Württemberg) 1999. Pflege- und Entwicklungsplan Weberalten. IDF-Report (Newsletter of the International Dragonfly Fund, vol. 2, no. 1), 9–12.

St Quentin D. 1960. Die Odonatenfauna Europas, ihre Zusammenfassung und Herkunft. Zool. Syst. Ökol. Geograph. Tiere, 87, 301–316.

Trockur B. 1997. Bemerskwerte Libellenfunde im Kiesweihergebiet bei Remerschen. Wiederfund von *Epitheca bimaculata* und Erstnachweis von *Anax parthenope* für Luxemburg (Insecta, Odonata). Bull. Soc. Nat. Luxemb., 98, 105–112.

Van Tol J. and Verdonk M. J. 1988. The protection of dragonflies (Odonata) and their biotopes. Council of Europe (Strassbourg), Nat. Envir. Ser., 38, 1–181.

Weihrauch F. 1998. Die Entwicklung von *Gomphus vulgatissimus* (L.) in Kiesgrubengewässern: seltene Ausnahme oder lediglich übersehen? (Anisoptera: Gomphidae). Libellula, 17, 149–161.

Wildermuth H. 1994. Dragonflies and nature conservation. An analysis of the current situation in Central Europe. Adv. Odonatol., 6, 199–221.

Wildermuth H. and Krebs A. 1983*a*. Die Bedeutung von Abbaugebieten aus der Sicht des biologischen Naturschutzes. Beih. Veröff. Naturschutz Landschaftspflege Bad.-Württ., 37, 105–150.

Wildermuth H. and Krebs A. 1983*b*. Sekundäre Kleingewässer als Libellenbiotope. Viertelj. naturfosch. Ges. Zürich, 128, 21–42.

Xylander W.R. and Stephan R. 1998. Die Libellen des Braunkohletagebaugebietes Berzdorf. Abh. Ber. Naturkundemus. Görlitz, 70, 65–80.