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Abstract

With respect to the distribution of Odonata, the European part of Russia belongs to the most poorly studied areas of Europe. Records of 12 dragonfly species at the northern limits of their distribution are provided and discussed based on materials collected on the Courish Spit, Kaliningrad Oblast, western Russia, in ornithological "Rybachy" traps in the years 2007-2011. Six species were recorded for the first time in the Kaliningrad Oblast (*Aeshna affinis*, *Orthetrum albistylum*, *O. brunneum*, *O. coerulescens*, *Crocothemis erythraea*, and *Sympetrum meridionale*), and occurrence of two species was confirmed (*Lestes viridis* and *Sympetrum fonscolombii*). The data suggests that the migration route of dragonflies runs along the coast of the Baltic Sea.

Резюме

Фауна стрекоз Европейской части Рссии изучена крайне слабо. На основании материала, собранного в 2007-2011 гг на Куршской косе (Калининградская обл) большими стационарными ловушками для отлова птиц („рыбачинского тыпа"), представлены данные о находках 12 видов стрекоз на северной границе их распространения. 6 видов были отмечены впервые для Калининградской обл (*Aeshna affinis*, *Orthetrum albistylum*, *O. brunneum*, *O. coerulescens*, *Crocothemis erythraea* и *Sympetrum meridionale*). Достоверно подтверждено присутствие еще 2-х видов (*Lestes viridis* и *Sympetrum fonscolombii*). Проанализированные данные говорят о существовании миграционного пути стрекоз вдоль восточного побережья Балтийского моря.

Zusammenfassung

Bemerkenswerte Libellenfänge aus Vogelreusen auf der Kurischen Nehrung, Oblast Kaliningrad, Russland – Der europäische Teil Russlands gehört zu den odonatologisch am wenigsten erfassten Gebieten Europas. Die im Artikel präsentierten und analysierten Daten basieren auf Libellen, die zwischen 2007 und 2011 in Vogelreusen vom „Rybachy"-Typ auf der Kurischen Nehrung (Oblast Kaliningrad, Westrussland) gefangen wurden. Sechs Arten wurden zum ersten Mal im Oblast Kaliningrad festgestellt, nämlich *Aeshna affinis*, *Orthetrum albistylum*, *O. brunneum*, *O. coerulescens*, *Crocothemis erythraea* und *Sympetrum meridionale.* Das Vorkommen zweier weiterer aus faunistischer Sicht interessanter Arten – *Lestes viridis* and *Sympetrum fonscolombii* – wurde bestätigt. Die Daten legen nahe, dass die Wanderrouten der beobachteten Arten an der Ostseeküste entlang verlaufen.

Introduction

Drastic changes in distribution of dragonflies related to climate changes are observed in Europe on a local and continental scale. Therefore the analysis of expansion of Mediterranean species is of high cognitive significance. Dragonflies are among the most important climate warming indicators. Simultaneously, the effect of such changes on local faunas is observed, including regression of species preferring low temperatures (Ott 2001, 2010; Hassall et al. 2007; Flenner & Sahlén 2008; Bernard et al. 2009; De Knijf et al. 2011). The changes of climate are overlapped by the results of anthropogenic transformations of the environment (Bönsel 2001; Buczyński et al. 2002; Clausnitzer 2003; Bernard & Wildermuth 2005).

The front of a northward expansion of dragonflies in central and eastern Europe in the last years reached northern Poland, Belarus, Lithuania, Latvia, and the Kaliningrad Oblast (Bernard 2005; Buczyński 2007; Buczyński & Moroz 2008; Bernard et al. 2009; Gliwa & Stukonis 2011; Kalniņš 2011). The completeness of data from this area, however, is highly unsatisfactory. Data from the Kaliningrad Oblast is the least complete (Tumilovich 2009b). Our purpose is to analyse new data from this area; APS has conducted long-term studies on bird migrations there, and the side-effect is the collection of dragonfly imagines. Detailed analysis of the material will be a subject of a separate publication. This paper focuses on a selected zoogeographical aspect, namely expansion of dragonflies in the direction from south to north. It discusses species for which the Kaliningrad Oblast is located near the boundary of distribution or outside the known range of occurrence. Such data is useful for knowledge on distribution of individual species and the course of their expansion.

Methods and material

The material was collected on the Courish Spit, at the Biological Station Fringilla (55°05'N, 20°44'E), a field station of the Zoological Institute of the Russian Academy of Sciences, located 12 km south of the village of Rybachy (Fig. 1).

The Courish Spit, separating the Baltic Sea from the Courish Bay, is located in the north-western part of the Kaliningrad Oblast and in the south-western part of Lithuania. Its length amounts to 98 km, and its width to 0.4-4.0 km. It is covered with forests, mainly 70 % planted pine woodland. Stretching along the coast there is a belt of dunes with a mean height of 20-40 m, and maximum height of 67.2 m. Surface waters are scarce, particularly in the vicinity of the Fringilla station, where currently few small water bodies exist; these are often strongly periodical. Approximately 10 km to the north, in the vicinity of the village of Rybachy, several small lakes are located. To the south of the village, several systems of drainage canals exist. The climate of the Courish Spit is relatively mild due to the influence of the Baltic Sea. Mean air temperature in July is 17°C, and in January: -3°C. Annual precipitation is 643 mm (Dolnik & Napreenko 2007; Albrecht 2008).

The study was carried out in the years 2007-2011. Two 'Rybachy' type ornithological traps were used. Each trap consisted of a net cone about 45 m long, with an entrance gate measuring 12×36 m. The cone ends with a netted box serving as a receiving chamber (Fig. 2). Dragonflies were collected every day from 01-iv to 31-x. Maximum air temperature was measured every day as well. The traps were

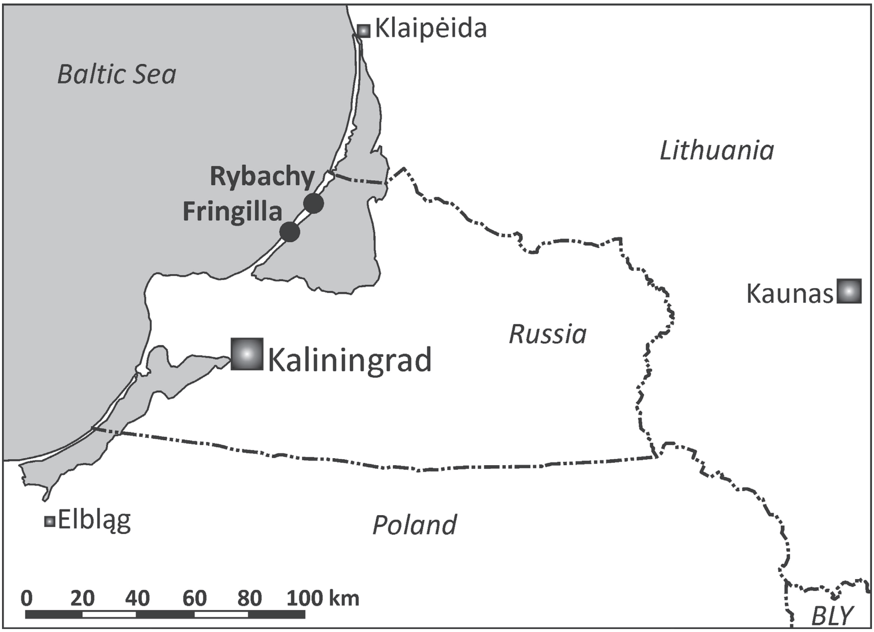

Figure 1: Map of the Kaliningrad Oblast, Russia, with location of the study site on the Courish Spit. – Abbildung 1: Karte des Oblast Kaliningrad, Russland, mit Lage des Untersuchungsgebietes auf der Kurischen Nehrung. BLY Belarus, Weißrussland.

located at the boundary between pine forest and the dune belt, 0.4 km from the seashore. They were oriented in the north-eastern and south-eastern directions.

Values of the Pearson's correlation coefficient were calculated in the Statistica 10.0 programme.

Results

Altogether 97 individuals of 12 species of Odonata were recorded between 01-iv--2007 and 31-x-2011. In detail the following species were caught:

- *Sympecma fusca* (Vander Linden, 1820): 24-viii-2011, 1♀.
- *Lestes barbarus* (Fabricius, 1798): 17-vii-2010, 1♂; 23-vii-2010, 1♂; 31-vii--2010, 3♂♂ 2♀♀; 16-viii-2010, 1♂ 3♀♀; 17-viii-2010, 1♂.
- *Lestes viridis* (Vander Linden, 1825): 09-ix-2009, 1♂.
- *Aeshna affinis* Vander Linden, 1820: 09-viii-2007, 1♂; 10-vii-2010, 1♀; 12-vii--2010, 1♂ 1♀; 13-vii-2010, 1♀; 22-vii-2010, 2♂♂ 2♀♀; 01-viii-2010, 1♀; 19--vii-2011, 1♂; 30-vii-2011, 1♀.

Figure 2: Ornithological 'Rybachy' traps on the Courish Spit. Biological Station Fringilla near Rybachy, Kaliningrad Oblast, Russia (08-vi-2006). – Abbildung 2: Vogelreusen vom ‚Rybachy'-Typ auf der Kurischen Nehrung. Biologische Station Fringilla bei Rybachy, Oblast Kaliningrad, Russland (08.06.2006). Photo: APS

- *Anax parthenope* (Selys, 1839): 05-viii-2007, 1♂; 06-viii-2007, 1♂ 1♀; 12-viii--2007, 1♀; 30-vi-2009, 1♂; 11-vii-2010, 1♀; 17-vii-2010, 1♀; 18-vii-2010, 1♂; 22-vii-2010, 2♀♀; 16-viii-2010, 1♀; 11-ix-2010, 1♂; 31-v-2011, 1♀; 05-vi-2011, 1♂; 05-vii-2011, 1♂; 06-vi-2011, 2♂♂ 1♀; 07-vi-2011, 1♀; 17-vii-2011, 1♂ 1♀; 19-vii-2011, 1♂; 22-vii-2011, 1♂ 1♀; 24-vii-2011, 2♂♂ 2♀♀; 29-vii-2011, 1♂; 04-viii-2011, 2♀♀; 08-viii-2011, 1♀; 25-viii-2011, 1♀.
- *Orthetrum albistylum* (Selys, 1848): 05-viii-2011, 1♀.
- *Orthetrum brunneum* (Fonscolombe, 1837): 11-viii-2007, 1♀; 16-viii-2007, 1♀; 26-vii-2008, 1♂; 30-vi-2011, 1♂; 24-vii-2011, 1♀; 26-vii-2011, 1♂; 01-viii--2011, 1♀; 02-viii-2011, 1♀; 03-viii-2011, 1♀; 07-viii-2011, 1♀; 08-viii-2011, 1♀; 09-viii-2011, 1♀.
- *Orthetrum coerulescens* (Fabricius, 1798): 18-vii-2011, 1♀.
- *Crocothemis erythraea* (Brullé, 1832): 05-vii-2008, 1♂; 12-vii-2008, 1♀.
- *Sympetrum fonscolombii* (Selys, 1840): 20-viii-2007, 1♀; 30-ix-2007, 1♂; 24-vii--2010, 1♂.
- *Sympetrum meridionale* (Selys, 1841): 22-vii-2010, 1♀; 08-viii-2010, 1♂.
- *Sympetrum pedemontanum* (Allioni, 1766): 12-viii-2007, 1♂; 22-vii-2010, 2♂♂ 2♀♀; 04-viii-2010, 1♂; 13-viii-2010, 1♀; 24-ix-2010, 1♂; 25-ix-2010, 1♂; 05--viii-2011, 1♀; 06-viii-2011, 1♂; 07-viii-2011, 1♂ 1♀; 08-viii-2011, 3♂♂; 27--viii-2011, 1♀.

The species collected most frequently and in the highest numbers was *Anax parthenope* (34.0 % of individuals, 32.9 % of records). Moderately frequent and numerous were *Lestes barbarus*, *Aeshna affinis*, *Orthetrum brunneum* and *Sympetrum pedemontanum*. Other species were collected sporadically and in low numbers of individuals. The Aeshnidae and Libellulidae were dominant in quantitative terms (46.4 % and 39.2 % of individuals, respectively), and the Libellulidae were dominant in qualitative terms (58.3 % of species).

The largest amounts of material were collected in the years 2011 (43.3 % of individuals) and 2010 (40.2 %). In 2007, 10.3 % of individuals were caught, and in the years 2008 and 2009 only 3.1 and 2.1 %. This does not correlate with air temperatures at the Fringilla station. 2008 and 2009 were the warmest with mean maximum daily temperature during the study of 16.3°C and 16.8°C, respectively, followed by 2007 with 16.0°C, 2011 with 15.8°C, and 2010 with 15.1°C. The correlation between mean annual air temperatures and the number of caught individuals, although statistically insignificant ($p > 0.05$), was strongly negative with $r = -0.844$.

The species analysed were recorded from the third decade of May to the third decade of September. The period of the strongest migration activity lasted for approximately one and a half months, from the second decade of July to the second decade of August. In this period, 74.2 % of the entire material was collected, and the highest number of species was recorded with five to six per decade (Fig. 3).

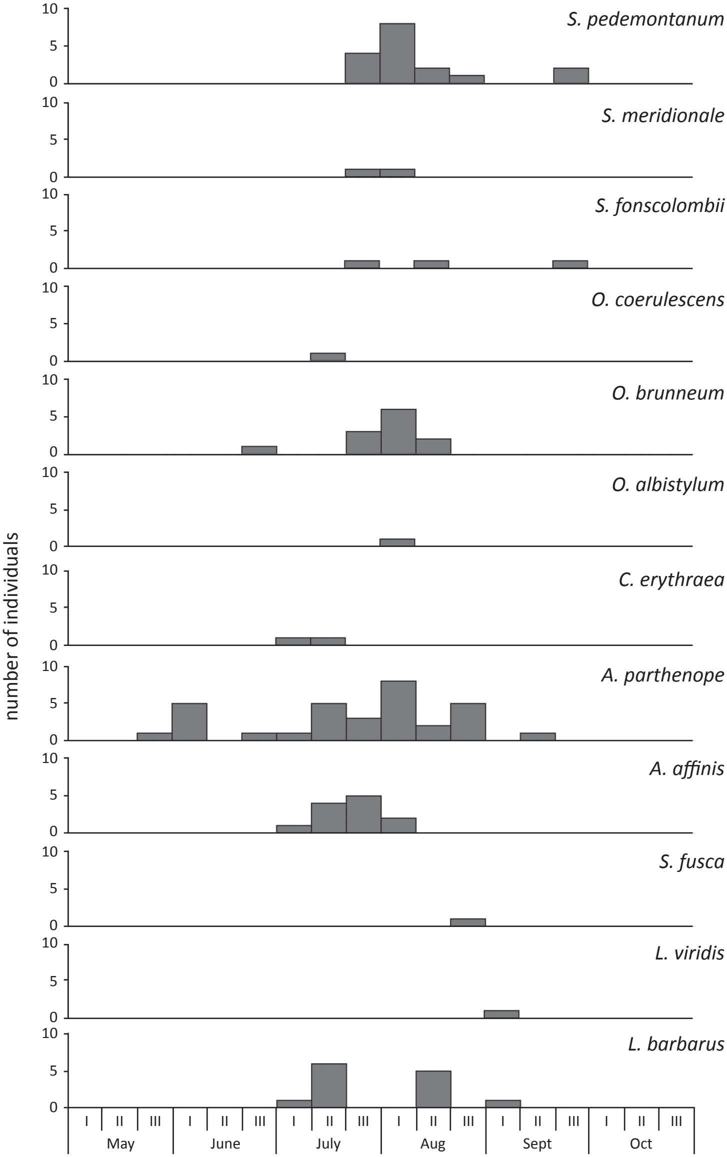

Figure 3: Phenology of species recorded between 2007 and 2011 in ornithological traps on the Courish Spit. Vertical axis: number of individuals, horizontal axis: months and decades. – Abbildung 3: Phänologie der Arten, die in den Jahren 2007-2011 in Vogelreusen auf der Kurischen Nehrung gefangen wurden. Vertikale Achse: Artenzahl, horizontale Achse: Monate und Dekaden.

Maximum air temperatures recorded in the study period ranged from 2 to 31°C. The dragonfly species studied were caught between 17 and 31°C. The number of individuals increased along with an increase in temperature. At temperatures between 17 and 20°C, it averaged 0.06 individuals per day, with 0.23 individuals at 21-25°C, 0.56 individuals at 26-30°C, and as many as 3.25 individuals at > 30°C.

The value of the coefficient of correlation between air temperature and number of dragonflies collected, calculated for the entire material and study period, was very low: $r = 0.26$ ($p < 0.05$). In the scope of temperatures favouring migrations (17-31°C), the correlation was moderately strong ($r = 0.68$, $p < 0.05$). No statistically significant correlation between air temperature and number of collected individuals of specific species was observed.

Discussion

Our data constitutes a substantial supplement to knowledge regarding the dragonflies of the Kaliningrad Oblast, an area very neglected in terms of studies of this group of insects. Until recently, the main sources for data on dragonflies were still the papers by La Baume (1908), and, most importantly, by Le Roi (1911). They were not always analysed in detail. Although they concern an area stretching from contemporary northern Poland to the Baltic countries, the number of 53 species mentioned by Le Roi (1911) was sometimes attributed to the Kaliningrad Oblast itself. The older period of the studies was critically summarised by van Tol et al. (2004), who list 50 species for the region.

The record of an individual of *Coenagrion armatum*, collected in Kaliningrad (Königsberg) by A. Gundlach in the first decade of the 20th century, is also of historical significance (Bönsel & Kühner 2000).

The history of contemporary studies was initiated by papers regarding the peat bog of Zehlau near Pravdinsk (Lewandowski 1996) and dragonflies collected in ornithological nets on the Courish Spit, with *Sympecma fusca* and *Anax parthenope* new for the Oblast (Bertram & Haacks 1999). Extensive data is only provided in publications by Tumilovich (2007, 2008, 2009a, 2009b, 2010). These are the first systematic studies, conducted during several years, for more than a century (Tumilovich 2009b), and include the first records of four species in the Kaliningrad Oblast, viz *Lestes viridis*, *Ceriagrion tenellum*, *Sympetrum depressiusculum* and *S. fonscolombii* (Tumilovich 2009a, b). The record of the western European *C. tenellum*, however, is probably a mistake. Its occurrence in the Kaliningrad Oblast is very unlikely. Its expansion has been observed lately, but hitherto the nearest site of collection of a single individual was Brandenburg in north-eastern Germany, approximately 350 km to the west from the Kaliningrad Oblast. Autochthonous populations of the species are located even further to the west, by 50-85 km (Brauner 2009). Moreover, if there was an expansion towards the east, *C. tenellum* would have been recorded earlier in Poland, which was simultaneously intensively researched during the work on "A distribution atlas of dragonflies

(Odonata) in Poland" (Bernard et al. 2009). This did not happen. Finally, after publication of the paper by Tumilovich (2009b), PB together with Rafał Bernard asked the author to provide documentary proof of the record. To date they have not received this, except for a photograph of an imago from a British website. Doubts are also cast by other elements of the paper by Tumilovich (2009b), e.g., for modern standards of faunistic studies, the extremely low number of species recorded during four years (31), or lack of record of *Coenagrion puella*, which is common in all neighbouring countries. Due to this, the records of *L. viridis*, *S. depressiusculum*, and *S. fonscolombii* by Tumilovich (2009b) should also be treated as probable, but requiring confirmation. Accordingly, confirmation is provided herewith for the records of *L. viridis* and *S. fonscolombii*.

The dragonflies of the Kaliningrad Oblast are also treated in the monograph by Skvortsov (2010). This data is not easy to analyse. Some of the markings on the maps are equivocal, and it is not always certain what was recorded in the area, and what was not recorded, but should occur according to the author. *Sympecma paedisca* and *Sympetrum striolatum* were recorded for the first time. *Lestes parvidens*, marked as an uncertain species, arouses doubts. It is a southeastern European damselfly, known from southern Slovakia as the closest site (Olias 2005), while *L. viridis* was omitted. However, it is a species reported by Tumilovich (2009a, 2009b), and recorded regularly in neighbouring regions of Poland (Bernard et al. 2009). The second doubtful species is *Cordulegaster bidentata* – a dragonfly typical of mountains and foothills, which finds no convenient habitats in the lowland landscape of the Old-Prussian Plain. Its closest occurrence is recorded in the Świętokrzyskie Mountains in central Poland, almost 400 km to the south from the borders of the Kaliningrad Oblast. This follows information from Spuris (1964), who probably cited the data after Le Roi (1911). However, Le Roi (1911) reported *Cordulegaster boltonii* from Krasnolesye (Rominten) in the Romnicka Forest, and Spuris (1964) probably made a mistake in citation. *Cordulegaster boltonii* was also lately recorded in the Polish part of the Romnicka Forest (Bernard et al. 2009).

Data on the dragonflies of the Kaliningrad Oblast also has been published in hydrobiological papers, but the larval identifications these records are based upon are often very doubtful. For example, Shibaeva et al. (2011) reported larvae of *Ischnura pumilio* and *Libellula depressa* from the littoral of lakes. Those are pioneer species, typical of anthropogenic water bodies, e.g. sand pits and clay pits, and in the case of *L. depressa*, also ecologically strongly disturbed fish ponds. However, Shibaeva et al. (2011) do not list two common species occurring numerously in lakes, viz *Ischnura elegans* and *Libellula quadrimaculata*. In our opinion, this suggests identification mistakes.

Therefore, the number of certain or probable dragonfly species reported from the Kaliningrad Oblast so far amounts to 57. Our data extend it to 63, by six species, namely *Aeshna affinis*, *Orthetrum albistylum*, *O. brunneum*, *O. coerulescens*, *Crocothemis erythraea*, and *Sympetrum meridionale*. Other species recorded by us were so far known only from single, or at most several sites (La Baume 1908;

Le Roi 1911; Lewandowski 1996; Bertram & Haacks 1999; Tumilovich 2009a, 2009b).

The dragonfly species caught by us mainly belong to the Mediterranean (refugial) element of the European fauna sensu St. Quentin (1960). In detailed division, they represent the following elements: common Mediterranean, Atlantic-Mediterranean, Pontian-Mediterranean, and Pontian-Caspian. Only *Sympetrum pedemontanum* is a Siberian dragonfly (Bernard et al. 2009). The Kaliningrad Oblast is also located at the boundaries of distribution of all of them, although the significance of their records at the Fringilla station for knowledge concerning them is of varied importance.

Records of *L. viridis*, *C. erythraea*, *O. albistylum* and *S. meridionale* determine their new boundary of distribution, or at least migration in Central Europe. Until now, they have been reported from northern Poland as their furthest north (Bernard et al. 2009). For *L. viridis*, *O. albistylum* and *S. meridionale*, the Fringilla station is currently the northernmost European site, and for *C. erythraea* the second northernmost after the isolated record in the Yaroslavl Province in Russia (Skvortsov 2010). For *Sympecma fusca*, the Fringilla station is the northernmost site in the eastern part of the Baltic coast, along with two sites in Lithuania (Gliwa & Stukonis 2011). Further north, it has only been recorded in southern Sweden (Jödicke 2006).

For *A. affinis*, *O. brunneum* and *O. coerulescens* the Kaliningrad Oblast is located within a forecasted or already confirmed migration range. *Anax parthenope*, in turn, develops in lakes of southern Lithuania, and in 2008 its development was observed in the south of Latvia (Kalniņš 2008, 2011; Tumilovich 2009a, 2009b; Skvortsov 2010). It was also found in Sweden (Schröter & Karjalainen 2009). For other species only single or few sites from Scandinavia are known further to the north: for *S. fonscolombii* from southern Finland (Sudenkorento.fi 2011), for *A. affinis* and *S. pedemontanum* from Finland and Sweden (Schröter & Karjalainen 2009; Billqvist & Heitzenberg 2010; Lejfelt-Sahlén 2011; Sudenkorento.fi 2011).

The case of *Lestes barbarus* is interesting. The species has been known from the Kaliningrad Oblast since as early as the first half of the 19th century (Hagen 1846). Rapid expansion of the dragonfly's range is not observed, but frequency of its occurrence in the northern part of the area increases (Bernard et al. 2009).

One question that arises is where dragonflies collected at the Fringilla station do come from. The location of the station at the Baltic coast, its location in relation to the areas of occurrence of the species, and scarcity of surface waters in its vicinity exclude the indigenous character of the species analysed, and suggest their medium- and long-distance migration from a southerly direction. Migration from outside the Kaliningrad Oblast is also indicated by lack of correlation between general temperature conditions at the Fringilla station in a given study period and number of individuals collected. The observed correlation with daily temperature mainly results from an increase in activity of dragonflies at a given moment along with an increase in temperature. The most probable source of migration is Poland.

In the nearby, northern part of the country *A. parthenope* is very numerous, and indigenous populations of other species like *L. barbarus*, *L. viridis*, *S. fusca*, and *S. pedemontanum* are regularly recorded. For the remaining species, the migration source would be central or southern Poland (Bernard et al. 2009; Buczyński et al. 2010; Buczyński 2011). Migration from the Czech Republic and Slovakia, located further to the south, is strongly limited by the barrier of the Carpathians. Migration from Ukraine is possible, along the Bug and Narew River valleys.

It is highly probable that the eastern coast of the Baltic Sea constitutes a permanent route of dragonfly migrations. This is suggested not only by the high number of migrating species collected by us, but also by earlier data from the Fringilla station (Bertram & Haacks 1999) and from the Pape station in south-western Latvia (von Rintelen 1997). Considering the close vicinity of the Fringilla station to the Latvian border, dragonfly researchers of the country should pay special attention to the Baltic Sea coast, particularly in terms of appearance of species analysed by us.

The species analysed in this paper were probably involved in individual migrations related to dispersion. No mass migrations in the initial outbreak period were observed, either related to overpopulation (Corbet 1999), or obligatory autumn migration, described e.g. for *A. parthenope* and *S. fonscolombii* by Borisov (2010).

In view of the data presented in this paper and literature on the subject (Baccetti et al. 1990; von Rintelen 1997; Bertram & Haacks 1999; Borisov 2009), ornithological nets – particularly Rybachy type traps – are an effective tool of studies on migration of Anisoptera. This suggests the need for systematic cooperation of odonatologists with ornithologists, which can result in valuable data that is difficult to obtain in other ways.

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