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Is *Aquarius najas* (Heteroptera: Gerridae) bivoltism possible in central Poland ?

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ABSTRACT. *Aquarius najas* (DE GEER, 1773) has a univoltine life cycle above the latitude of 53°47' N, (BRINKHURST 1966) but may be bivoltine in warmer climates. On the Grabia River (51°34' N; 19°15' E) in central Poland its life cycle is probable partially bivoltine. The peak abundance of overwintering adults occurs in late April. The first early summer generation occurs from May till November. Second generation nymphs appear in August and September and overlap with later instars of the first generation. Only the first three instars of the second generation are present, and it is unlikely that adults of the second generation were produced. Because only adults are present in early spring, this indicates that nymphs of the second generation do not overwinter.

KEY WORDS: *Aquarius najas*, life cycle, water striders.

INTRODUCTION

Pterygopolymorphism and life history are strongly correlated with geographical distribution in many European water strider species (VEPSÄLÄINEN 1974) but these also appear to be dependent upon habitat diversification at a local scale (PFENNIG & POETHKE 2006). Factors thought to influence nymphal growth rate and morphology include food limitation, climatic conditions and photoperiod (BLANCKENHORN & FAIRBAIRN 1995, BLANCKENHORN 2006) but pterygopolymorphism in some species is determined by genetics at the population level (AHLROTH et al. 1999).

The population dynamics of *A. najas* have been described in detail by BRINKHURST (1966) and KURZĄTKOWSKA (2007) in different parts of its range. On Lake Windermere

(Britain) and in northern Poland it is univoltine. Despite Brinkhurst's (1966) study which was carried out over nine years, in a favourable environmental locality for observing this mobile insects, his results cannot be easily transferred to all *Aquarius najas* populations because it was carried out in an untypical habitat for the species. This large pond-skater is a reophilic species, rarely living on lakes in isolated populations within boathouses. BRINKHURST'S (1966) investigation was also carried out near the northern limit of the species' distribution. WRÓBLEWSKI (1980) suspected that in Poland, where conditions are more favourable, a second generation of this species may occur. KURZĄTKOWSKA (2007) found *Aquarius najas* had one generation divided into two main cohorts coming from two batches of egg-laying. Her studies took place in a northern, cold climatic region of Poland. An unrelated investigation made in Central Poland, where the climate is warmer and photoperiod related to a different latitude, is here presented. The aim of this study is to test the hypothesis that *Aquarius najas* has a bivoltine life cycle in central Poland.

Study area

An investigation was carried out on the medium sized (81 km long) lowland Grabia River. It is a natural, mostly unregulated river. In the middle sections it has numerous old beds and reservoirs attached. The slope of 0,9 m/km is moderate for a lowland river. Mean discharge is 5,75 $dm^3/s \cdot km$. The Grabia River basin catchment covers 819,5 km^2 of agricultural and forested area (MAKSYMIUK 1970, SICIŃSKI & TOŃCZYK 2005).

Central Poland has a moderate climate. Thermal summer takes 90-100 days. Mean temperature in July is 18°C, winters are mild (mean temperature in January is - 2°C) and precipitation is about 550 mm a year, the highest rainfall being in summer (MARTYN & OKOŁOWICZ 1978, OKOŁOWICZ 1978, WISZNIEWSKI 1978). In last century summer mean temperature in central Poland rose on 0,3 °C and vegetation season got longer on 5 days (OLSZEWSKI & KICIŃSKA 2008). Samples were collected in the river's middle section at Zimne Wody's (51º40´N; 19º10´E). The width of the river there is about 9 m. The river banks project 0,8-0,6 m above water level. They are overgrown by meadow riparian vegetation – mostly grasses (*Phalaris arudinacea*) and some trees: alders (*Alnus glutinosa*) and willows (*Salix* sp.). Mean current velocity on this site is 0,1 - 0,4 m/s.

Material and methods

The samples were collected from April to November 2002, fortnightly except from 24 May - 18 June because of flooding conditions in half of June. On each visit 20 quantitative samples were taken: 10 for imagines and 10 for nymphs. Sites were chosen by presence of pond-skater aggregation. Samples were collected by hand net (0,5 m wide with a square frame) by sweeping approximately 1m. All samples were collected by the same person (first author) and are comparable semiquantitative. Insects were preserved in 4% formaldehyde. Altogether, 280 samples including 514 imagines and 1307 nymphs of *A. najas* were collected. Density of water striders was calculated as a sum of 10 sweepings of larvae and sum of 10 sweepings of imagines.

RESULTS

Aquarius najas formed aggregations in places where floating prey derived from the nearby bushes, trees or banks accumulated in small bays. Imagines preferred the lotic parts of the river, while nymphs preferred lentic sections. There were two generations of this insects (Table 1). After the spring peak in abundance nearly all imagines formed copulating pairs, and the density of adults in each aggregation during the following month decreased from about 100 specimens/10 sweepings (25.IV) (Table 1) to 28 specimen/10 sweepings (24.V). This trend was maintained until 18 June when density of imagines reached only 5 specimen/10 sweepings. This low abundance occurred during the first week after the floods on the Grabia river. The first instars nymphs appeared in the second half of May. The period of highest abundance of the first instar nymphs was missed in this study. On 24.V abundance of first and second instars achieved respectively: 153 specimens/10 sweepings and 496 specimens/10 sweepings. Third instar nymphs were collected at first time from 18 June (35 specimens/10 sweepings). Their abundance exceeded 58 specimen/10 sweepings in 30.VI (Tab. 1, Fig. 1). The end of the June was also the period when fourth and fifth instar nymphs were found in greatest numbers (107 specimens/10 sweepings and 106 specimens/10 sweepings). On 11 July the number of fifth instar nymphs reached 165 specimens/10 sweepings. At that time, the number of nymphs belonging to the early summer generation consequently decreased. In July the number of imagines increased from 54 to 69 specimens/10 sweepings and maintained around this level to 28.VIII. After two months of absence, the first instar nymphs appeared on 15.VIII. Correspondingly the abundance of second instar nymphs, after the absence on 25.VII, increased on 15-28. VIII. Third instar nymphs also appeared in late August, with their density increasing to 23 specimens/10 sweepings by 11.IX. The number of fourth instar nymphs increased in second part of August followed by a decrease, they were also present on 04 November. Fifth instar nymphs slightly increased on 11.IX. This was also the moment when the number of imagines was the lowest since 18.VII. Then they increased for a short time and almost disappeared on 04.XI. Most specimens of *Aquarius najas* were apterous. Only two macropterous females were caught on 25th April and 11th July as well as one brachypterous female caught on 11th July.

Table 1. Density of *Aquarius najas* developmental life stages on conglomeration per 10 net sweeping in subsequent sampling date.

Life stage	12.04	25.04	13.05	24.05	18.06	30.06	11.07	25.07	15.08	28.08	11.09	02.10	27.10	04.11
I	0	0	0	153	0	0	0	0	1	0	0	0	0	0
II	0	0	0	496	3	21	1	0	2	4	0	0	0	0
III	0	0	0	0	35	58	8	12	3	13	23	1	0	0
IV	0	0	0	0	0	107	11	8	12	16	4	6	0	1
V	0	0	0	0	0	106	165	9	13	1	3	2	0	0
Imag.	18	99	31	28	5	27	54	69	36	71	11	37	25	3

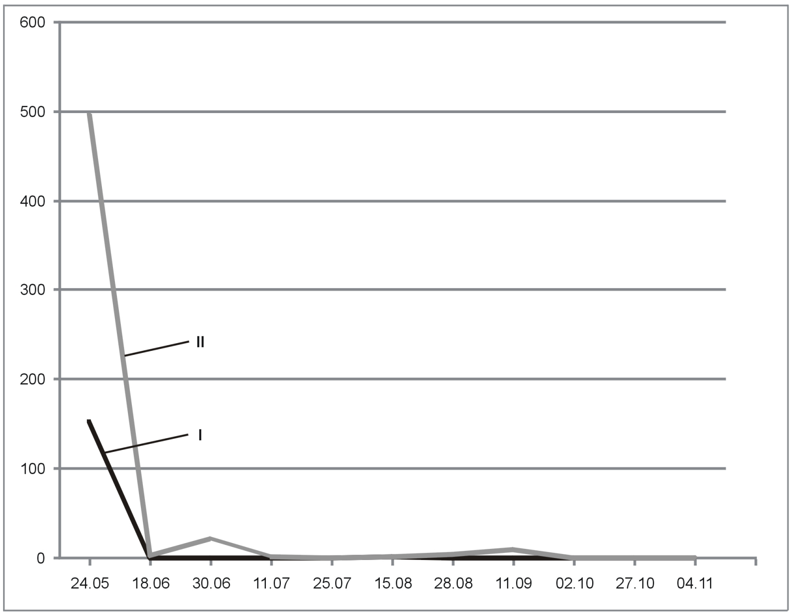

Fig. 1a. *Aquarius najas* life cycle - occurrence of nymphs instars and imagines: I and II instar nymphs occurrence.

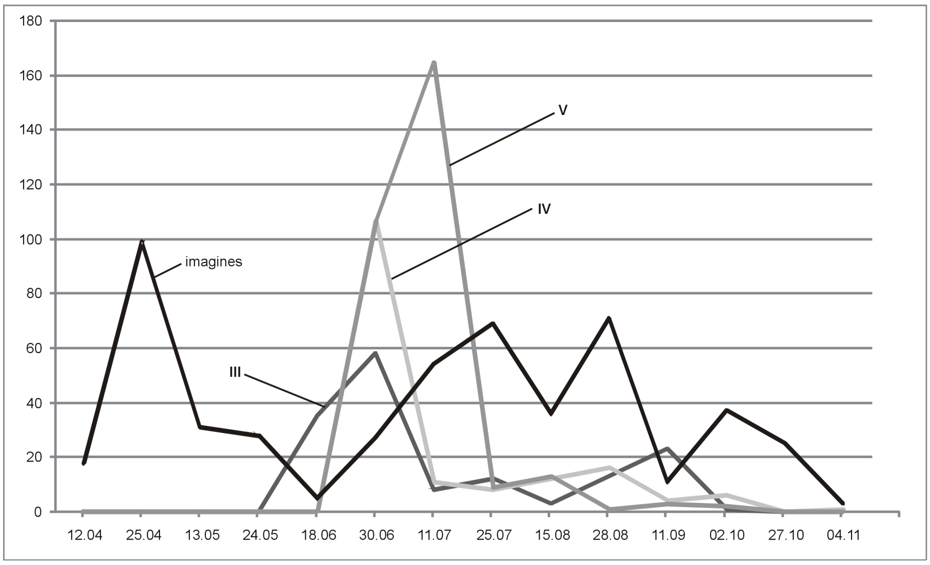

Fig. 1b. *Aquarius najas* life cycle - occurrence of nymphs instars and imagines: III, IV, V instar nymphs and imagines occurrence.

DISCUSSION

It is considered that life cycle of *Aquarius najas* in northern Europe (BRINKHURST 1966, VEPSÄLÄINEN 1974) is univoltine, but WRÓBLEWSKI (1980) suspected that there may be two generations in Poland. Occurrence of females with eggs from April to August, nymphs from July until October, along with the length of development of eggs and larval stage indicate that possibility (WRÓBLEWSKI 1980). If the development of *Aquarius najas* from egg to imago takes not less than 70 days, (WRÓBLEWSKI 1980) it means that first instar nymphs, which developed on 15.VIII (Table 1), may come from eggs laid by females belonging to the early summer generation. It also means that in favourable conditions they could transform into imagines by November. On Lake Windermere *Aquarius najas* life cycle is univoltine. The generation time took about two months (50 - 70 days). Females of the overwintering generation die shortly after egg-laying, before the nymphs begin to emerge, however first instar nymphs hatch continuously throughout a 3 month period. There were two peaks in nymph abundance separated by one month due to eggs being laid in two batches (BRINKHURST 1966). On the Grabia River, specimens of the first generation remained for about two months. Here also two peaks of nymphs of the first two instars, separated by more than one month, was found (Table 1), however this was not visible among other instars. The second abundance peak was not as significant as the first one. There is a possibility that the second generation of nymphs (15.VIII - 04.XI) comes from the second batch of overwintering females. The time between the first appearance of first instar nymphs and second instar nymphs takes more than two months, but first instar nymphs might be overlooked. According to BRINKHURST (1966), they should be the last emerged specimens, but on 28.VIII and 11.IX on the Grabia River a peak of abundace of second and third instar nypmhs, was noticed 100 days after first nymphs was recorded. The nymphs of *Aquarius najas* appeared on the River Grabia in spring at least two weeks earlier than on Lake Windermere, so they were present on the river for over 150 days. It means that a second, residual generation could has developed. Residual, because larvae of the second generation probably did not transform into imagines. Lower temperatures and a smaller availability of food in autumn makes development doubtful. One larva of the fourth instar was found on 04 November and none on 27 October. Fifth instar nymphs on 2 October could came from the second batch of the early summer generation. In spring, only imagines appeared. This means that imagines recolonising the river in spring belong entirely to the first, early summer generation. Later developed females of the first generation probably did not start reproduction because of environmental conditions (short photoperiod, decreasing temperature or food limitation). KURZĄTKOWSKA'S (2007) investigation shows that the peak of abundance of the overwintering generation takes place two months later on Mazury Lakeland. On the River Grabia there were two peaks of abundance of early the summer generation and it was earlier than on Mazury Lakeland (by one to two months compared with the studied section of the River Łyna). On the River Łyna, the starting time of winter hibernation is also earlier. On forested sections of the river valley the last imagines were found on the water in the beginning of October, on the studied section gerrids lasted until late autumn (KURZĄTKOWSKA 2007). It appears that on the Łyna, the life cycle of *Aquarius najas* is univoltine, and the two main cohorts of nymphs come from two bouts of egglaying. The life cycle of *Aquarius najas* starts there about two months later than in central Poland. KURZĄTKOWSKA'S (2007) investigation took place in the coldest region of Poland. Thermic summer is 20 days shorter there and the July mean temperature is 1 ºC degree lower than in the central part of Poland. Also the mean annual temperature is 1 ºC lower and winters are 20 days longer (OKOŁOWICZ 1978). Our investigation on the River Grabia suggests that in the southern distributional range of *Aquarius najas* two generations of this species are completed, similar to the closely related species *Aquarius remigis* on the East Coast of North America. In this species photoperiod and genetic differentiation drive voltinism. A population of intermediate (New York) latitude shows higher diversity, longer oviposition and longer female longevity than the southern (New Jersey) and northern (Quebec) populations. However, development time was shorter in the northern, univoltine population (BLANCKENHORN & FAIRBAIRN 1995). Populations of *Aquarius najas* which developed on the River Grabia might be genetically determined to bivoltism and photoperiod might allow the development of larvae of the second generation, but lower temperatures and food limitation in autumn prevent transformation into imagines (VEPSÄLÄINEN 1974, BLANCKENHORN 1994). However, the cause of voltism of *Aquarius najas* is still unknown. ALTHORN et al. (1999) found correlation between higher number of winged forms and southern short daylength conditions. They also indicateed higher mortality of winged forms during overwintering. It is probable that potential bivoltinism and a higher proportion of winged forms in southern regions may be advantageous to gerrids living in temporary rivers. High habitat instability during drought may favour specimens capable of moving between watercourses and reproducing in new localities. However, having found few macropterous specimens in the early-summer generation, it is unknown if they reproduce in the same year. Partial bivoltinism was also found among other species of Gerridae and local environmental conditions (like forestry at the reservoir edge) were shown to influence the life cycle of water striders (HAUSER 1982, FAIRABAIRN 1985, PFENNING & POETHKE 2006, KURZĄTKOWSKA 2007). Favourable conditions for a full second generation development in autumn in central Poland appear very rare. This local habitat is considered to be favourable when compare to other flowing waters in the region. It seems that a univoltine life cycle in *Aquarius najas* may appear on the Grabia River as well during years with more rain and with lower mean temperature. Research on population dynamics of Gerridae is often based on laboratory investigations (BLANCKENHORN & FAIRBAIRN 1995) or on investigations which takes place in semi natural conditions (BRINKHURST 1966). This mitigates against migrations, problems with mobility of insects and their tendency to hide or escape, so results are more precise. On the other hand, investigations in typical, natural habitats are also necessary because experimental conditions are always far from natural, however results are usually less precise. Here, the first instar nymphs were missed. The amount of imigration is also unknown. Changes in gerrid species assemblages and density show that migration occurs in early spring, but assemblage composition remains stable from 13 May until autumn. The date of appearance of nymphs and fluctuations in imagines density is not indicative of migration alone. Analysis suggests that changes in the density of imagines and nymphs is associated with the life cycle.

Our investigation don't give certain results. It is unambiguous, if the flood on first half of June did not bring to pass gap in the oviposition caused by shift of some adults into terrestrial conditions. Such gap can also induce "phenology with two peaks of nymph occurrence" and temporary shift of last younger nymphs into conditions that are not favorable for successful finish of development. However in authors opinion the investigation shows rather that *Aquarius najas* in central Poland may have one, full, diapausing generation and a second partial generation, in which nymphs do not transform into imagines to natural river conditions. The study indicates that bivoltinism of this species in southern latitudes is possible.

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