Presence of exuviae as an indication of successful reproduction of dragonflies (Odonata) in the "Overasseltse- en Hatertse vennen"

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Abstract: The observation of immature adult dragonflies (Odonata) or activities such as mating and egg-laying can be seen as an indication of successful reproduction of that species. However, only the presence of exuviae can be considered a real confirmation. Exuviae were sampled in 23 heathland pools of the nature reserve the "Overasseltse- en Hatertse vennen", The Netherlands, to determine successful reproduction. Secondly, the presence of exuviae was related to the water quality of the pools as measured by the pH.

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Introduction

In 23 heathland pools, belonging to the "Overasseltse- en Hatertse vennen", southwest of Nijmegen, The Netherlands, an ecological research was carried out in 1985 (Peters et al., 1985). The main objective of this research was to assess the possibility of classifying dragonflies into "communities". The research was continued to establish the real importance of the heathland pools as breeding sites for dragonflies: which species do in fact reproduce in the pools? The duration of the aquatic stages of dragonflies varies from several months to some years, whereas the reproduction phase normally lasts up to two months. The teneral adult sexually matures at some distance from the water in which it developed as a larva and may return to it after a week or two. This maiden flight may take the adult only a few yards from its breeding site, as in some Zygoptera, or it may be extended into a prolonged migration, as in some Anisoptera. An important function of the maiden flight is to take the young dragonfly out of the sphere of activity of sexually active males, so that it may feed and develop without harassment. The adults seldomly return to the place where they emerged (Geijskens & Van Tol, 1983). This could be a strategy to enlarge their distribution. For these reasons the observation of adults, even when they display reproductive behaviour, does not always indicate successful reproduction; only the presence of exuviae can be used to establish successful reproduction.

A second objective was to investigate whether a relation exists between the presence of exuviae (successful reproduction) and water quality. Some parameters of water quality, such as anions, cations, (heavy) metals, are related with the pH in weakly buffered waters (Leuven & Schuurkens, 1984). Therefore the pH can be used as a representative measure of the water quality. However, many other factors, such as soil and structure of the vegetation, may also be involved.

Methods

The nature reserve "Overasseltse- en Hatertse vennen" covers 450 ha, mainly forested area (*Pinus sylvestris* L.). A map showing the location of the 23 pools is presented in figure 1. Originally the pools are acid, oligotrophic and surrounded by forest, heath and cultivated land. The last few years the pools have become

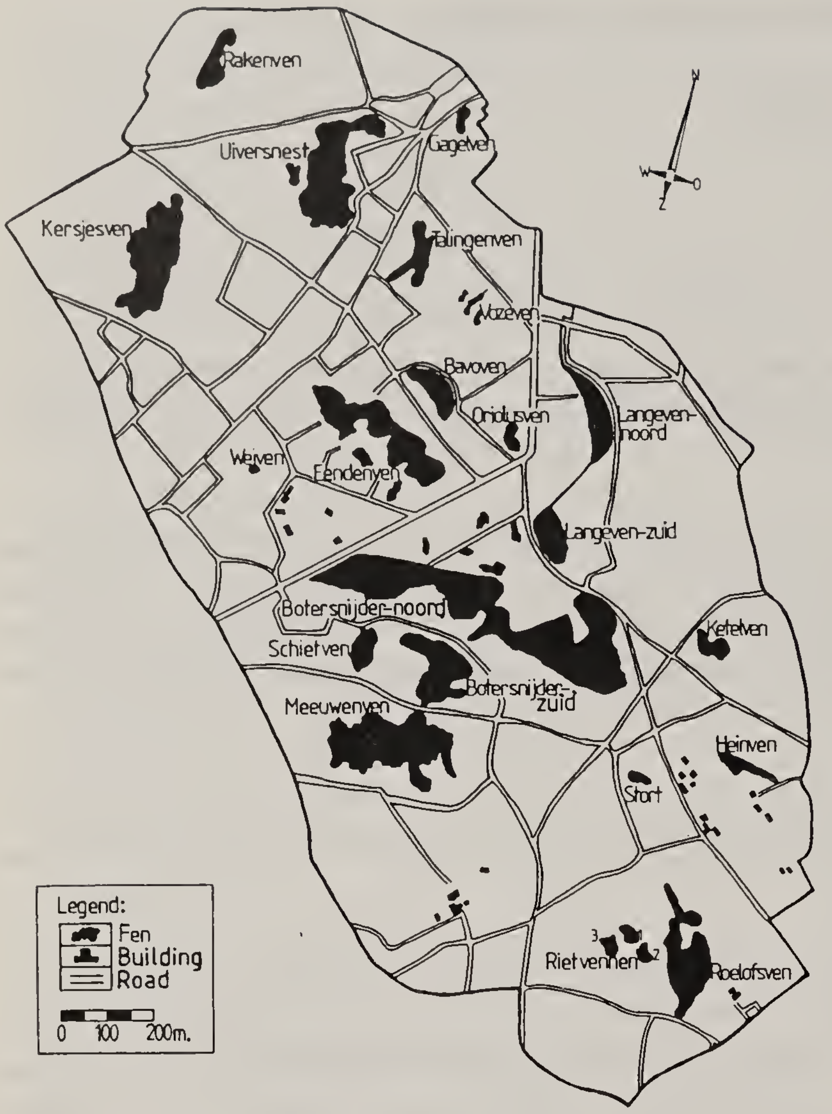

Fig. 1. Location of the 23 heathland pools of the "Overasseltse- en Hatertse vennen".

more acid (Kersten, 1985b). Due to the presence of a loam layer, which prevents ground water from entering the pools, the water levels of the pools fully depend on precipitation. Therefore some of the pools occasionally may dry up, which may effect both the reproduction of dragonflies and the water quality.

From 8 May till 10 October 1986 the shores of the pools were searched for the presence of exuviae. The pools were visited frequently; on an average 16 times and during 600 minutes. In 1987 some additional data were collected.

Identification of the exuviae was often possible in the field when the teneral adults were just emerging from their exuvial skin (figs 2, 3). In cases where only exuviae were found they were collected for later identification, using several keys to larvae (Carchini, 1983; Gardner, 1983; Geijskens & Van Tol, 1983). From each pool at least one exuviae of each species was collected as a reference.

Data on water quality (pH) were collected in March and April 1984 (Kersten, 1985a). However, the pH of the "Gagelven" and "Vozeven" was measured in 1986 (Peters, 1988).

Results and discussion

Presence of exuviae and adults

Table 1 presents the Zygoptera and Anisoptera, of which adults or exuviae were observed in the "Overasseltse- en Hatertse vennen" in the period 1985-1987. Also the pH-values are given for each of the pools, which are arranged according to decreasing acidity.

Since 1950 a total of 58 adult species were recorded in The Netherlands (Geijskens & Van Tol, 1983). In the "Overasseltse- en Hatertse vennen" a total of 36 species was observed. Exuviae were found of 24 species. This means that at least 40% of the species recorded in The Netherlands reproduce successfully and that more than 60% of the Dutch species were observed in this nature reserve.

However, if no exuviae were found in a particular pool, it cannot be concluded that the species dit not reproduce successfully in this pool. There are a number of reasons why lists of species with observed exuviae will probably be very incomplete. Some of the pools were not easily accessible for the investigator ("Gagelven", "Rakenven", "Stort"). Furthermore, the length of time spent in the larval stage may vary much according to species and environmental conditions, from a few months up to five years (Askew, 1988).

In the "Schietven", for example, exuviae of *Lestes sponsa* and *Sympetrum danae* were found in 1987, when only a few visits were made to this pool. Exuviae were not observed in 1985 and 1986, when this pool was visited for six days (180 minutes) and for 14 days (545 minutes) respectively. Moreover, in both 1985 and 1986 reproduction activities, such as mating and egg-laying, were frequently observed in the "Schietven". Another possible explanation for the probable absence of *L. sponsa* and *S. danae*, might be the presence of large numbers of larvae of *Aeshna juncea*, a species which is highly predatory; adults hunt among others

Fig. 2. Exuviae and teneral adult of *Aeshna juncea* observed in the "Schietven".

species of *Lestes* and *S. danae* (Lieftinck, 1926, in Geijskens & Van Tol, 1983). Askew (1988) also indicates that the dragonfly larva itself is subject to predation, particulary from fish but also from larger dragonfly larvae.

Exuviae of *Sympetrum striolatum*, due to their bad conditions of conservation and their similarity with *Sympetrum vulgatum*, were hard to identify with certainty, even with the use of a stereomicroscope. This could be the reason why they are hardly present in table 1. Heidemann and Seidenbusch (1993) also indicate that the identification of these *Sympetrum* species can be problematic. Askew (1988) even mentions that larvae of most European Odonata are recognizable to the genus, but that identification to the species level can be very difficult. Specific characters of many larvae, particularly those in the larger genera, have not yet been satisfactorily worked out and there are contradictory statements in the literature.

It must be concluded that the number of pools in which successful reproduction was

Fig. 3. Exuviae and teneral adult of *Lestes viridis* observed in the "Ketelven".

established for a particular species, will be an underestimation. In most dragonflies studies, conclusions on the (successful) reproduction of species are therefore only based on observations of mating, egg-laying and tenerals. However, it's true that the presence of exuviae is the best indication of successful reproduction. Also Heidemann & Seidenbusch (1993) assert that only the presence of exuviae proofs that the corresponding species has settled and developed in that biotope and was not merely a temporary visitor, even when displaying reproduction activities.

pH and presence of exuviae

The presence of some species seems to be restricted to acid waters with a pH < 4.1. Table 1 shows that in particular *Leucorrhinia dubia* and *L. rubicunda* seem to reproduce successfully in such pools, but also exuviae of *Coenagrion lunulatum, Aeshna juncea* and *Anax imperator* were mainly observed in very acid pools.

Exuviae of species such as *L. sponsa, S. danae* and *Libellula quadrimaculata*, were observed in most pool, indicating that these species can reproduce successfully in pools with various pH levels. However, in acid and oligotrophic pools, such as the "Botersnijdernoord", the numbers of exuviae and adults observed, were much larger than in less acid and metatrophic pools, such as "Heinven". These data are in agreement with results from

Table 1. Zygoptera and Anisoptera species (upper and lower part respectively) observed in the "Overasseltse- en Hatertse vennen" (○). If exuviae were also observed the symbol is ●. The pools are arranged according to decreasing acidity.
1 = Langeven-noord; 2 = Langeven-zuid; 3 = Rietven-2; 4 = Schietven; 5 = Bavoven; 6 = Kersjesven; 7 = Rietven-1; 8 = Meeuwenven; 9 = Rakenven; 10 = Rietven-3; 11 = Talingenven; 12 = Botersnijder-noord; 13 = Botersnijder-zuid; 14 = Uiversnest; 15 = Oriolusven; 16 = Gagelven; 17 = Eendenven; 18 = Ketelven; 19 = Vozeven; 20 = Roelofsven; 21 = Weiven; 22 = Heinven; 23 = Stort.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
pH	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.9	3.9	3.9	3.9	4.0	4.0	4.0	4.1	4.5	4.6	4.9	5.6	5.9	6.0	6.8	7.8
Calopteryx splendens (Harris)	○			○								○							○				
Lestes barbarus (Fabricius)							○														○		
L. dryas Kirby					○		○			○					○	○			○	○			
L. sponsa (Hansemann)	●	●	●	●	●	●	○	●	●	○	●	●	●	●	●	●	●	●	●	●	●	○	○
L. virens (Charpentier)				○	○						○	○		○			○	○					
L. viridis (Vander Linden)	●	●	○	○	●	●	○	●	○	○	●	●	○	●	●	○	●	●	○	●		○	○
Ischnura elegans (Vander Linden)	○	○	○	○	○	○	○	○	○	○	○		○	○		○	○	○	○	●	○	●	○
I. pumilio (Charpentier)																			○				○
Pyrrhosoma nymphula (Sulzer)	●	●		○	●	●	○	●	○	○	○	●	○	●	●	●	●	●	●	●	○	●	○
Enallagma cyathigerum (Charpentier)	●	●	○	●	●	●	○	●	○	○	●	●	●	●	●	○	●	●	○	●	○	●	○
Coenagrion lunulatum (Charpentier)	●	●		○	●	●		●			●	●	○	●	●		●	○	○	○		○	○
C. puella (Linnaeus)	○	●	○	○	●	○	○	○	○	○	○	○	○	○	●	○	●	●	●	●	○	●	●
C. pulchellum (Vander Linden)		○	○	○	○	○	○		○	○	○			○	○		○	○		●		●	○
Erythromma najas (Hansemann)																				●			
E. viridulum (Charpentier)	○					○					○			○									
Ceriagrion tenellum de Villers						○																	
Brachytron pratense (O. F. Müller)		○	○	○	○	○		○	○	○	○	○		○	○	○	○	○		○		○	
Aeshna cyanea (O. F. Müller)	●	●			○	○	○	○	○		○	●	○	●	●	●	●		○	●			●
A. grandis (Linnaeus)	○	○	○	○	○	○	○	○	○		○	○		○	○		○	○		○	○		
A. juncea (Linnaeus)	●	○	●	●	●	○	●	●	○	●	●	●	●	●	●	○	●	○	○	○	○	○	○
A. mixta Latreille	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○	●	○	○	○	○	○	○
Anax imperator Leach	●	○	○	●	●	○	○	○		○	●	○	●	●	○		○	●		○	○	○	○
Cordulia aenea (Linnaeus)	●	○			○	○		○	○		●	●	○	●	●		○	●	○	●		○	
Somatochlora metallica (Vander Linden)	○	○										●		○						●		○	
Libellula depressa Linnaeus				○			○		○					○		○			○		○	○	○
L. quadrimaculata Linnaeus	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●	●	●	●	●	○	○	○
Orthetrum cancellatum (Linnaeus)	○	○		○		○	○	●	○		○	●	●	○			○		○	●	○	○	○
Sympetrum danae (Sulzer)	●	●	●	●	●	●	●	●	○	○	●	●	●	●	●	○	●	●	●	●	○	○	○
S. flaveolum (Linnaeus)	○	○	○	○	○	○	○	○	○	○	○	○						○	○	○	●	○	○
S. pedemontanum (Allioni)																				○			
S. sanguineum (O. F. Müller)	○	○	○	○	●	○	○	○	○	○	○	●	○	○	●	○	●	●	○	●	●	●	●
S. striolatum (Charpentier)	○	○		○	○	●		○	○	○	○	○	○	○	○	○	○	○	●	○			○
S. vulgatum (Linnaeus)	○	○	○	○	○	○	○	●	○	○	○	●	○	○	●	○	○	●	●	●	○	●	○
Leucorrhinia dubia (Vander Linden)	●	○	○	●	●	●	●	●	○	●	●	●	●	●	●	○	○	○	○	●	○	○	○
L. pectoralis (Charpentier)											○			○	○		○	○					
L. rubicunda (Linnaeus)	●	●		●	●	●		●	○		●	●	○	●	●	○	○	○	○				
Total ●	13	10	4	8	13	11	4	12	1	3	11	16	8	13	15	4	12	11	7	17	3	7	3
Total ○	25	25	17	25	25	26	22	23	23	19	27	25	20	28	23	19	25	24	24	27	18	22	22

Huijs & Peters (1983) and Hermans (1992). Also species such as *Lestes viridis, Pyrrhosoma nymphula, Coenagrion puella, Cordulia aenea* and *Sympetrum sanguineum* were observed in pools with various pH levels (3.7-5.9).

Exuviae of *Coenagrion pulchellum* and *Ischnura elegans*, both species with a preference for eutrophic waters, were particulary observed in the metatrophic "Roelofsven" and "Heinven".

Enallagma cyathigerum is found in waters with different trophic levels, but was observed in larger numbers in acid environments. Verbeek et al. (1986) found numbers of larvae of *E. cyathigerum*, as well as *L. quadrimaculata*, to increase with acidification.

Acidification of the breeding sites will affect larvae of several dragonflies. Especially the moult and emerging phases are susceptible. Indirect influences of the acidification may be caused by alteration in food availability and composition, the increase of the concentration of heavy metals which may lead to toxification, a possible change of the pressure of predation and structural changes of the vegetation.

Acidification of weakly buffered waters in general is known to lead to a decline of the diversity of micro- and macroflora and fauna (Leuven & Schuurkens, 1984). Some acid tolerant species, such as beetles, bugs and dragonflies may become dominant, whereas others, such as mayflies (Ephemeroptera), amphibians and certain fishes, will disappear (Leuvel & Schuurkens, 1984).

For example, in Sweden several fish species have disappeared due to acidification of lakes. The decrease of predation by fishes may have led to an increase in numbers of Odonata, especially of *Leucorrhinia* spp. in the littoral zones (Eriksson et al., 1980; Nilsson, 1981).

More research will be needed to get a better understanding of the effects of water quality on the suitability of heathland pools as reproduction sites. Preservation of the unique and rich dragonfly fauna of the "Overasseltse- en Hatertse vennen" can only be achieved by means of strict and unconditional biotope protection. Research can help to convince the national and provincial authorities of the value of this nature reserve.

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