Distribution, phenology, food and habitat of *Hygrobia hermanni* in The Netherlands (Coleoptera: Hygrobiidae)

J. G. M. Cuppen

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Abstract: *Hygrobia hermanni* (Coleoptera: Hygrobiidae) has extended its distribution area since the mid 20th century from the southwestern (and central) part of The Netherlands towards the remainder of the country. Nowadays *Hygrobia* is common all over the country with the exception of the northern part where it is rare. In the northern, southern and eastern parts of The Netherlands *H. hermanni* is mainly restricted to (heathland) pools, ponds, (small) lakes and regulated streams, while in the central and western parts the species is most frequently met with in dune ponds, ditches and canals. Therefore, water type is not considered as a key factor for *Hygrobia*, but both extremely shallow, small water bodies as well as very large water bodies are avoided. Measured physico-chemical variables vary within wide ranges and their mean values can be found all over The Netherlands. Only brackish conditions are avoided by *H. hermanni*. The life-cycle of *H. hermanni* is univoltine. Dissected adults (n = 27; 12 with empty crops) were found feeding on benthic Chironomidae and, less frequently, on Oligochaeta.

Department of Aquatic Ecology and Water Quality Management, Wageningen University and Research Centre, Ritzema Bosweg 32a, 6703 AZ Wageningen, The Netherlands.

Introduction

The water beetle family Hygrobiidae comprises only the genus *Hygrobia* Latreille with five species (Franciscolo, 1979; Holmen, 1987; Dettner, 1997), one of which is restricted to China, and three to Australia. The only European representative of the family, *Hygrobia hermanni* (Fabricius) (= *Hygrobia tarda* (Herbst)), occurs also in The Netherlands, where it was considered widely distributed and occasionally not rare in pools and ditches on clayish soils (Everts, 1898). Everts (1922) mentions *Hygrobia* as common near Loosduinen (province of Zuid-Holland) in the mud of ditches with a sandy soil. Nowadays it is considered a fairly common species distributed all over the country (Schreijer, 1992).

Identification of *Hygrobia hermanni* is very easy with the available keys on water beetles (adults and larvae) (e.g. Franciscolo, 1979; Holmen, 1987; Schreijer, 1992; Dettner, 1997).

The aim of this paper is to present an overview of the distribution of *H. hermanni* in the past and present in The Netherlands, its habitat, including the physico-chemical conditions, the phenology, and, finally, some preliminary data on its food.

Material and methods

The material of this study includes three main sources: 1) the (museum) collections of Naturalis, Leiden (RMNH), the Zoological Museum, Amsterdam (ZMAN), the Natural History Museum, Tilburg (NHMT), the Department of Entomology, Wageningen University and Research Centre, and the Department of Aquatic Ecolgy, Catholic University of Nijmegen; 2) the private collections of J. Blommaart (Oosterhout), H. Cuppen (Apeldoorn), B. Drost (Wadenoyen), Th. Heijerman (Wageningen), M. Hielkema (Gouda), T. Joosten (Groningen), B. van Maanen (Roermond), F. van Nuenen (Vianen), P. Poot (Maastricht), C. van de Sande (Amsterdam), B. Storm (Groningen), A. Teunissen (Vlijmen), O. Vorst (Utrecht), P. van Wielink (Berkel-Enschot), J. Wieringa (Nijmegen) and the author; and 3) data-sets from Water Authority Boards, Pro-

Fig. 1. Distribution of *Hygrobia hermanni* in The Netherlands prior to 1950.

Fig. 2. Distribution of *Hygrobia hermanni* in The Netherlands between 1950 and 1975.

vincial Authorities and Research Offices: AquaSense, Gemeenschappelijke Technologische Dienst Oost-Brabant, Hoogheemraadschap Delfland, Hoogheemraadschap Rijnland, Hoogheemraadschap Schieland, Hoogheemraadschap Uitwaterende Sluizen, Hoogheemraadschap West-Brabant, Provinciale Waterleidingen Noord-Holland, Provincie Noord-Holland, Provincie Overijssel, Provincie Utrecht, Waterschap Friesland, Waterschap Groot Salland, Waterschap Regge en Dinkel, Waterschap Rijn en IJssel, Zuiveringschap Amstel en Gooiland, Zuiveringschap Drenthe, Zuiveringschap Hollandse Eilanden en Waarden, Zuiveringschap Limburg, Zuiveringschap Veluwe.

The material from the museum collections was identified by the author. The remainder of the material was identified for the greater part by the collectors themselves. Their identification (of both larvae and adults) is considered reliable as *H. hermanni* cannot be confused with any other Dutch water beetle.

The distribution of *Hygrobia hermanni* in The Netherlands is plotted using the 10 km-squares of the UTM-grid.

Data on habitat, physical and chemical variables are mainly derived from observations by the author and partly from those of Water Authority Boards. Phenology data are derived from all available material.

The contents of the crops (proventriculus) were investigated for 15 specimens collected in a cattle drinking pool in a meadow at the Meinweg (province of Limburg) on 5 September 1998, and 12 specimens from a dune pool near Oostvoorne (province of Zuid-Holland) on 4 September 1999.

Table 1. Records of *Hygrobia hermanni* in three time-periods, and numbers of adults and larvae in relationship with the sources.

	N (records)				N (adult)	N (larvae)
	<1950	1950-1975	>1975	total		
Private	2	13	228	243	358	62
Water Authority	0	0	414	414	1042	278
Museum	137	67	24	228	758	2
Total	139	80	666	885	2158	342

Fig. 3. Distribution of *Hygrobia hermanni* in The Netherlands after 1975.

Data

The records of the three sources (private collections, museum collections and data-sets from Water Authorities Boards) can be divided into three periods (pre-1950, 1950-1975 and post-1975) (table 1). The privately owned material includes both larvae and adults of *Hygrobia* but only collected since 1950. This applies also to the material from Water Authority Boards but it covers only the last period. Museum material consists of adults mainly originated in the first two periods. In general, most of the material has been collected during the last period.

Distribution

Hygrobia hermanni is widely distributed in southern and central Europe, and in North Africa. It is known from England, Wales, Scotland (one old record) and Ireland (see Foster, 1981), The Netherlands, Belgium, Germany, France (see Leblanc, 1991), Spain, Portugal, Italy, Austria, Slovenia, Croatia, Bosnia-Herzegovina, Greece and Ukraine in Europe, and Morocco, Algeria and Tunisia in North Africa. For more detailed information about the European distribution one is referred to Dettner (1997), who presents a distribution map.

The distribution of *Hygrobia hermanni* in The Netherlands is given in figures 1-3. Figure 1 clearly shows that prior to 1950 *H. hermanni* only occurred in 19 grid-squares in the southwestern part of the country (provinces of Zeeland and Zuid-Holland and the western part of Noord-Brabant), and from some isolated localities in the central part of the country (Baarn, Nunspeet, Laag Soeren and Brummen). It is a puzzle why Everts (1898) considered *Hygrobia* a well distributed species in The Netherlands since, at that time, the species was only known from the provinces of Zeeland and Zuid-Holland. As Everts lived in

Table 2. Numbers of localities of *Hygrobia hermanni* per province in three time-periods, with first year of recording.

	N (localities) <1950	1950-1975	> 1975	Year of first record
Friesland	0	0	5	1991
Groningen	0	0	2	1983
Drenthe	0	1	9	1961
Overijssel	0	0	44	1975
Flevoland	0	0	4	1983
Gelderland	3	5	55	1920
Utrecht	1	2	53	1935
Noord-Holland	0	3	129	1958
Zuid-Holland	10	12	135	1881
Zeeland	6	3	17	1876
Noord-Brabant	3	14	52	1915
Limburg	0	5	29	1970
Total	23	45	534	

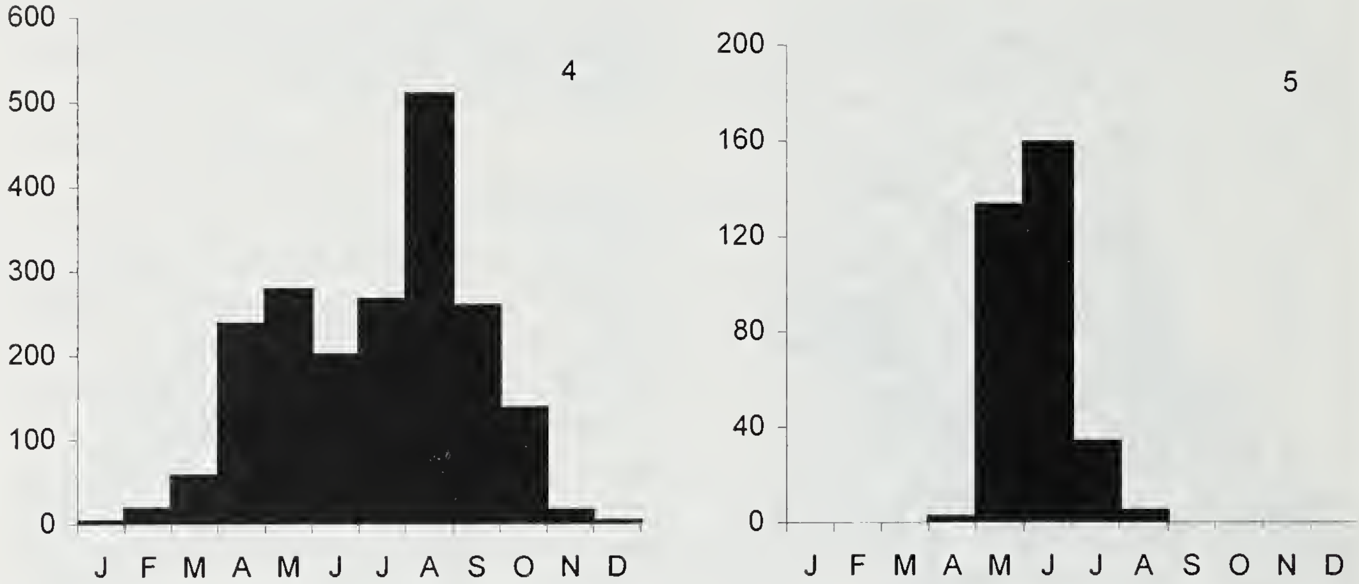

Fig. 4-5. Phenology of *Hygrobia hermanni* in The Netherlands on the basis of the number of specimens. 4, adults; 5, larvae.

Den Haag, where *Hygrobia* was very common, he supposed perhaps, that the species would be common everywhere.

Since 1950 *Hygrobia hermanni* has extended its range in The Netherlands considerably (fig. 2-3). Between 1950 and 1975 (fig. 2; 36 grid-squares) these extensions were mainly in the southeastern direction and small in the nortwestern direction. One "isolated" population was found at Gieten (province of Drenthe) by Westra (1967) in the northeast.

Since 1975 (fig. 3; 195 grid-squares) *H. hermanni* has extended its range further in the northeastern direction. The species is nowadays common in the southern, western and central part of The Netherlands, rather common in the eastern, and rare in the northern part. In general, there is a tendency for a decrease in the number of records from west to east and more clearly from south to north.

The extension of the distribution area in The Netherlands probably started in the late fifties and sixties (fig. 2, table 2) with the first records for the provinces of Noord-Holland in 1958 and Drenthe in 1961 (the second record from Drenthe, however, dates from 1983). Thereafter the provinces of Limburg and Overijssel followed in 1970 and 1975, respectively. The first record of *Hygrobia* in the newly reclaimed Flevoland dates from 1983. The two northernmost provinces (Groningen and Friesland) were reached in 1983 and 1991, respectively. The Groningen record of 1983 is based on elytra found in the stomach of a blue heron (17.ii.1983, coll. ZMAN). The only other record from this province is from 1987.

Brakman (1966) mentions *H. hermanni* from seven provinces in the western and southern part of The Netherlands, including the province of Limburg; the latter could not be confirmed by presence of material from an earlier date. At present *H. hermanni* is recorded from all (12) Dutch provinces (table 2). The total number of occupied grid-squares during the three periods is 207 (41% of the total number of Dutch grid-squares).

Phenology

Adults of *Hygrobia hermanni* (fig. 4) were found all through the year, but substantial numbers of adult beetles occur from April to October with a slight dip in June and an optimum in August. Winter observations are very scarce due to a combination of low collectors' activity and hibernation of the species in the (submerged) mud of their habitats. Here they overwinter motionless with legs and antennae folded in against their body until next spring (Balfour-Browne, 1922).

Larvae were found between April and August (fig. 5), but mainly in May and June.

Only rarely was the larval instar established, but certainly most larval observations refer to the second and third instars. The combined result of both figures strongly indicates a univoltine life-cycle of *H. hermanni* with mortality of the old generation in June and July and the appearance of a new generation of adults in July and August.

The development time for eggs and larvae is strongly dependent on temperature. The data from Balfour-Browne (1922) for *Hygrobia*, partly based on breeding experiments, are compiled here, as they are the only ones available. Under experimental conditions eggs are found at the end of March, but under natural conditions from the second week of April onwards. Eggs are laid in rows on the surface of submerged plants. Under field conditions eggs hatch after 25 days in April but in June nine or ten days are the rule. The first instar larvae develop in six to eleven days, seven or eight days is the usual period. The development of the second instar larvae takes nine to thirteen days and that of the last (third) instar 22 days. The full-fed larvae migrate to land where they dig a burrow and prepare a pupal room. The construction of the cell takes about half a day, but occasionally two or three days. After completion of the cell the larva rests for six to eleven days before pupation. The pupal period lasts for about sixteen days. The imago stays in the cell for a week or more before emerging. The whole development from hatching of the eggs to imago takes nine to sixteen weeks.

The development period given by Balfour-Browne (1922) fits the field observations of adults and larvae in The Netherlands. Bivoltinism during hot years, as discussed by Balfour-Browne (1922), seems possible but unlikely to occur in The Netherlands. Both the duration of the complete development under Dutch climatic conditions and the low number of observations of larvae in July and August suggest univoltinism.

Habitat

The habitat of *Hygrobia hermanni* is most often described as ponds (Balfour-Browne, 1922; Westra, 1967; Dettner, 1997), especially muddy ones, in lowland areas, though occasionally at high altitudes (Bertrand, 1972): French Pyrenees at 2000 m. The occurrence in lakes and ditches seems to be rare since e.g. Balfour-Browne (1922) and Westra (1967) explicitly mention never having taken *Hygrobia* in these habitats. Occurrence in slowly running streams is restricted to southern Europe (Bertrand, 1972; Dettner, 1997). Burmeister (1939) gives all the above mentioned habitats without further specifications or restrictions.

For The Netherlands, the habitat of *H. hermanni* is mentioned in 589 out of 885 in terms such as ditch, canal, dune pool, etc. The occurrence in isolated waters as ponds and lakes is recorded in about 40% of the cases (248 records). Ponds and lakes can be subdivided in heathland-pools (83 records) and others (165 records), which are not further described. Records from lakes are, however, scarce and most often these lakes are small with a surface of less than one ha. The remainder of the records (60%; 341 records) concern sluggish streams (mainly regulated lowland streams; only a few records), and, for the major part, ditches and canals. For ditches it concerns mainly the larger and deeper ones with permanent water. In a geographical context, in the western and northern parts of The Netherlands *H. hermanni* is found in ditches, canals and, less frequently, in ponds and lakes; in the dunes, southern and eastern parts of The Netherlands most records are from ponds, heathland-pools and regulated streams. This indicates that the water type is not a key factor for *Hygrobia hermanni*, but very small (temporary) and very large water bodies are avoided.

With respect to soil *H. hermanni* occurs frequently on both clay and sandy substrata, but peaty substrata are not avoided, though less frequently recorded. Usually the substratum is at least partly covered by a thin (or exceptionally thick) layer of (very) fine silt and detritus, which is usually not anoxic. On the often mentioned muddy substrata (Balfour-Browne, 1922; Dettner, 1997) *H. hermanni*

Table 3. Numbers of observations, minimum and maximum, 90% and 75% range, and median of some physical/chemical variables on localities with *Hygrobia hermanni*.

	N	min	max	90% range	75% range	median
pH	163	3.8	9.3	4.5-8.7	5.9-8.2	7.4
EGV (µS/cm)	155	21	3872	68-1702	103-1089	577
Cl^- (mg/l)	156	1.9	810	8.2-272	12.0-156	53.6
°D	63	1	63	1-29	1-15	8

has been observed only occasionally in The Netherlands.

Very often *H. hermanni* is encountered in recently created or dredged ponds and ditches. Despite this pioneer character of the species and its frequent occurrence in isolated waters, there are no flight observations of *Hygrobia* in The Netherlands.

Physico-chemical variables

The main characteristics of water samples from localities with *Hygrobia hermanni* are given in table 3. The range for pH is very wide from very acid to alkaline. The 75% range curtails the range to the circumneutral area. Also ranges for electrical conductivity, chlorinity and total hardness are wide, but brackish waters are avoided. The 75% range and the median value of these variables can be encountered in waters in all parts of The Netherlands. The median value with respect to pH is the same as found by Steenbergen (1993) in the province of Noord-Holland. The median value for chlorinity (53,6 mg/l) in the present survey is distinctly lower than the weighted mean (132 mg/l) found by Steenbergen (1993), but well within its 75% range.

The broad ranges with respect to the measured variables indicate that *Hygrobia hermanni* in The Netherlands can find waters with the right conditions everywhere except in areas with brackish water.

Food

The contents of the crop (proventriculus) of ten males and five females of *Hygrobia hermanni*, collected on 5 September 1998 in a cattle drinking pool at the Meinweg (province of Limburg), were investigated. Two males and two females had empty crops (26%), which is within a range which is normal for Dytiscidae (Deding, 1988; Dettner et al., 1986). The other specimens had one or more prey items in their crop, consisting of Oligochaeta and especially larvae of Chironomidae. Apart from four nearly intact specimens of Tubificidae without hair-chaetae (cf *Limnodrilus*) in three specimens of *Hygrobia*, all other chaetae of Oligochaeta were normally present inside the guts of *Procladius* and *Psectrotanypus varius* (Fabricius) (Chironomidae) or, rarely, in a very loose matrix. In the latter case it was impossible to decide whether these Oligochaeta were eaten as prey by *Hygrobia* or entered their crops as prey of *Procladius* or *Psectrotanypus*.

The remnants of the Chironomidae in the crops consisted of either nearly complete specimens or head capsules, allowing identification at least to genus level. Some capsules of Chironomidae inside the guts of *Procladius* and *Psectrotanypus* were not counted as separate prey. Measurements of the head capsules of the Chironomidae indicated that most specimens were second and third instar larvae, while fourth instar larvae were rare. The range of the number of consumed chironomids in the crops of 11 *Hygrobia* specimens varied between 1 and 8 (mean 3.5). The Chironomidae represented the following taxa: *Procladius* (17 times), *Psectrotanypus varius* (7 times), Pentaneurini (2 times), *Polypedilum* gr. *nubeculosum* (5 times), *Cryptocladopelma* gr. *lateralis* (5 times), *Tanytarsus* (2 times) and *Paratanytarsus* (one time). *Procladius*, *Psectrotanypus* and Pentaneurini are carnivorous, while the other chironomids are detritivorous.

No other fragments of animal origin were found in the crops. Vegetable material in the crops consisted of Diatomaeae and *Closterium*

(Desmidiaceae). These algae were nearly always found in large amounts in the guts of ingested *Psectrotanypus varius* and, in one occasion, *Procladius*. It is clear that they were not consumed on purpose by *Hygrobia*.

At a second locality, a dune pool near Oostvoorne (province of Zuid-Holland), 12 specimens of *Hygrobia* were collected on 4 September 1999. Only four specimens had a filled crop. The content comprised only Oligochaeta.

Discussion

The three sources of material used in the present study each have their own values and shortfalls. Museum material is usually old, gives little or no information about habitat, but is easy accessible for (reexamination of) identification and is stored safely at a few localities. For the determination of the present day distribution of a species it is insufficient. Material from private collections collected during the last fifty years gives more information about habitat, is accessible, but stored on many localities. Most of this material will eventually be deposited in museum collections. The material from Water Authority Boards covers the last decade only and is available via databases. Information about habitat and physico-chemical variables is the most extensive. The material itself is distributed over many localities, difficult to access or not stored at all. Most of this material will get lost in the future (thrown away or labelled insufficiently). As a source for present day investigation of the distribution of water beetles and their habitats, this material should be made more accessible and safed more carefully.

The extension of the distribution area of *Hygrobia hermanni* in The Netherlands during the second half of this century can only be determined on the basis of the examination of material from at least two sources: museum material and either privately collected material or material from Water Authority Boards, or both. Use of data of Water Authority Boards is very informative, very up-to-date and their network covers the whole country. In case of unreliable identifications these data can hardly be used as reexamination of material is very difficult and time-consuming. In the last case (as for all terrestrial beetles!) only material available via amateurs can be used for geographical studies.

The values of measured physico-chemical variables in the western part of The Netherlands are higher than those in the southern, central and eastern parts of the country. By selecting only a part of the distribution area of a species as study area (this also applies to the present study!), results can only be used without restrictions for the studied area. The extension of the distribution area of *Hygrobia hermanni* in the second half of this century is not determined by large scale changes in these variables, but possibly by a change in climatological conditions.

The food of *Hygrobia hermanni*, kept in captivity, consisted of insect larvae and worms (Balfour-Browne, 1922), and they accepted chopped earthworms readily. Zygopteran nymphs, *Chironomus*, *Sialis* and various other invertebrates were readily devoured, but active nymphs of *Cloeon* usually escaped. According to Dettner (1997), adults of *H. hermanni* feed on Oligochaeta, small Crustacea and insect larvae. In the present investigation, the total lack of microcrustaceans (Cladocera, Copepoda) in the proventriculus of the examined specimens is at least remarkable. Oligochaeta were the exclusive prey in Oostvoorne and were present in some specimens from the Meinweg. Here, larvae of Chironomidae were here the most consumed prey. The lack in the proventriculus of the phanton midge *Chaoborus* and the mayfly *Cloeon dipterum* (Linnaeus), which were abundant in both pools, is in accord with Balfour-Browne's observations. These species are usually living in open water and in vegetation, respectively. It seems reasonable to assume that adult *Hygrobia* feed on benthic invertebrates on the substratum and do not prey on inhabitants of the open water and vegetation. Either that or these potential prey escape predation by their sudden movements when disturbed. Whether the observed "preference" for Chironomidae versus Oligochaeta is realistic or simply a matter of local abundance of the groups, cannot be decided on basis of this investigation. The occurrence of mainly third and second instar larvae of Chironomidae (while also fourth instar larvae were consumed) could simply be a matter of seasonality or an indication of preference for these prey by *Hygrobia*.

According to Balfour-Browne (1922) the larvae feed exclusively on Tubificidae, while *Chironomus* larvae were accepted when offered. Balfour-Browne never succeeded in rearing larvae on any diet other than Tubificidae. In the presence of *Paramecium*, minute algae, Cladocera and Copepoda all first instar larvae of *Hygrobia* died. Only when bringing in fresh mud teeming with Tubificidae in the tumblers, was the food problem solved. In this way only Tubificidae were present in quantity as food resource. Probably also Chironomidae-larvae can be a good prey for *Hygrobia*-larvae, especially for the large third instar larva, when offered in quantity, as they have more or less the same size and habits as Oligochaeta. In all other experiments by Balfour-Browne (1922), the water in the tumblers was changed frequently, but not the substratum. In this way hatching of adult Chironomidae at high temperatures can soon reduce numbers of their larvae in the tumblers, especially as oviposition by adult Chironomidae is often impossible indoors. Dettner (1997) often found guts of *Hygrobia*-larvae filled with mud, but it was not clear whether this was the result of direct uptake or indirect uptake via the gut contents of ingested Tubificidae. However, microscopic investigation of the gut content of *Hygrobia* can easily give an answer as the characteristic chaetae of Oligochaeta are well preserved in guts (and proventriculi of adults). Of course, presence of single, loose chaetae can be the result of the direct uptake of mud, but when characteristic bundles of chaetae are present in the guts indirect uptake via Oligochaeta seems the most likely way to explain the presence of mud. Regrettably, neither author gives quantitative details. Therefore, more research is necessary to explain the presence of mud in the guts of larvae of *Hygrobia*.

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