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Analysis of the inland cladocerans of Flanders (Belgium) – Inferring changes over the past 70 years

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The four crustacean orders of the cladocerans represent, together with copepods and rotifers, the most common zooplankton taxa in all types of lentic freshwater bodies (1). They exhibit a parthenogenetic (clonal) reproduction mode during periods of favourable environmental conditions, and produce sexual dormant eggs (ephippia) when conditions deteriorate (2). As such they are capable of remaining dormant in the habitat for decades (3). Because of their capacity for rapid population growth, some pelagic members of the group (especially the large-bodied *Daphnia* and *Diaphanosoma*) are able of keeping water bodies in a clear water state by grazing down the phytoplankton (4). Most species feed on bacteria, protists, periphyton, and detritus (many chydorids and macrothricids), some are parasitic (e.g. *Anchistropus* on the polyp *Hydra*) or predacious on small-sized zooplankton (e.g. *Leptodora* and *Polyphemus*) (5; 6). Cladocerans themselves are a main food source for fish, macro-invertebrates, and amphibians (7).

So far, several authors have provided species lists and updates on the occurrence of cladocerans in Belgium (summarized in 8; 9; 10; 11). However, there are virtually no published data on the geographic distribution and the frequency of occurrence of these species in Flanders. A notable exception is the monograph of Luyten (12), dating from the first half of the 20th century, and reporting on the occurrence of 56 cladocerans in 35 sites, spread over Flanders. Furthermore, data on the current status of cladocerans from regions in Europe are almost nonexistent (apart from [13] who provided a Red List of Cladocera from Carinthia).

In this paper, we present contemporary data on the frequency of occurrence and geographic distribution of inland cladocerans in Flanders (Belgium), and compare our results with the observations of (12). We try to identify major trends in the occurrence of species, and indicate hot spots of rare species. Finally, we also report the occurrence of two cladocerans new to the Belgian fauna.

During the period 2000-2005, we collected zooplankton samples from 64 different sites that are evenly spread over Flanders (Fig. 1, App. 1). In each site (defined as an area of ca 28km²) we sampled multiple types of water bodies (ditches, temporary pools, ponds, lakes, and canals) once in summertime. During the entire survey, 605 different water bodies were sampled, with an average of 9.5 (SE 0.9) water bodies per site.

Cladoceran samples were obtained with a tube sampler (diameter 75mm, length 2m), taking an integrated sample of the water column at random sites in the water body. The collected water was filtered through a plankton net (mesh size 64µm) and preserved in formaldehyde (4%) saturated with sucrose. When water bodies were too shallow (e.g. temporary pools with a water depth of less than 30cm), samples were taken by a plankton dip net (mesh size 64µm). In 13% (80 out of 605) of the water bodies, samples were taken from both the active and dormant cladoceran community. The dormant egg bank was sampled using a hand corer (diameter 52mm, length 1m). Eggs were isolated from the surficial 3cm of the sediment applying the sugar flotation technique, and hatched under simulated summer conditions (see [14] for protocol details). Cladocerans in the samples were identified to species level following the key of (6), with the exception of the genera *Chydorus* and *Bosmina*, which were identified to the genus level.

For each taxon, we calculated the frequency of occurrence (% of the sites) to obtain an idea of the representation of each species in Flanders. We distinguished between six categories using the ACFOR scale : Abundant (>75%), Common (75%-51%), Frequent (50%-26%), Occasional (25%-6%), Rare (5%-1%), and Not observed (not detected in any of the investigated sites; the species may be extinct). The same categorization was performed on the dataset of (12).

SPECIES LIST AND FREQUENCY OF OCCURRENCE

In total, 88 different cladocerans, belonging to seven families, have up till now been recorded for Belgian freshwater bodies (Table 1). The majority of the 69 cladocerans observed in our study display no distinct geographic distribution across Flanders (Fig. 2). Only a limited number of species seem to be restricted to certain ecoregions (e.g. *Daphnia atkinsoni* and *Macrothrix hirsuticornis* are confined to the Polders region and the sphagnophile *Acantholeberis curvirostris* to the Campine region). On average, the number of species detected at a site was 19 (SE 1), and this species number was not significantly different among sites located in separate ecoregions. Only 6% of the species were found to be abundant (i.e. *Bosmina* s.l. [mostly *Bosmina longirostris*], *Ceriodaphnia pulchella*, *Chydorus* s.l. [mostly *Chydorus*

sphaericus], *Scapholeberis mucronata*, and *Simocephalus vetulus*) (Fig. 3). Overall, 63% of the cladocerans were not widespread in Flanders : occasional (30%), rare (16%), or not observed (potentially extinct, 17%).

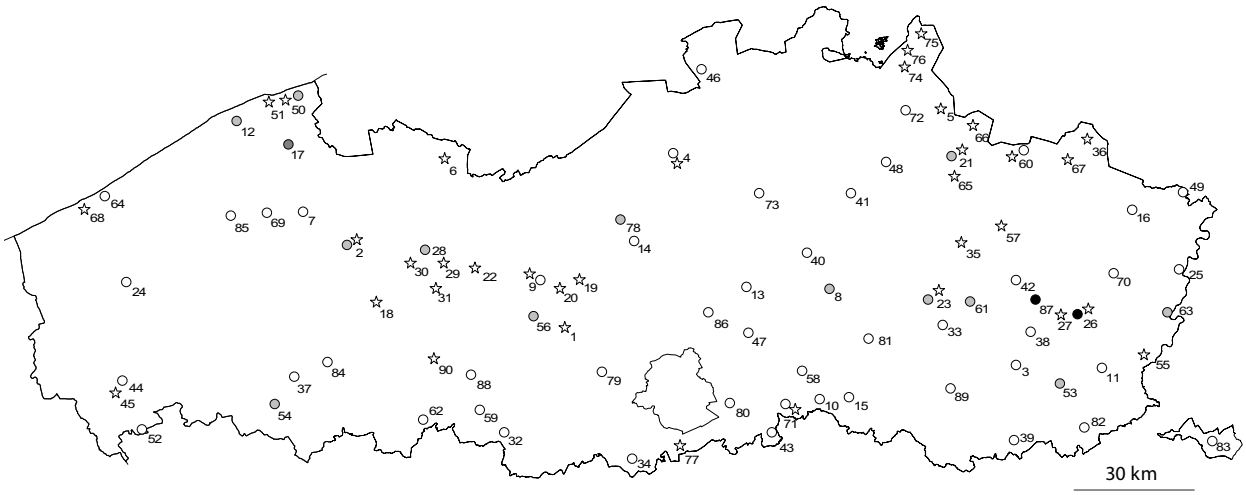

Fig. 1. – Geographic location of the different investigated sites in Flanders (Belgium). Each site is indicated by a circle, and the number of rare cladocerans is shown by the filling (white : 0 rare species; light gray : 1 rare species; dark gray : 2 rare species; black : 3 rare species). Sites that were sampled by (12) are indicated with stars. Numbers accord to the site names listed in App. 1.

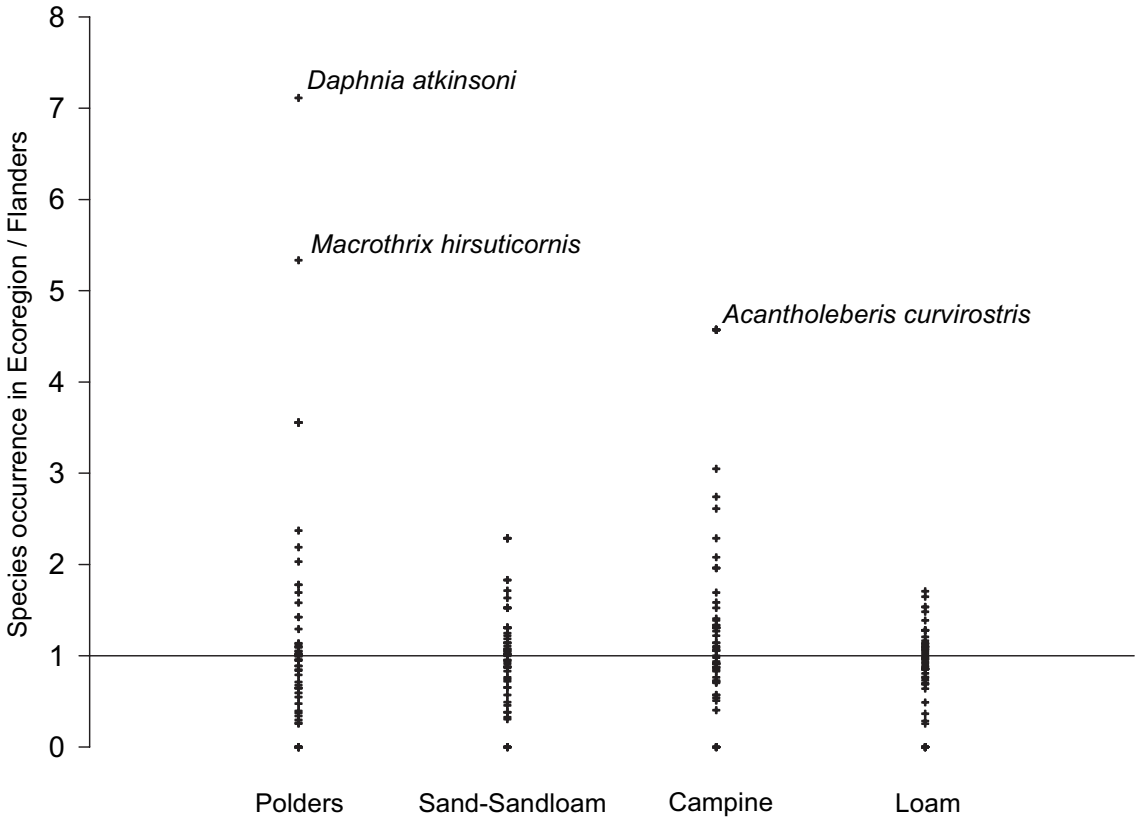

Fig. 2. – The proportion of the frequency of occurrence of each species in the four main ecoregions (spatial entities which are homogenous with respect to abiotic characteristics) of Flanders on its frequency of occurrence in Flanders (the Coastal dunes and Meuse ecoregions were omitted because less than three sites were sampled). Three species which are clearly linked to a certain ecoregion are indicated.

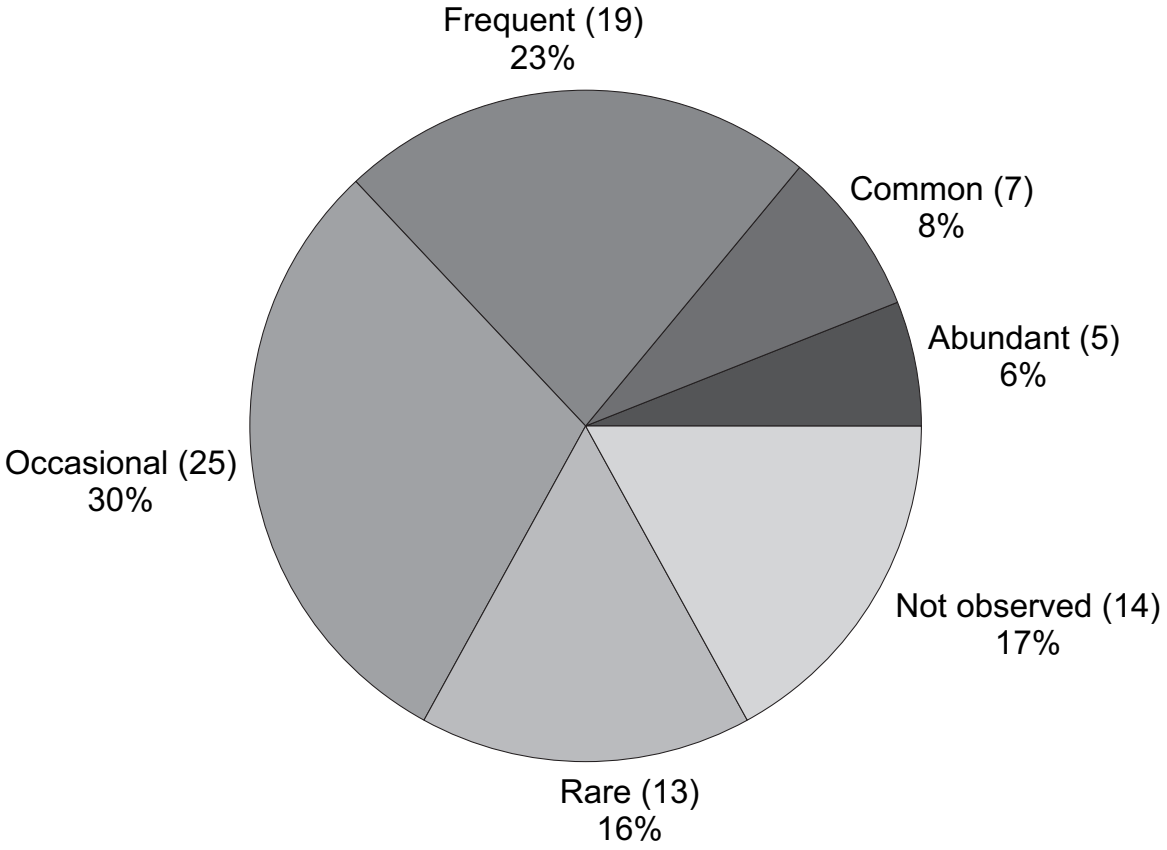

Fig. 3. – Percentage of occurrence of each category of cladocerans known to occur in Flanders. The number of species in each category is presented between brackets.

TABLE 1

Complete list of all different cladocerans that have been reported for Belgian water bodies. For each species, the current status in Flanders as revealed by the present study, and the status during Luyten's days (12) is presented. Species where no status is assigned are indicated by (–).

Species	Current status	Status Luyten
Sididae		
Diaphanosoma brachyurum (Liévin, 1848)	Frequent	Occasional
Sida crystallina (O.F. Müller, 1776)	Frequent	Occasional
Daphniidae		
Ceriodaphnia dubia Richard, 1894	Occasional	Not observed
Ceriodaphnia laticaudata P.E. Müller, 1867	Common	Occasional
Ceriodaphnia megops Sars, 1862	Occasional	Occasional
Ceriodaphnia pulchella Sars, 1862	Abundant	Frequent
Ceriodaphnia quadrangula (O.F. Müller, 1785)	Frequent	Occasional
Ceriodaphnia reticulata (Jurine, 1820)	Frequent	Occasional
Ceriodaphnia rotunda Sars, 1862	Not observed	Not observed
Ceriodaphnia setosa Matile, 1890	Not observed	Rare
Daphnia ambigua Scourfield, 1946 **	Frequent	–
Daphnia atkinsoni Baird, 1859	Rare	Not observed
Daphnia cucullata Sars, 1862	Frequent	Frequent
Daphnia curvirostris Eylmann, 1887 *	Occasional	–
Daphnia galeata Sars, 1864 *	Common	–
Daphnia hyalina Leydig, 1860	Rare	Not observed

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Species	Current status	Status Luyten
Daphnia longispina O.F. Müller, 1785	Occasional	Frequent
Daphnia magna Straus, 1820	Frequent	Occasional
Daphnia obtusa Kurz, 1874 *	Common	–
Daphnia parvula Fordyce, 1901 **	Frequent	–
Daphnia pulex Leydig, 1860	Common	Occasional
Megafenestra aurita (Fischer, 1849)	Occasional	Not observed
Moina brachiata (Jurine, 1820)	Occasional	Occasional
Moina macrocopa (Straus, 1820)	Occasional	Not observed
Moina micrura Kurz, 1874	Occasional	Not observed
Moina weismanni Ishikawa, 1896 **	Not observed	–
Scapholeberis mucronata (O.F. Müller, 1785)	Abundant	Frequent
Scapholeberis rammneri Dumont & Pensaert, 1983 *	Occasional	–
Simocephalus exspinosus (Koch, 1841)	Occasional	Occasional
Simocephalus serrulatus (Koch, 1841)	Rare	Not observed
Simocephalus vetulus (O.F. Müller, 1776)	Abundant	Frequent
Bosminidae		
Bosmina coregoni Baird, 1857	–	Occasional
Bosmina longirostris (O.F. Müller, 1785)	Abundant	Common
Bosmina longispina Leydig, 1860	–	Not observed
Macrothricidae		
Acantholeberis curvirostris (O.F. Müller, 1776)	Occasional	Occasional
Drepanothrix dentata (Eurén, 1861)	Rare	Occasional
Ilyocryptus acutifrons Sars, 1862	Not observed	Rare
Ilyocryptus agilis Kurz, 1878	Occasional	Occasional
Ilyocryptus sordidus (Liévin, 1848)	Frequent	Frequent
Lathonura rectirostris (O.F. Müller, 1785)	Not observed	Occasional
Macrothrix hirsuticornis Norman & Brady, 1867	Occasional	Not observed
Macrothrix laticornis (Jurine, 1820)	Occasional	Rare
Macrothrix rosea (Jurine, 1820)	Rare	Occasional
Streblocerus serricaudatus (Fischer, 1849)	Rare	Not observed
Chydoridae		
Acroperus harpae (Baird, 1835)	Frequent	Common
Alona affinis (Leydig, 1860) *	Frequent	–
Alona costata Sars, 1862	Frequent	Frequent
Alona elegans Kurz, 1875	Not observed	Not observed
Alona guttata Sars, 1862	Common	Frequent
Alona intermedia Sars, 1862	Rare	Not observed
Alona phreatica Dumont, 1983 *	Not observed	–
Alona protzi Hartwig, 1900	Not observed	Not observed
Alona quadrangularis (O.F. Müller, 1785)	Occasional	Common
Alona rectangula Sars, 1862	Common	Frequent
Alona rustica Scott, 1895	Not observed	Not observed
Alonella excisa (Fischer, 1854)	Occasional	Frequent
Alonella exigua (Lilljeborg, 1853)	Occasional	Occasional
Alonella hamulata (Birge, 1879) **	Rare	–
Alonella nana (Baird, 1843)	Frequent	Frequent
Alonopsis elongata (Sars, 1861)	Rare	Occasional
Anchistropus emarginatus Sars, 1862	Not observed	Occasional
Camptocercus lilljeborgi Schoedler, 1862	Not observed	Rare

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Complete list of all different cladocerans that have been reported for Belgian water bodies. For each species, the current status in Flanders as revealed by the present study, and the status during Luyten's days (12) is presented. Species where no status is assigned are indicated by (–).

Species	Current status	Status Luyten
Camptocercus rectirostris Schoedler, 1862	Occasional	Occasional
Chydorus gibbus Sars, 1890	–	Not observed
Chydorus latus Sars, 1862	–	Not observed
Chydorus ovalis Kurz, 1874	–	Occasional
Chydorus sphaericus (O.F. Müller, 1785)	Abundant	Abundant
Disparalona rostrata (Koch, 1841)	Frequent	Frequent
Eurycercus glacialis Lilljeborg, 1887	Not observed	Not observed
Eurycercus lamellatus (O.F. Müller, 1785)	Frequent	Frequent
Graptoleberis testudinaria (Fischer, 1848)	Frequent	Frequent
Leydigia acanthocercoides (Fischer, 1854)	Occasional	Occasional
Leydigia leydigi (Schoedler, 1863)	Frequent	Occasional
Monospilus dispar Sars, 1862	Rare	Rare
Oxyurella tenuicaudis (Sars, 1862)	Occasional	Occasional
Paralona pigra (Sars, 1862)	Not observed	Not observed
Pleuroxus aduncus (Jurine, 1820)	Common	Frequent
Pleuroxus denticulatus Birge, 1879 **	Frequent	–
Pleuroxus laevis Sars, 1862	Occasional	Rare
Pleuroxus trigonellus (O.F. Müller, 1785)	Occasional	Occasional
Pleuroxus truncatus (O.F. Müller, 1785)	Frequent	Frequent
Pleuroxus uncinatus Baird, 1850	Occasional	Occasional
Pseudochydorus globosus (Baird, 1843)	Rare	Occasional
Rhynchotalona falcata (Sars, 1862)	Rare	Occasional
Tretocephala ambigua (Lilljeborg, 1900)	Rare	Not observed
Polyphemidae		
Bythotrephes longimanus Leydig, 1860	Not observed	Not observed
Polyphemus pediculus (Linnaeus, 1761)	Occasional	Occasional
Leptodoridae		
Leptodora kindtii (Focke, 1844)	Occasional	Occasional

Note : (12) did not yet identify some taxa as separate species (*); some species were not yet present in Flanders (non-indigenous species, **).

In order to search for trends in the frequency of occurrence of cladocerans over the past 70 years, we made an attempt to compare our results with those of (12) (Table 1). We are fully aware that the interpretation of this comparison should be done with care, as there are differences among both datasets in geographic location and number of sites, number and type of water bodies sampled ([12] sampled in most cases only one water body per site), and frequency of sampling in the habitats. Table 1 illustrates that many species show no or only minor shifts between categories of the ACFOR scale. Only a limited number of species is nowadays more widespread than before (i.e. mostly daphniids such as *Ceriodaphnia* and *Moina*, *Daphnia pulex*, *Megafenestra aurita*, *S. mucronata*, and *S. vetulus*). Their increase in frequency of occurrence may be attributed to the greater number of small water bodies incorporated in our survey, but may also be related to an increased nutrient load in many water bodies during the last decades (15; 16). The increased nutrient load has lead to a higher production of organic material, and as such to an increased availability of food sources. This may explain why (12) found *Daphnia magna* only twice during his survey, whereas it is now frequently observed. Other species of non-indigenous origin (e.g. *Daphnia ambigua*, *Daphnia parvula*, and *Pleuroxus denticulatus*) were only introduced in Europe many years after Luyten's study (6), and are now frequently observed. For a subset of species, a comparison of the frequency of occurrence cannot be made, as (12) did not yet identify them as separate species (*Daphnia curvirostris* probably identified as *D. pulex*; *Daphnia galeata* probably identified as *Daphnia longispina*; *Daphnia obtusa* probably identified as *D. pulex*; *Scapholeberis rammneri* probably identified as *S. mucronata*; and *Alona affinis* probably identified as *Alona quadrangularis*).

The relatively large proportion of species (17%) that were not observed during our intensive survey may indicate the loss of specific habitats. For instance, the degradation of clear, weakly buffered, and oligotrophic water bodies may explain the disappearance of some species. Other species were only recently recorded as isolated cases, and are relict species (e.g. *Eurycercus glacialis*

reported by [17]) or non-indigenous species (*Moina weismanni* reported by [9]). More detailed research in the Campine region would probably result in the rediscovery of some species that were not observed during our study.

Hot spots for cladocerans, identified as sites in which 2 or 3 rare species were observed, are sites which contain clear, weakly buffered, and oligotrophic to mesotrophic water bodies such as Zonhoven (De Teut), and Genk (De Maten and Het Wik) (Fig. 1). The site of Damme is another hot spot, as it contains many small, turbid and often temporary habitats, which are frequented by migrating waterfowl (see further).

NEW SPECIES FOR BELGIUM

Streblocerus serricaudatus

This extremely rare macrothricid was found in a *Sphagnum* rich pond in only one site (De Teut, Zonhoven) during summer 2005. The accompanying cladocerans existed, amongst others, of several species that are typical for clear, weakly buffered, and oligotrophic water bodies (*A. curvirostris*, *Alonopsis elongata*, *Drepanothrix dentata*). The geographic distribution of *S. serricaudatus* is Holarctic, but the species is only rarely observed (6).

Alonella hamulata (synonym *Disparalona hamata* in [18])

This non-indigenous chydorid was observed in two different sites. First, it was observed in Bekkevoort (belongs to site 81, Fig. 1) during summer 2003 in a heavily stocked fish pond. One year later (summer 2004), the species was detected both in a fish pond and a dead arm of the Demer river near Vorsdonkbos (belongs to site 8, Fig. 1). *A. hamulata* has a cosmopolitan distribution, but seems to be largely restricted to tropical and subtropical regions (6). In Europe, the species has most probably been accidentally introduced and is recorded only twice : in Prague (Czech Republic), and in Slovakian lowland abandoned river arms (19). As fish ponds in Flanders are regularly stocked with cyprinids imported from East European countries, it is not unlikely that the species was introduced in Belgium during such translocations. Combined with rising temperatures due to climate change, the species may potentially extend its geographic distribution towards the north.

NEW LOCATIONS OF RECENTLY DISCOVERED SPECIES

Daphnia atkinsoni

The species was observed for the first time in Belgium in a newly created pond in Damme (2002). In this site, it was found to also occur in several other small water bodies in the immediate neighborhood (10). Since then, two nearby sites were found to also harbour this large daphniid. So far, all *D. atkinsoni* populations in Belgium have been found in small and turbid (due to suspended clay particles) fishless ponds in the East Coast Polders region of Flanders : Blankenberge (Uitkerkse Polder), Damme (Oude Stadswallen), and Knokke-Heist (Zwinbosjes). The incidence of the species might be linked to the presence of wintering geese in the region, which may act as dispersal agent for their propagules (10).

Tretocephala ambigua

The extremely rare chydorid *T. ambigua* was first detected as a new record for Belgium (Koolkerke; belongs to site 17, Fig. 1) in summer 2002 in a shadowed ditch with a thick layer of leaf litter on its bottom (10). In summer 2004, the species was found in another location (Honegem; belongs to site 56, Fig. 1) in two neighboring water bodies, i.e. a flooded meadow and a ditch. The species has a pan-European distribution, but is found only accidentally (6).

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APP. 1.

Names (city, municipality or toponym) of the sampled sites in Flanders (Belgium). Sites investigated by (12) are indicated in italics.

No	Site name	No	Site name	No	Site name	No	Site name
1	*Aalst (Moorsel)*	22	*Destelbergen*	45	*Ieper (Dikkebus)*	68	*Nieuwpoort*
2	Aalter	23	Diest	46	Kalmthout	69	Oostkamp
	Aalter (Bellem)		*Diest (Deurne)*	47	Kampenhout	70	Opglabbeek
3	Alken	24	Diksmuide	48	Kasterlee	71	Oud-Heverlee
4	Antwerpen	25	Dilsen-Stokkem	49	Kinrooi		*Oud-Heverlee*
	Antwerpen	26	Genk	50	Knokke-Heist	72	Oud-Turnhout
5	*Arendonk*		*Genk*		*Knokke-Heist (Knokke)*	73	Ranst
6	*Assenede*	27	*Genk (Bokrijk)*	51	*Knokke-Heist (Heist)*	74	*Ravels*
7	Beernem	28	Gent	52	Komen-Waasten	75	*Ravels (Poppel)*
8	Begijnendijk	29	*Gent*	53	Kortessem	76	*Ravels (Weelde)*
9	Berlare	30	*Gent (Drongen)*	54	Kortrijk	77	*Sint-Genesius-Rode*
	Berlare (Overmere)	31	*Gent (Zwijnaarde)*	55	*Lanaken*	78	Temse
10	Bierbeek	32	Geraardsbergen	56	Lede	79	Ternat
11	Bilzen	33	Halen	57	*Leopoldsburg*	80	Tervuren
12	Blankenberge	34	Halle	58	Leuven	81	Tielt-Winge
13	Bonheiden	35	*Ham (Kwaadmechelen)*	59	Lierde	82	Tongeren
14	Bornem	36	*Hamont-Achel (Achel)*	60	Lommel	83	Voeren
15	Boutersem	37	Harelbeke		*Lommel*	84	Waregem
16	Bree	38	Hasselt	61	Lummen	85	Zedelgem
17	Damme	39	Heers	62	Maarkedal	86	Zemst
18	*Deinze (Astene)*	40	Heist-op-den-Berg	63	Maasmechelen	87	Zonhoven
19	*Dendermonde*	41	Herentals	64	Middelkerke	88	Zottegem
20	*Dendermonde (Schoonaarde)*	42	Heusden-Zolder	65	*Mol*	89	Zoutleeuw
21	Dessel	43	Huldenberg	66	*Mol (Postel)*	90	*Zwalm (Nederzwalm)*
	Dessel	44	Ieper	67	*Neerpelt*		

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