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## The genus *Megacyclops* (Crustacea: Copepoda) in the Netherlands: Distribution and ecology

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### Abstract

This paper describes the distribution and ecology of the genus *Megacyclops* in the Netherlands. Three species of this genus are present in the Netherlands: *Megacyclops gigas* (Claus, 1857), *Megacyclops latipes* (Lowndes, 1927), and *Megacyclops viridis* (Jurine, 1820). *M. latipes* is new to the Dutch fauna. The taxonomic position and status of *Megacyclops viridis* var. *pelagica* (De Lint, 1922) is clarified.

**Keywords:** *Cyclops viridis* var. *pelagica*, *Megacyclops latipes*, *Megacyclops gigas*, distribution, ecology

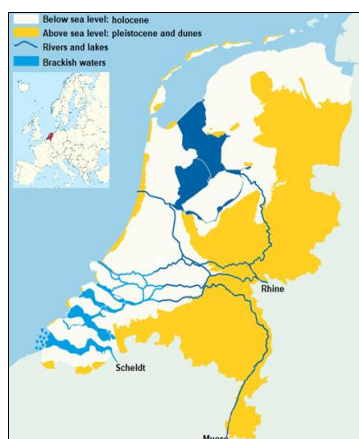
### Introduction

*Megacyclops* is a small genus in the family *Cyclopidae*. This genus is predatory on mosquito larvae and can play a role in the fight against invasive mosquitos (Dieng *et al.*, 2002; Awasthi *et al.*, 2012; Blaustein & Margalit, 2013; Früh *et al.*, 2019)<sup>[1-4]</sup>. *Megacyclops* is represented by five species in Europe and eight species worldwide (Einsle, 1993, 1996; Dussart & Defaye, 2006; Błędzki & Rybak, 2016)<sup>[5-8]</sup>.

The checklist of planktonic copepod species of the Netherlands has been updated. *M. viridis* and *M. gigas* were known from the Netherlands (Dresscher, 1976; Dekker & Zwerver, 1997)<sup>[9, 10]</sup> and a pelagic form of *M. viridis* is described by De Lint (1922)<sup>[11]</sup>. The status of this taxon is uncertain (Gurney, 1933; Kiefer, 1978; Dussart & Defaye, 2006; Aquo, 2020)<sup>[12, 13, 7, 14]</sup>. The distribution and ecology of the genus *Megacyclops* was examined in more detail because of this unclear taxonomic position of *C. viridis* var. *pelagica* De Lint, 1922. This article discusses the distribution and ecology of the genus *Megacyclops* in the Netherlands.

### Material and Methods

The Netherlands is a country in western Europe, approximately 50% of which is situated below sea level (Fig. 1). Three rivers meet the sea in the Rhine-Meuse-Scheldt estuary. Fresh water is almost exclusively found above sea level (Redeke, 1948)<sup>[15]</sup> at the pleistocene sand bottoms. Oligotrophic acid fens are restricted to the pleistocene parts of the Netherlands. The Holocene part consists of clay and peat and the waters are oligo- to mesohaline.



**Fig 1:** The Netherlands above and below sea level and the main water bodies

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A literature review and internet survey were conducted to update the checklists of the Dutch planktonic copepods (Mol, 1984) [16]. Samples from the author's collection were used to check for the recent presence of species in the Netherlands. Special attention was given to *Cyclops viridis* var. *pelagica* De Lint, 1922. The original description (De Lint, 1922) [11] and other publications in which this taxon is mentioned or discussed (Scourfield, 1903; Van Breemen, 1907; De Lint, 1922, 1924; Otto, 1927; Redeke, 1935, 1948) [17-22, 15] were consulted to clarify its position. Most of the literature under study is in Dutch and is made accessible in this article. The records from the literature are brought together with distribution maps and a diagram combining acidity and chlorinity.

## Results

The results of the literature search are given in this paper. The literature in which the species are mentioned and the samples in which the species were found are given below.

### *M. gigas* (Claus, 1857)

This species is mentioned in Van Breemen (1907) [15], De Lint (1924) [20], Redeke and De Vos (1932) [23], and Dresscher *et al.* (1952) [24]. It was not found in recent samples.

### *M. latipes* (Lowndes, 1927)

This species is probably described as *M. viridis* in Dresscher *et al.* (1952) [24]. *M. latipes* was found in sample MSO1246 from Drenthe in 2018 (Fig. 2-3).



**Fig 2:** Habitus *Megacyclops latipes* Ven A52, 4 January 2018 (Photo: Martin Soesbergen)



**Fig 3:** Furca of *Megacyclops latipes* Ven A52, 4 January 2018 (Photo: Martin Soesbergen)

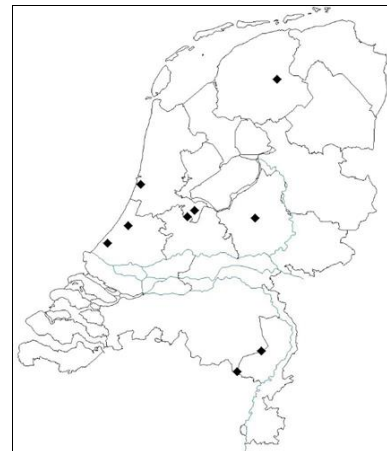
### *M. viridis* (Jurine, 1820)

This species is mentioned Havinga (1920) [25], De Lint (1922, 1924) [11, 20], Otto (1927) [21], Vorstman (1939) [26], Nadort 1943 [27], Redeke (1948) [15], De Vos (1949, 1954a, 1954b, 1960) [28-31], Wibout Isebree-Moens (1954) [32], Geelen and Davids (1962) [33], Schroevers (1963) [34], Creuzberg and Leentvaar (1969) [35], Gysels (1972) [36], Heip (1973) [37], Hovius (1973) [38], Dresscher (1976) [9], Smit and Daan (1978) [39], Butter (1981) [40], Gulati (1990) [41], Dekker and Zwerver (1997) [10], and Dekker *et al.* (1998) [42]. *M. viridis* was found in samples taken in Vught (2009; MSO0002), Weerterbergen (2019; MSO1631), De Hoort (2020; 1640), and Lelystad (2020; MSO1675).

### *M. viridis* var. *pelagica* (De Lint, 1922)

This variety is described in De Lint (1922) [11] and mentioned in De Lint (1922, 1924) [19, 20], Otto (1927) [21], Redeke (1935, 1948) [22, 15], Bijlmer (1938) [43], and Vorstman (1939) [26].

The distribution of *M. gigas* is given in Fig. 4. It is found along the coast in small ponds in the dunes, and all other records are from diluvial sandy soils. *M. latipes* is found only in the province of Drenthe (Fig. 5), in an area with undisturbed acid fens. *M. viridis* has its centre of distribution along the former Zuiderzee (now Lake IJsselmeer) and in the western provinces (Fig. 6). It is almost completely absent from the diluvial sandy soils in the eastern and southern part of the country. *C. viridis* var. *pelagica* was found in lakes in the peaty meadow area in the west and north of the Netherlands and in ponds along the rivers (Fig. 7).



**Fig 4:** Distribution of *M. gigas*



**Fig 5:** Distribution of *M. latipes*

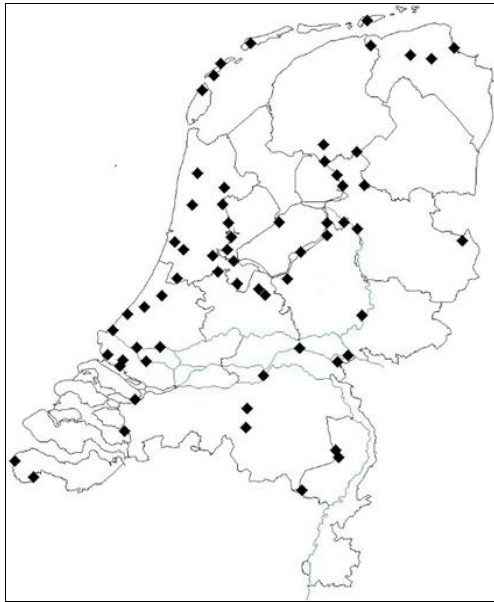


Fig 6: Distribution of *M. viridis*

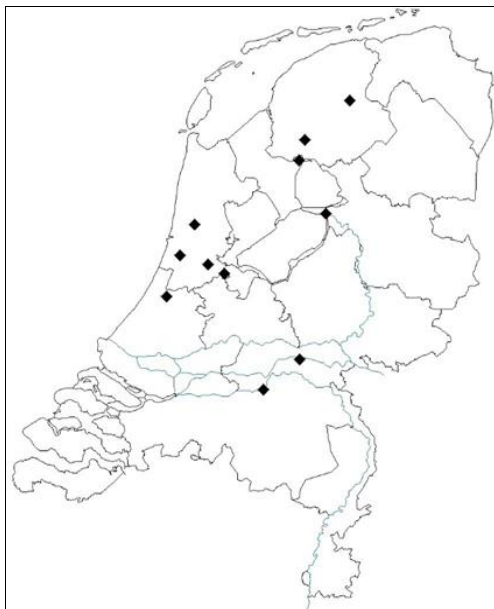


Fig 7: Distribution of *C. viridis* var. *pelagica*

The measurements of acidity and chlorinity mentioned in the literature are merged in figure 8.

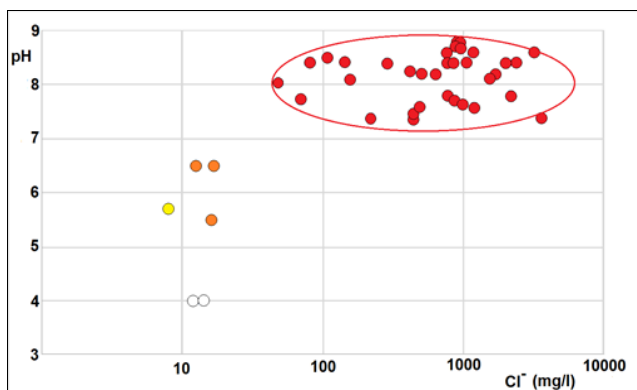


Fig 8: Records of *Megacyclops* according to acidity (pH) and chlorinity (Cl<sup>-</sup>), red bullets *M. viridis*, orange bullets *M. gigas*, yellow bullet *M. latipes*, and white bullets '*M. viridis*' from Dresscher *et al.* (1952) [24]

## Ecology

The records of *M. gigas* come from small fresh waters (Van Breemen, 1907) [18] and acid oligotrophic fens (Redeke & De Vos, 1932; Dresscher *et al.*, 1952) [23, 24]. This species is present in winter and disappears before summer; and it is found between October and April (Van Breemen, 1907; Sars, 1913; De Lint, 1924) [18, 44, 20]. *M. gigas* was found in January 1931 in the Gerritsfles, a slightly acid fen with pH 6.5 and Cl<sup>-</sup> 16.6 mg/l, together with the copepod *Diaptomus gracilis* and the cladocerans *Acantholeberis curvirostris* and *Coronatella rectangula* (Dresscher *et al.*, 1952) [24]. It is a species restricted to pleistocene sandy regions and the dunes where fresh waters are found. There are no recent records of this species in the Netherlands.

Abroad, it is found in small ponds (Sars, 1913; Gaviria, 1998) [44, 45], in the littoral of lakes (Einsle, 1993; Walseng *et al.*, 2006) [5, 46], and at considerable depths in the profundal of lakes (Sars, 1913; Kiefer, 1978; Gaviria, 1998) [44, 13, 45].

*M. latipes* is found in an oligotrophic fen in Drenthe in winter. It was found on 4 January 2018 in turbid water at pH 5.7, with electric conductivity of 38 µS/cm. The fen has a depth of one metre and 50% is covered with peat moss. *M. latipes* was found together with the cladocerans *Acantholeberis curvirostris*, *Acroperus neglectus*, *Chydorus ovalis*, and *Chydorus sphaericus*. The first three are species of oligotrophic waters and have a northern distribution in Europe.

Abroad, *M. latipes* is only found in small puddles and ditches (Gurney, 1933; Cole, 1959; Einsle, 1996) [12, 47, 6] and in the littoral of lakes. In the United States, it is believed to be a species of temporary waters (Cole, 1959; Marten *et al.*, 2000; Bruno *et al.*, 2001) [47-49]. This species has a northern distribution and prefer cold water (Kiefer, 1939) [50].

*M. viridis* prefers small ponds and ditches (Otto, 1927; Gurney, 1933; Creutzberg & Leentvaar, 1969; Gysels, 1972; Smit and Daan, 1997) [21, 12, 35, 36, 40] and is also found in the weedy margins of lakes (Havinga, 1920; De Vos, 1954; Stella, 1964; Gaviria, 1998) [25, 29, 51, 45]. *M. viridis* is found in ditches with species-rich submerged vegetation (Smit and Daan 1979) [40]. It is found on holocene clay and peat soils, where oligo- to mesohaline waters are found, but also in fresh waters along the rivers. It is found in eutrophic conditions (Schroevers, 1963; Gulati, 1990) [34, 42] and is absent in oligotrophic peatlands (Schroevers, 1963) [34]. It is present from February until October (Van Breemen, 1907; De Lint, 1924) [18, 20]. *M. viridis* is found together with *Eurytemora velox*, *Macrocyclus fuscus*, *Eucyclops serrulatus*, *E. speratus*, *Acanthocyclops robustus*, and *Macrocyclus albidus*, as well as the cladocerans *Simocephalus vetulus*, *Coronatella rectangula*, and *Pleuroxus truncatus*. These crustaceans are bound to vegetation. The records of *M. viridis* at pH 4 in an oligotrophic fen are questionable. It has been found in vegetation of *Sphagnum subsecundum* and *Eleocharis palustris*, together with the cladocerans *Acantholeberis curvirostris* and *Eubosmina obtusirostris* (Dresscher *et al.*, 1952) [24].

Abroad, *M. viridis* is also found in large lakes, where it inhabits the bottom, the profundal, at considerable depths of up to 300 meters (Monakov, 1958; Stella, 1964) [52, 51].

*M. viridis* is restricted to slightly alkaline to alkaline waters with low (70 mg/l) to high (3650 mg/l) chlorinity (Fig. 8). The few records of *M. gigas* and the one of *M. latipes* are from acid to slightly acid waters with very low (8-16 mg/l)

chlorinity (Fig. 8). The Dutch records show a clear difference between the habitat preference of *M. viridis* and the records of the other two species in the Netherlands.

## Discussion

The observed preference of *M. viridis* for alkaline waters with higher conductivity (Fig. 8) is in concordance with the findings of Fryer (1993) [53] in Yorkshire and of Walseng (2016) [54] in Norway. In Norway, *M. viridis* is more common in the south and prefers waters with conductivity above 700  $\mu\text{S}/\text{cm}$  (Walseng, 2016) [54]. *M. viridis* was found primarily in alkaline waters in Yorkshire (Fryer, 1993) [53]. The range of pH is wider in Yorkshire and Norway (4.5-10.2) than in the Netherlands, but *M. viridis* was never found at a pH lower than 4.5 in Norway (Walseng, 2016) [54] and only three times – out of 124 – at lower than 6.0 in Yorkshire (Fryer, 1993) [53]. The only record of *M. gigas* in England is from Wicken Fen (Harding & Smith, 1974) [55]. *M. gigas* is a common species in Norway. It is found over a broad range of pH and conductivity, but not below pH 4.5. Some Dutch records of ‘*M. viridis*’ at pH 4.0 are lower than observed for both *M. viridis* and *M. gigas* and these are probably records of *M. latipes*. This species was not accepted as valid in 1952.

De Lint describes *Cyclops viridis* var. *pelagica* as a small pelagic taxon, being absent from diluvial sandy soils in the Netherlands (De Lint, 1922a, 1922b, 1924) [11, 19, 20]. It is found in the warmer season and is absent from November until April (De Lint, 1924) [20]. The description (translated from the German) is as follows:

‘The size is small. The length of adult females of the variety found by me is between 1.2 and 1.7 mm. The inside of the furcal rami is bold or very minimally occupied with hairs. It is a planktonic species. That is why I call it *Cyclops viridis* var. *pelagica*. It is very common and most abundant in summer. Some animals from De Poel near Amstelveen and Alkmaardermeer have cuticular pits.’

De Lint (1922, 1924) [11, 20] refers in her text to Scourfield (1903) [17], who mentions a pelagic taxon without hairs on the furcal rami. Van Breemen (1907) [18] thought he had found the taxon seen by Scourfield in the river Spaarne. Gurney (1933) [12] states, ‘De Lint has recorded a *C. v.* var. *pelagica* as common in Dutch plankton; but there is reason to believe that this is really *C. vernalis americanus*’. Gurney did not substantiate this claim. The Dutch checklist refers to it as *Acanthocyclops viridis pelagica* and thus as part of *Megacyclops viridis*; and later, Kiefer (1978) [13] and Dussart and Defaye (2006) [7] treat it as synonymous with *Megacyclops gigas*. Thus, there are at least three possible names for this taxon. The bold furcal rami are a good reason why this taxon does not belong to the genus *Megacyclops*. *M. gigas* is a species 2.0 to 3.5 mm in length (Einsle, 1996) [6] and the size and hairy inner margin of the furcal rami rule out *M. gigas*. It is not *M. viridis* because De Lint described it as ‘variety’, and *M. viridis* is not a pelagic species (De Lint, 1922; Otto, Gurney, 1933; De Vos, 1954; Monakov, 1958; Stella, 1964; Harding & Smith, 1974; Dekker *et al.*, 1998; Walseng *et al.*, 2006) [11, 12, 29, 52, 51, 55, 44, 46] and has a hairy inner margin of the furcal rami (Einsle, 1993 and 1996) [5, 6]. An overlooked remark on *Cyclops viridis* var. *pelagica* comes from Redeke (1948) [15]. He writes (translated), ‘Further investigation has shown this taxon to be *Cyclops vernalis americanus* Marsh’ (Redeke, 1948) [15], thereby confirming the assumption of Gurney (1933) [12]. *Cyclops vernalis*

*americanus* Marsh is now considered to be a valid species *Acanthocyclops americanus* Marsh, 1893 (Karanovic & Bláha, 2019) [56].

The animals with cuticular pit markings should be regarded as another taxon, because *C. vernalis americanus* has no pit markings (Harding & Smith, 1974) [55]. Cuticular markings are good properties by which to distinguish the species pairs *A. robustus/A. americanus* without pits on the genital segment and *A. vernalis/A. europensis* with pits (Karanovic & Bláha, 2019) [56]. *A. vernalis* is not found in lakes or open water (Harding & Smith, 1974; Fryer, 1985; Walseng *et al.*, 2006) [55, 57, 46], and does not contribute to the species richness of the pelagic in lakes (Walseng *et al.*, 2006) [46]. The Dutch animals with cuticular pit markings (De Lint, 1922) [11] might belong to *Acanthocyclops europensis* Karanovic & Bláha, 2019.

## Conclusion

Three species of *Megacyclops* are present in the Netherlands: *M. gigas*, *M. latipes*, and *M. viridis*. While there are no records of *M. gigas* after 1952, *M. latipes* is new to the Dutch fauna and *M. viridis* is a common species in the Netherlands.

*M. viridis* prefers eutrophic, slightly alkaline waters and it is present in fresh, oligo- and mesohaline inland waters. *M. viridis* is found in all kinds of water, including the littoral of the large lakes and small vegetated ditches. *M. gigas* and *M. latipes* are found in small oligotrophic fresh waters, especially in acid fens.

*Cyclops viridis* var. *pelagica*, as described by De Lint (1922), is not a member of the genus *Megacyclops* but is *Acanthocyclops americanus* Marsh, 1893. The Dutch pelagic animals with cuticular pit markings mentioned by De Lint (1922) [11] might belong to *Acanthocyclops europensis* Karanovic & Bláha, 2019.

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