BULLETIN
ZOÖLOGISCH MUSEUM

UNIVERSITEIT VAN AMSTERDAM

Vol. 16 No. 13 1999

CURRENT STATUS OF THE FRESHWATER MYSIDAE IN THE NETHERLANDS, WITH RECORDS OF *LIMNOMYSIS BENEDENI* CZERNIAVSKY, 1882, A PONTOCASPIAN SPECIES IN DUTCH RHINE BRANCHES

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ABSTRACT

The freshwater Mysidacea of The Netherlands are presently composed of three species. The indigenous mysid, *Neomysis integer* (Leach, 1814) has recently been joined by two Pontocaspian species, *Limnomysis benedeni* Czerniavsky, 1882 and *Hemimysis anomala* G.O. Sars, 1907. All three species now coexist in the Dutch Rhine. The present paper deals with the first records of *L. benedeni* in The Netherlands with ecological notes on the three species.

INTRODUCTION

Until recently, only one mysid species, *Neomysis integer* (Leach, 1814), was found in freshwaters of the Netherlands (Borghouts-Biersteker, 1969). This species occurs mainly in brackish coastal waters and estuaries, but also in eutrophic freshwater canals and lakes. In 1997/1998, two Pontocaspian mysids, *Limnomysis benedeni* Czerniavsky, 1882 and *Hemimysis anomala* G.O. Sars, 1907, were encountered in Dutch inland waters. This paper describes the first records of *L. benedeni* in The Netherlands and provides diagnostic features of the freshwater Mysidae in The Netherlands. The ecology and likely dispersal modes of the exotic mysids are discussed. Reference material has been deposited at the Zoological Museum Amsterdam, The Netherlands (ZMA Mys. 203.912).

FIRST RECORDS OF *Limnomysis benedeni*

L. benedeni was first observed on 23-VII-1997 in the Dutch lower Rhine during a macro-invertebrate survey of floodplain waterbodies of the river Waal. Two female specimens were collected with a hand-held dip net (1 m depth) at the Kaliwaal (51°51'N, 05°09'E), a large stagnant sandpit in open connection with the main channel, near Millingen aan de Rijn. The area sampled had been recently inundated and had a significant coverage of terrestrial macrophytes with a substrate of gravel and sand.

After this, regular observations have been made in wetland pools near a backwater connected to the river Waal near Tiel (51°53'N, 05°26'E). This floodplain site has been sampled monthly since January 1998. The pools where *L. benedeni* was found were shallow (less than 2 m) with abundant aquatic and semi-aquatic vegetation, and with only seasonal connection to the backwater and the river. Between January and May 1998, specimens were collected at mean densities varying from 0.2 to 7.0 per m^2 at 1.0-1.5 m depth from different pools within the wetland. Highest densities occurred in stagnant pools with a dense vegetation, dominated largely by *Ceratophyllum* and *Myriophyllum*. Coloration of these specimens varied from brown-black to translucent. No specimens were recorded in the main backwater where vegetation is scarce and water velocities vary between 0 to 1m/s, depending on proximity to the main channel. However, *N. integer* were often found in the main backwater (max. mean density of 27 ind./m^2). Sampling of the main river channel's littoral zone (groyne stones) was also undertaken in August 1997 and monthly since January 1998, but no specimens of *L. benedeni* were collected from this habitat.

On 18-V-98, in another floodplain area on the river Waal, in the easterly channel of the Gamerense Waard

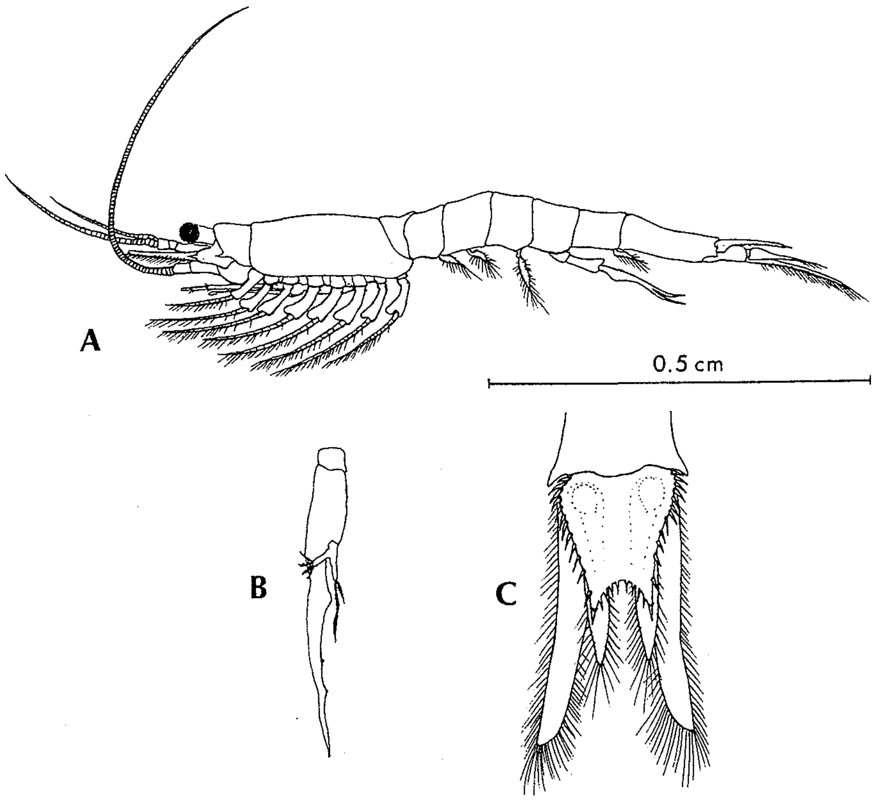

Fig. 1: *Limnomysis benedeni*. A: specimen with bifurcate pleopod IV. B: Example of typical form pleopod IV. C: Dorsal view of telson.

(51°49'N, 05°12E), one specimen of *L. benedeni* was found (leg. A.G. Klink & D. Tempelman; det. D. Platvoet).

Between 18-VII-98 and 20-VII-98, 7 specimens of *L. benedeni* were sampled in riparian helophytic vegetation at the Zuiderdiep, a still-standing to slow flowing waterbody in connection with the Haringvliet, near Stellendam (51°48'N, 04°05'E). Other exotic crustaceans sampled here were two Pontocaspian amphipods, *Corophium curvispinum* G.O. Sars and *Dikerogammarus villosus* Sowinsky, and the North-American amphipod, *Gammarus tigrinus* Sexton. Three native species; the isopod *Asellus aquaticus* (L.), the amphipod *Gammarus duebeni* Liljeborg and *N. integer* were also noted.

On 23-VII-98, two male specimens of *L. benedeni* were collected with a hand-held dip net in 0.5-1 m depth between boulders in the turbid and slowly running waters of the river Lek, the smallest and slowest flowing branch of the river Rhine, at Nieuwegein Zuid at the mouth of the Merwede canal (52°00'N, 05°06'E) [material deposited at the Natural History Museum of Vienna, Crustacean Coll. no. 18314]. Further macro-neozoans found at this station were the freshwater shrimp *Atyaephyra desmaresti* (Millet) from the Mediterranean, and three invaders from the Pontocaspian: *C. curvispinum*, the polychaete *Hypania invalida* (Grube) and the zebra mussel, *Dreissena polymorpha* (Pallas).

Another record of more than a hundred specimens of *L. benedeni* in the Netherlands was made by Ketelaars et al. (in press) on 14-IX-98 in a stand of water plants in a creek in the Biesbosch; 'Gat van de kleinen Hil', which runs parallel to the Nieuwe Merwede river (51°45'N, 04° 45'E) in the freshwater part of the Rhine-Meuse estuary.

Diagnostic features

The three mysids currently found in freshwaters of The Netherlands may be distinguished by the characters given below (detailed figures are available in Tattersall & Tattersall, 1951 and Bacescu, 1954). For fast determination it may be sufficient to examine the structure of antennal scale and telson.

Neomysis integer

Body size of adults is in the range of 6-19 mm. Body colour translucent to pale grey. Antennal scale slender, strongly elongate, setose all around, terminating in an acutely pointed apex; apical segment separated by a distinct or indistinct suture, measuring 12-18% length of antennal scale. Pleopods I, II, III and V of males reduced, fused and styliform, as typical also for all pleopods in females. Fourth male pleopod modified, biramous, strongly elongate; with 2-segmented exopod reaching beyond the base of the uropods. Telson entire, long, narrow and triangular; narrow apex with a lateroterminal pair of long spines, and a median pair of short spines. Endopods of uropods with dense series of 14-55 spines along proximal half of inner margin. Variability in telson morphology of *N. integer* in The Netherlands has been described by Mees et al. (1995).

Limnomysis benedeni (Fig. 1)
Body size (measured from tip of rostrum to the terminal margin of the telson, without spines) of adults ranges from 6 to 13 mm. Coloration dark brown to translucent. Antennal scale setose all around, with 8-15 setae on large (25-35% length) sexually dimorph apical segment, terminally rounded in females, or pointed with flexured tip in males. Pleopods I, II, and V of males reduced, fused and styliform, as typical also for all pleopods in females. Third male pleopod also terminally fused, but with larger 2-segmented sympod. Fourth male pleopods of medium size, exopod not reaching to the base of uropods; fourth pleopod of unique fashion, sympod fused with exopod, endopod distinct and entire. Telson short and rather stout, subtriangular, with small apical incision; lateral margins with 7-14 spines; cleft with 4-10 laminar processes. Endopods of uropods with one spine below statocyst.

Interestingly, a high percentage (26%) of male specimens with bifurcate exopods of fourth pleopods was found by Bacesco (1940) in populations of the Galati-Isacea reach of the Lower Danube, while this feature is rare in remaining Danubian populations studied. A similar proportion (30%, n = 50) of males collected in the Lower Rhine possesses this condition, which was usually emphasised as abnormality and related to regeneration.

Hemimysis anomala
Body size of adults ranges from 7 to 12 mm. Body colour pink to translucent. Antennal scale suboval, setose, without spines on outer margin; terminally rounded apical segment only 3-7% length of antennal scale. Pleopods I and II of males reduced, fused and styliform, as typical also for all pleopods in females. Third male pleopod with large sympod and small, but distinct, unisegmented endopod; exopod rudimentary (poorly visible without dissection). Fourth male pleopod large and modified; biramous, with 6-segmented exopod reaching beyond base of uropods. Fifth male pleopod small, but biramous and well articulated. Telson apically truncate, without apical cleft; distally with 12-15 laminar processes, 5-17 spines run the entire length of lateral margins. Endopods of uropods with 6-9 spines on proximal half of inner margin.

ECOLOGY

Neomysis integer
A common mysid in temperate to boreal waters of the NE-Atlantic coastline, with a disjunct population in the Rhône Delta (Mediterranean coast of France). It is found mainly in brackish waters, but is also tolerant of freshwater and hypersaline conditions. *N. integer* is hyperbenthic, tolerating a wide range of temperatures, breeding in summer and producing 2-3 generations per year. It forms large near-shore schools in daylight, and migrates to offshore areas at night. Although the species is omnivorous, zooplankton forms a major part of diet (Hanazato, 1990). Cannibalism is avoided as shoals are formed by specimens of uniform length (Välipakka, 1992). In fish diets, *N. integer* is especially important in estuaries, but has been found in large numbers in the stomachs of percids collected from the river Waal, near Nijmegen since September 1997 (leg. B. Kelleher & G. van der Velde). As mentioned earlier, it has also been found in high numbers in a connected backwater near Tiel since January 1998. The implications of the co-existence of *N. integer* with the other new members of the Mysidae in the Lower Rhine ecosystem remain to be seen.

Limnomysis benedeni
Shows autochthonous distribution in the coastal waters and tributaries of the Pontocaspian and Marmara seas (including Lake Beysehir in Anatolia). It is a typical Pontocaspian mysid in as far as it is well adapted to low salinities, dense populations existing at salinities of S = 0-5‰. Low densities were found in the mesohaline reach (S = 6-12‰) of river estuaries and lagoons along coasts of the Marmara and Black Seas (leg. K.J. Wittmann). In the laboratory, it showed a low tolerance for salt concentrations above 10‰ (Bacesco, 1940). It is potamophilous, preferring still-standing water to a maximum velocity of 0.5 m/s (Wittmann, 1995). *L. benedeni* is phytophilous, often being associated with stands of littoral vegetation. If no macrophytes are available, it may also be associated with diverse types of hard substrate, and more rarely with soft substrate. It is positively phototropic, and is often found in great densities on the shore in depths of only 0-0.5 m, although they can occur at a depth of 6 m. It may feed on planktonic algae or on filamentous algae growing on stones or on macrophytes, such as *Ceratophyllum*, *Elodea* and *Potamogeton*, which are also used for habitat provision (Bacescu, 1954). It reproduces from March to November, especially occurring in macrophyte stands for breeding and development of young. Breeding females bear 12-40 eggs in the brood pouch where egg numbers tend to increase with increasing individual body size. This species is an important source of food for various fish, having being deliberately introduced for the improvement of fisheries into Lake Balaton, Lake Aral, and tributaries of the Baltic Sea (Woynarovich, 1955; Mordukhai-Boltovskoi, 1979; Leppäkoski, 1984).

Hemimysis anomala
Shows autochthonous distribution in coastal waters and tributaries of the Pontocaspian seas. It is strongly euryhaline, from freshwater to an optimum in mesohaline conditions, tolerating salinities of up to 19‰. It swims actively under the cover of rocks and weeds, avoiding sunlight. It occurs benthically at a wide range of depths, from the shallow sublittoral to a maximum of about 30 m depth. *H. anomala* gathers in swarms during the day in crevices, microcaves or in the shelter of dense macrophyte stands and breeds from April to October (Bacescu, 1954). It feeds on zooplankton, particulate and algal matter (Bacescu, 1954), and Ketelaars et al. (in press) reported it as omnivorous, but with a strong feeding preference for cladocerans over copepods. Faasse (1998) collected specimens in the

Noorder-IJ-plas, near the Noordzeekanaal, in June 1997. It was also found in stomachs of young perch (*Perca fluviatilis*) and pikeperch (*Stizostedion lucioperca*) taken from the river Waal, near Nijmegen (51°51'N, 05°5'E) in September 1997 (leg. B. Kelleher & G. van der Velde). Van Beek et al. (1998) observed six specimens at one location on the river Meuse near the mouth of the Meuse-Waal canal (51°45'N, 05°52'E) in November 1997. Furthermore, *H. anomala* was recorded in November 1997 in the Biesbosch reservoir where, since July 1998, it has been sampled in very high densities (0.01-6.61 ind. l^{-1}) (Ketelaars et al., in press). These densities coincided with a large decrease in chlorophyll-a concentrations in the Biesbosch reservoir, indicating that *H. anomala* also feeds on phytoplankton. Fragments of *H. anomala* have also been found in a side channel of the river Waal, at Opijnen canal (51°49'N, 05°19'E), where one observation of the species was made on both 26-VI-98 and 4-IX-98 (leg. A.G. Klink & D. Tempelman). In October 1998, specimens were found in the river Meuse at Keizersveer, and the Andijk reservoir which abstracts water from Lake IJsselmeer in the north-west of the Netherlands (Ketelaars et al., in press). *H. anomala* has also been found in stomach contents of percids collected in the Haringvliet in 1998 (leg. J. de Leeuw). This species has been intentionally introduced for the enrichment of fish food bases in tributaries of the Baltic Sea where it widely dispersed in brackish coastal waters up to the coasts of Finland (Leppäkoski, 1984; Salemaa & Hietalahti, 1993).

DISCUSSION

L. benedeni and *H. anomala* have joined the Pontocaspian assemblage of species which have invaded the Dutch Lower Rhine over the last decade. Exactly from where these mysids invaded remains difficult to answer. From autochthonous populations in the Lower Danube, *L. benedeni* invaded the Middle Danube where it was detected in 1946 in the Winter Harbour of Budapest (Dudich, 1947; Woynarovich, 1955). Animals from the Hungarian Danube population were intentionally introduced into Lake Balaton for enrichment of fish food in 1950 (Woynárovich, 1955). From the Hungarian reach, the mysid spread further upstream in the Danube to Slovakia, Austria and Germany, possibly via passive dispersal by navigation (Wittmann, 1995). The species was also intentionally introduced into rivers discharging into the Baltic Sea in the 1970/1980's, where it established populations in a few impoundment basins (Vaitonis, 1991). Intentional introduction of the species to the Lower Rhine is unlikely, and the Danube is the most likely origin of the invasive Rhine population of *L. benedeni*.

Both *L. benedeni* and *H. anomala* were found for the first time in the German reach of the Rhine in October 1997; *L. benedeni* in a stand of *Myriophyllum spicatum* lying in an isolated sidebranch, 576 km, right side, (Geissen, 1997), and *H. anomala* in a stony bank of the river (Schleuter et al., 1998). These authors emphasised the difficulty of identifying means and pathways of mysid dispersal, although it is likely that *L. benedeni* reached the Rhine via shipping traffic mediated by the opening of the Rhine-Main-Danube canals. This is also indicated by the fact that *L. benedeni* showed an upstream migration to the Upper Danube, and recently invaded the Main-Danube canal and river Main (Wittmann, 1995; Reinhold & Tittizer, 1998; Wittmann et al., in press). For *H. anomala* the question of dispersal is more difficult, because there are two alternative pathways of invasion to be considered. Besides a possible invasion from the Danube river, where is has recently been found in the upper Danube (Wittmann et al., in press), it may be suggested that *H. anomala* arrived in the Rhine via ballast water of ships coming from the Baltic coast. The observation by Faasse (1998) of *H. anomala* in a small water body near the Noordzeekanaal in Amsterdam, also indicates a migration from the estuaries by this species, which prefers brackish water. The use of electrophoretic allozyme analysis could be considered to resolve this puzzling question, however while it is clear that Danubian *H. anomala* are of Black Sea origin, there is conflicting evidence as to the source of Baltic populations which are derived either from the Caspian Sea or Black sea regions (leg. K.J. Wittmann). Geissen (1997) and Schleuter et al. (1998) suggested that both recently discovered species may have actually existed in the Rhine for quite some time before being detected in monitoring. The fact that specimens of both species were collected in The Netherlands, a few months before the first records in Germany, supports the validity of their arguments, and highlights the drawbacks of normal monitoring programs in detecting invasive taxa like Mysidacea.

The invasion of these mysids may cause profound effects on the Lower Rhine and other Dutch aquatic ecosystems. Little is known of their competitive abilities, and their importance as food for predatory fish may cause an alteration of macrofaunal and fish assemblages in some habitats. The feeding ecology of both species may be quite different from that of *Mysis relicta* (Lovén, 1862), which provoked detrimental effects on the planktonic community, especially on daphnids, following their intentional introduction into freshwaters of northern Europe and North America (Rieman & Falter, 1981; Fürst et al., 1984). However, the effects of *H. anomala* on planktonic assemblages in the Biesbosch reservoirs suggests it shares this capacity to alter community structure (Ketelaars et al., in press). *H. anomala* may not do so well in still-water areas of the Lower Rhine, due to its higher salinity optimum, but it seems to be already successful in some Dutch freshwater reservoirs, and occurs in the slow-flowing river Meuse. It may also find suitable environments in the many brackish water areas behind the dikes along the Dutch coast. Considering its macrophytic habit and low salinity tolerance, it is conceivable that *L. benedeni* could expand its local range to the stagnant, eutrophic inland lakes and canals of The Netherlands, becoming more than just part of the fauna of the Rhine and its connected large waters.

ACKNOWLEDGEMENTS

We would like to thank M.G. Versteeg, T. van Venrooy and C. ni Eidhin for technical assistance. We greatly appreciate the support by the Stichting 'Wetland Passewaay'. Much thanks are due to R. Munts (Bureau Waardenburg), H.A. M. Ketelaars (Waterwinningbedrijf Brabantse Biesbosch), A.G. Klink (Aquasense) and J. de Leeuw (Agricultural University of Wageningen) for providing us with information and records of freshwater mysids. M. Bruijs prepared the figure.

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Received: November 1998.
Distributed: 12 March 1999.

This periodical is irregularly published by the Zoological Museum and the Institute for Systematics and Population Biology, both of the University of Amsterdam.
Requests for exchange or subscription (NLG 120.- per volume) should be addressed to the Library of the Faculty of Biology, University of Amsterdam, Plantage Middenlaan 45, 1018 DC Amsterdam, the Netherlands.
This periodical may be quoted in abbreviation as Bull. zool. Mus. Univ. Amsterdam.
ISSN 0165-9464