

Introduction of *Ptilohyale littoralis* to The Netherlands

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The north-west Atlantic amphipod Ptilohyale littoralis has been introduced to The Netherlands. After its initial discovery in the port of Rotterdam, additional specimens were collected near the national centre of shellfish trade and culture Yerseke and along the Westerschelde estuary, which leads to the port of Antwerp.

Keywords: *Ptilohyale littoralis*, introduction, port, shellfish

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INTRODUCTION

In amphipods a pelagic larval phase is lacking and, as a consequence, secondary long-distance dispersal of introduced species of this group is mainly anthropogenic. Human-mediated introductions in general have a highly stochastic character, resulting in patchy distribution patterns for species without a dispersive larval phase (Chapman & Carlton, 1991, 1994). Smaller and larger leaps to new areas may be recorded by regularly surveying potential recipient areas. Three harbour regions and one location with shellfish trade and culture in The Netherlands were surveyed several times, which yielded a new introduced amphipod species and revealed probable leaps from one region to the other.

MATERIALS AND METHODS

Study area

Surveyed locations are, from north to south (Figure 1):

- (1) IJmuiden, Noordzeekanaal, gateway to the port of Amsterdam ($52^{\circ}27'47.04''\text{N}$ $4^{\circ}37'53.02''\text{E}$);
- (2) Rotterdam, Calandkanaal in port ($51^{\circ}56'17.80''\text{N}$ $4^{\circ}11'14.51''\text{E}$);
- (3) Yerseke, along the Oosterschelde embayment, centre of shellfish trade and culture ($51^{\circ}29'43.36''\text{N}$ $4^{\circ}03'14.39''\text{E}$);
- (4) Vlissingen, mouth of Westerschelde estuary, gateway to the port of Antwerp (Belgium) ($51^{\circ}26'25.70''\text{N}$, $3^{\circ}36'30.59''\text{E}$).

In the Noordzeekanaal, a canal connecting the port of Amsterdam to the North Sea near IJmuiden, horizontal and vertical salinity gradients exist, but tidal movement is absent due to sluice docks at the North Sea end. Surface water is brackish along the entire length of the canal; full salinity only

occurs in deeper water at the seaward end. The Calandkanaal in the port of Rotterdam has a semi-estuarine character, with mixing of seawater and freshwater, and some tidal influence. Yerseke is situated along the Oosterschelde, a fully marine, tidal embayment. The Westerschelde estuary, despite heavy dredging and reinforcement of the shores, has retained a significant part of its estuarine character. The mouth of the estuary near Vlissingen is almost fully-marine. Years in which locations were surveyed are indicated in Table 1.

Collecting methods

The principal method of collecting was overturning of boulders in the littoral zone. The underside of the boulders was inspected and hyalids were induced to jump into a sample container. Clumps of mussels were taken apart. In Rotterdam also cobbles and seaweeds were sampled. In Yerseke hyalids were collected with other invertebrates living under Pacific oysters *Crassostrea gigas* (Thunberg, 1793), after detaching the oysters. Specimens were preserved in 70% ethanol.

Identification

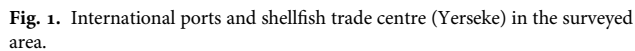
Specimens were dissected, parts mounted on temporary slides in glycerine and examined with a compound microscope. Photographs were taken with a consumer-grade digital single-lens reflex camera attached to the microscope. Specimens were identified using species descriptions in Bousfield & Hendrycks (2002) and works cited therein. Specimens were also compared with preserved specimens of *P. littoralis* from Rudee Inlet, Virginia Beach, Virginia, North America ($36^{\circ}49'48.80''\text{N}$ $75^{\circ}58'05.50''\text{W}$).

RESULTS

Records

Ptilohyale littoralis (Stimpson, 1853) was found to be abundant in the port of Rotterdam on 11 July 2009. On 6 August

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Fifteen specimens of *P. littoralis*, collected on 11 July 2009 in Rotterdam have been deposited in the collection of Naturalis Biodiversity Center: Leiden, with No. RMNH.CRUS.A.5046.

In species of *Ptilohyale* the posterior margins of the proximal part of the flagellum and the fifth segment (in the female only the distal half) of the peduncle of the antenna are densely covered with plumose setae (Bousfield & Hendrycks, 2002) (Figures 2 & 3). No European genus of the family Hyalidae shares this character. In the Mediterranean species *Parhyale plumicornis* (Heller, 1866), in addition to segment 5 of the peduncle and the proximal part of the flagellum, the posterior margin of peduncular segment 4 bears long setae as well (Krapp-Schickel, 1993).

Table 1. Years in which locations were surveyed, with indication of results. P, *Ptilohyale littoralis* found; –, *P. littoralis* not found.

Location	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
IJmuiden				-							-	-			
Rotterdam	-	-			-	-					p	p	p		
Yerseke									-	-	-	-	-	-	p
Vlissingen	-	-	-	-			-				-	-		-	p



Fig. 2. *Ptilohyale littoralis*, male, 6 August 2009, Rotterdam.

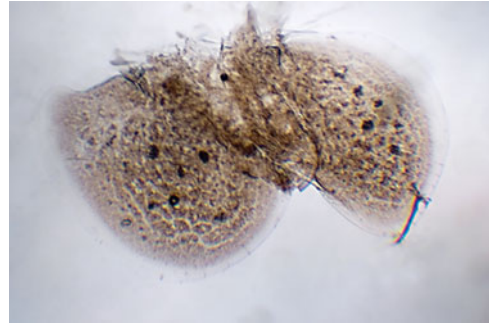


Fig. 5. *Ptilohyale littoralis*, male, left fifth coxa, lateral view (hind lobe to the right), 11 July 2009, Rotterdam.



Fig. 3. *Ptilohyale littoralis*, male, left second antenna, peduncle articles 3 (part), 4 and 5, and 3 proximal articles of flagellum, 11 July 2009, Rotterdam.



Fig. 6. *Ptilohyale littoralis*, male, left first gnathopod, basis without anterodistal lobe (arrow), 11 July 2009, Rotterdam.



Fig. 4. *Ptilohyale littoralis*, male, left first uropod revealing 4 marginal spines, 11 July 2009, Rotterdam.



Fig. 7. *Ptilohyale littoralis*, male, left second coxa, with pronounced marginal cusp (arrow), 11 July 2009, Rotterdam.

A key for the genus *Ptilohyale* is given by Bousfield & Hendrycks (2002). The most important characters used to identify the *Ptilohyale* specimens from The Netherlands as *P. littoralis* are illustrated in Figures 4–7. The number of spines on the margin of the outer ramus of uropod 1 is usually 3, sometimes 4 (Figure 4), seldom 5. The rami of the second uropod are subequal in length. The posterior lobe of coxa 5 is distinctly smaller than the anterior lobe (Figure 5). Gnathopod 1 basis (male) is lacking a distinct anterodistal lobe (Figure 6). Coxae 1–4 hind margins are provided with quite distinct cusps (Figure 7).

The number of marginal spines on the outer ramus of uropod does not fully agree with the key of Bousfield & Hendrycks (2002), who gave a figure of 2(3), but this character is variable. The only consistent difference with their key is the broadly rounded basis of the fifth pereopod. However, this

rounded basis of pereopod 5 is in agreement with specimens from Virginia.

DISCUSSION

Identification

The genus *Ptilohyale* Bousfield & Hendrycks, 2002 contains mainly estuarine, hopping amphipods that were formerly assigned to the genera *Hyale* and *Parhyale*.

The species of *Ptilohyale* are very similar morphologically and several of the named species may be synonyms. Bousfield & Hendrycks (2002) mention 7 named species. The describer of *P. iole* (Barnard, 1970) himself says it is a synonym of *P. crassicornis* (Haswell, 1880) (as *Hyale*

crassicornis): ‘can only be relegated to subspecific level and may not actually deserve this distinction’ (Barnard, 1974). According to Chapman (2007) *P. crassicornis* (as *P. crassicornis*) and *P. plumulosa* (Stimpson, 1857) are synonyms of *P. littoralis* (Stimpson, 1853). *Ptilohyale plumulosa* had already been synonymized with *P. littoralis* by Bousfield (1973). However, Bousfield & Hendrycks (2002) reversed this decision. The presence of *P. littoralis* in the north-west Atlantic, as well as the north-east Pacific and south-east Australia is explained by introduction by man (Chapman, 2007). *Ptilohyale plumulosa* (as *Hyale plumulosa*) has also been recorded from southern Africa (Griffiths, 1976). Species of the genus *Ptilohyale* have been recorded from Hong Kong several times. Moore (1990) mentions ‘*Hyale* B (aff. *iole*/barbicornis) from Victoria Harbour and/or Cape d’Aguilar, Hong Kong’. Tsoi & Chu (2005) recorded *P. crassicornis* from Tolo Harbour in Hong Kong. Horton (2008) recorded *Ptilohyale* aff. *barbicornis* from Cape d’Aguilar, Hong Kong. The lack of records of *Ptilohyale* species from surrounding areas (Lowry, 2000) suggests introduction to Hong Kong by man may be involved.

Ptilohyale explorator (Arresti, 1989) has been described (as *Parhyale explorator*) from the Bassin d’Arcachon in south-west France, the sole locality in the north-east Atlantic whence it has been recorded. This first record from a faunistically well-known area of shellfish culture, where many alien species have been introduced, strongly suggests the species concerned has been introduced by man as well. *Ptilohyale explorator* has been subsequently recorded from a single bay in the north-east Mediterranean Sea, i.e. Iskenderun Bay in Turkey (Bakir *et al.*, 2008). The amphipod fauna of the Mediterranean is well known (Bellan-Santini & Ruffo, 1998) and Iskenderun is a large port; it is likely the species has been introduced to Iskenderun Bay by man. The identity of *P. explorator* merits further investigation.

Introduction to The Netherlands

As *P. littoralis* is a littoral species occurring, for example, under cobbles it may have been carried around the world already in the days of wooden ships, in dry ballast. However, the presence of suitable hard substratum habitat in ports of The Netherlands is of relatively recent origin. The most likely route of introduction of *Ptilohyale littoralis* to The Netherlands is with ballast water or hull fouling in the port of Rotterdam. The species was found there abundantly in 2009, while in other locations it was only found in much lower numbers in 2013, in spite of surveys in previous years (Table 1). A species of the genus *Ptilohyale* has been recorded from hull fouling. Davidson *et al.* (2009) found *Ptilohyale* sp. in the hull fouling of a containership in California. This *Ptilohyale* sp. could even be *P. littoralis*, as the north-east Pacific *P. plumulosa* is considered a synonym by Chapman (2007).

Introduction with imported shellfish is less likely. In The Netherlands, release into the environment of shellfish imported from outside Europe is forbidden. If this rule is strictly adhered to, it would preclude the direct introduction of *P. littoralis* from North America to The Netherlands with imported shellfish. The possibility that the amphipod has been previously introduced to a different part of Europe unnoticed cannot be ruled out. Thus, imports of shellfish from such a region to The Netherlands could account for its

introduction here. However, numbers of *P. littoralis* found in Yerseke are very low, compared to Rotterdam. Furthermore, the species has not been recorded from samples of shellfish imported from European countries (A. Gittenberger, personal communication) and we are not aware of records of *Ptilohyale* from transported shellfish in general. However, *P. explorator* has been described from the Bassin d’Arcachon, an area of intensive shellfish farming.

Without further research it is impossible to distinguish between secondary introductions and multiple primary introductions of *P. littoralis* to The Netherlands. Secondary introduction is a more likely explanation for instances in which an alien species shows up at nearby localities within a short time, although the possibility of more than one introduction from the region of origin cannot be ruled out completely. Secondary introduction from Rotterdam to the Westerschelde estuary could result from ballast water release or hull fouling of coasters visiting both harbour regions or from the heavy inland ship traffic between the harbours of Antwerp and Rotterdam along the Schelde-Rijnkanaal. Secondary introduction from the port of Rotterdam to the shellfish trade centre in Yerseke is very hard to explain, unless *P. littoralis* is already widespread over the south-west of The Netherlands. Although the origin of the first population in The Netherlands is most likely the Atlantic coast of North America, any region where *P. littoralis* has been introduced can be the donor region and even introduction from elsewhere in Europe cannot be ruled out completely. Population genetics could help resolve the question of the origin of the different local populations.

Surveying early invasion histories

Similar leaps of introduced peracarid crustaceans between widely separated harbour regions are common. The first European record of the amphipod *Grandidierella japonica* Stephensen, 1938 is from Southampton Water on the south coast of the UK in 1997/1998 (Smith *et al.*, 1999). In 2004/2005 it was collected in the Orwell estuary on the east coast (Ashelby, 2006). *Caprella mutica*, first recorded in Europe from The Netherlands, probably hopped to Scotland and Norway by human interference (Cook *et al.*, 2007). Disjunct distribution of cryptogenic species has been advocated as evidence of an alien origin (Chapman & Carlton, 1991, 1994). Especially in groups without or with a short-lived dispersive larval phase (e.g. certain ascidians, bryozoans and gastropods), distribution of introduced species may long remain patchy in receptor regions. Introduced peracarid crustaceans, having no dispersive larvae and adults with restricted mobility, are ideal organisms to study the development of disjunct distributions by surveying harbours, marinas and shellfish culture areas. The early invasion history of aliens which do have dispersive larvae is much more difficult to track.

Ecology

Several indigenous amphipods of the family Gammaridae, the melitid *Melita palmata* (Montagu, 1804) and the hyalid *Hyale nilssoni* (Rathke, 1843) partly live in the same habitat as *P. littoralis* in The Netherlands. Near Vlissingen and Borssele *P. littoralis* was the only amphipod species found. In Rotterdam *P. littoralis* and *H. nilssoni* were mutually exclusive, *H. nilssoni* living more seaward. In Yerseke the latter two species and

Melita palmata occurred together; therefore it is not yet clear whether competition between them occurs.

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