

Research Article

The Australian feather-duster worm *Laonome calida* Capa, 2007 (Annelida: Sabellidae) introduced into European inland waters?

María Capa^{1,2*}, Godfried van Moorsel³ and David Tempelman⁴

¹University Museum, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

²Australian Museum, 6 College Street, Sydney 2010 NSW, Australia

³Ecosub, P.O. Box 126, 3940 AC Doorn, The Netherlands

⁴Grontmij|team Ecology, P.O. Box 95125, 1090 HC Amsterdam, The Netherlands

E-mail: maria.capa@ntnu.no (MC), vanmoorsel@ecosub.nl (GvM), david.tempelman@grontmij.nl (DT)

*Corresponding author

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Abstract

Laonome calida Capa, 2007, a feather-duster worm discovered in 2007 in estuaries and open water of tropical and subtropical Australia, was recently found at many locations in fresh and brackish waters of the delta region of the rivers Rhine, Meuse, and Scheldt in the Netherlands. Morphological differences between specimens from Australia and the Netherlands are insufficient to warrant specific distinction. A recent translocation from Australia to Europe, or from a third country to both, may explain the disjunct distribution of this species. A table with translocated and cryptogenic sabellids reported to date is provided.

Key words: Netherlands, Australia, Sabellidae, new record, translocation, alien species

Introduction

In 2009–2012, at many locations in the delta region of the rivers Rhine, Meuse and Scheldt, in the Netherlands, a new sabellid species showed up for the first time (Figure 1). The specimens have been identified as *Laonome calida* Capa, 2007, a medium-size fanworm (Sabellidae: Polychaeta), described from the opposite side of the planet in Australia (Figure 1). A possible explanation for the disjunct distribution is a non-deliberate translocation of members of this species from its native distribution (possibly Australia), followed by establishment in a non-indigenous geographic area (the Netherlands).

Australian specimens were found in open-water marine environments (Dampier Archipelago, Western Australia), but most sampling locations were in brackish, estuarine, non-tidal environments (Queensland and Northern Territory) (Capa 2007). The Dutch specimens were found exclusively in tidal and non-tidal estuarine and even fresh-water conditions with very low winter temperatures.

Considering the different habitats in Australia and the Netherlands, we do not exclude the possibility that the Dutch records represent a closely related species with morphological characteristics within the range of those in Australian specimens of *L. calida*.

This paper deals with the environment and the morphology of the Dutch specimens and discusses the possible origin and transport vector.

Materials and methods

The Dutch specimens were collected at twenty locations (Table 1S) using a variety of sampling gears (Table 2S), e.g. Ekman grab, Van Veen grab, and a pond net. In several cases, artificial substrates were deployed prior to sampling. The majority of sampling stations have been sampled on an annual basis (always in autumn, normally October). The method used at each station was kept identical over the years. For instance, the Canal Ghent-Terneuzen near Sluiskil was sampled

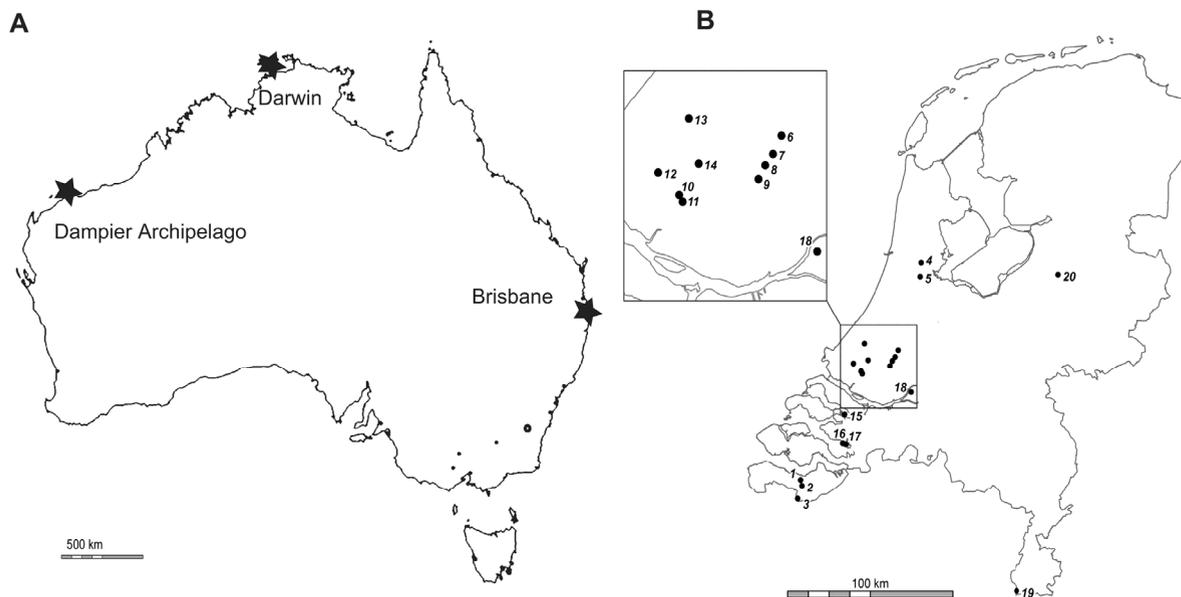


Figure 1. Collection sites: (A) Australia; (B) The Netherlands. For details see supplementary material.

annually from 2004 onwards, always using artificial substrates as sampling method. Five locations were sampled on each single occasion.

Samples were preserved in ethanol. The samples collected at the annual sampling stations were processed following a prescribed and constant protocol, involving sorting under a microscope. Microscopic sorting of ethanol-preserved material was also carried out in most other samples. Only the samples of the four city canals were sorted with the naked eye. In one case (Amsterdam Schinkelkade), a sample was collected without preservation and sorted alive.

Specimens were studied using stereo and light microscopes. Chaetae and uncini were removed and mounted on slides. The internal structure of radioles and dorsal lips were examined by cutting thin transverse sections of these structures at the base with a surgical blade and mounting them on slides. Photographs were taken using Olympus BX51 and Olympus SZH10 microscopes.

Some specimens were dehydrated in ethanol, critical-point dried, covered with 20 nm of gold and examined under a Leo 435VP scanning electron microscope, using Robinson backscatter and Everhart-Thornley secondary electron detectors. Acronym of museum collection referred to in the material examined sections: AM: Australian Museum, Australia.

Results

Description of the collection locations in Australia

The Australian collection locations are described in Capa (2007).

Description of the collection locations in the Netherlands

Specimens of *Laonome* sp. aff. *L. calida* from the Netherlands (referred to as *L. calida* from the Netherlands onwards) were collected in man-made canals as well as in environments associated with the rivers Rhine and Meuse (Tables 1S–2S). The sampling locations showed a large range of substrates and water quality. In the brackish and non-tidal man-made canals, salinities reach up to 4.5. Here, the species was collected on fully and permanently submerged stones. In several fresh-water city canals, the species was collected at depths of 1–2 m and substrates included loam, clay, and silt and were littered with debris (Figure 2A). Very different were the fresh-water (salinity ~0.4) intertidal biotopes. The tidal range was circa 0.5 m. When the semi-diurnal tide was out, small silty mudflats emerged but they never dried out (Figure 2B). At Eijsden in the southernmost part of the country, the species

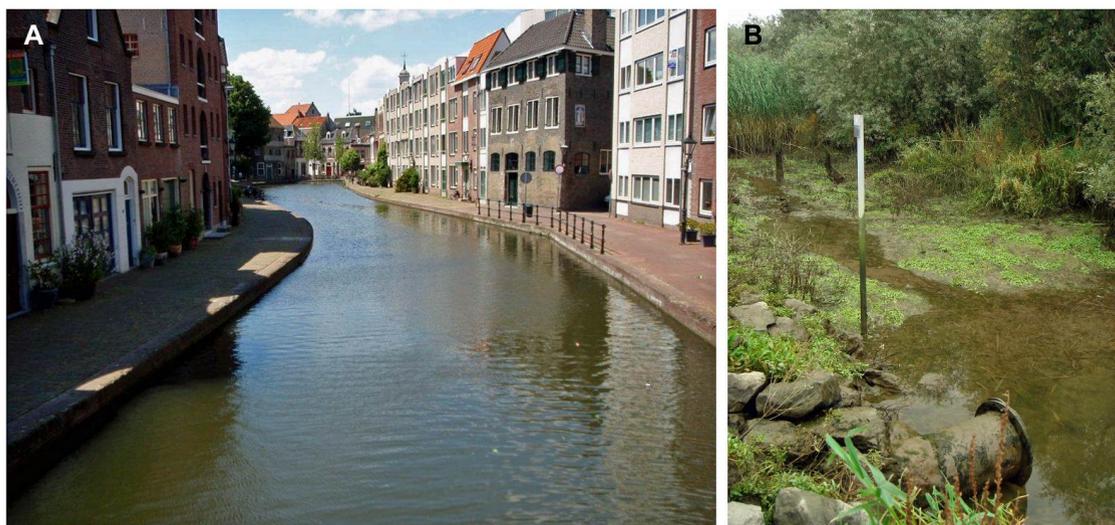


Figure 2. Sampling locations (A) Schiedam, 23 June 2009 (Figure 1B: location 14); (B) Oude Maas Ruigeplaatbosch, 28 September 2010 (Figure 1B: location 10). A, photo by Ernst Raaphorst; B, photo by David Tempelman.

was collected in riparian conditions from gravel substrate. During the sampling period, water temperatures ranged between 10 and 20°C. However, during winter, the water temperatures dropped to between 0 and 5°C.

Taxonomic account

Order SABELLIDA

Family SABELLIDAE Latreille, 1825

Genus *Laonome* Malmgren, 1866

Laonome calida Capa, 2007

(Figures 3–4)

Laonome calida: Capa, 2007: 544–547, Figures 2, 3A–G, 4A, B.

Material examined

Holotype: Australia, Queensland, Gladstone, Calliope River, 23°51'S, 151°10'E (+/-10 km), coll. 1974 (AM W31327).

Paratypes: same locality and dates as holotype (AM W31328).

Additional material: Specimens examined in Capa (2007).

Specimens from the Netherlands: see Tables 1S–2S.

Diagnosis: *Laonome calida* lacks dorsal and ventral radiolar appendages, and presents a smooth peristomial collar without dorsolateral notches. It lacks paleate chaetae on the first

chaetiger, only narrowly hooded chaetae are present instead. Companion chaetae are present on the thorax. Posterior abdominal segments are flattened ventrally forming an anal depression.

Description of material from the Netherlands

Specimen length 9–15 mm, width 0.5–0.8 mm. Radiolar crown about one third of total body length (Figure 3A). Body cylindrical, tapering posteriorly with 6–8 thoracic and 31–45 abdominal chaetigers, in largest specimens. Radiolar crown with 4–8 transverse pigmented lines in inner side of radioles and base of some pinnules (Figure 3A–C). Body pale, lacking pigmentation (Figure 3A–E). Radiolar crown with radioles arranged in semicircles on each lobe. Radioles quadrangular in cross-section, with ciliated outer ridge; lateral flanges absent (Figure 4A–C). Tips of radioles cylindrical, longer than pinnules at mid length of radioles. Pinnules arranged in two alternating rows, diminishing in size distally. Radioles supported by two rows of vacuolated cells (axial skeleton, Figure 3F). Basal membrane present but reduced, measuring less than one thoracic segment (Figure 4B). Dorsal lips with rounded distal ends. Radiolar and pinnular appendages absent. Anterior peristomial ring low and even in height all around. Posterior peristomial collar present, with dorsal margins fused to faecal groove, projecting anteriorly to sub-triangular ventral lappets; midventral incision about half

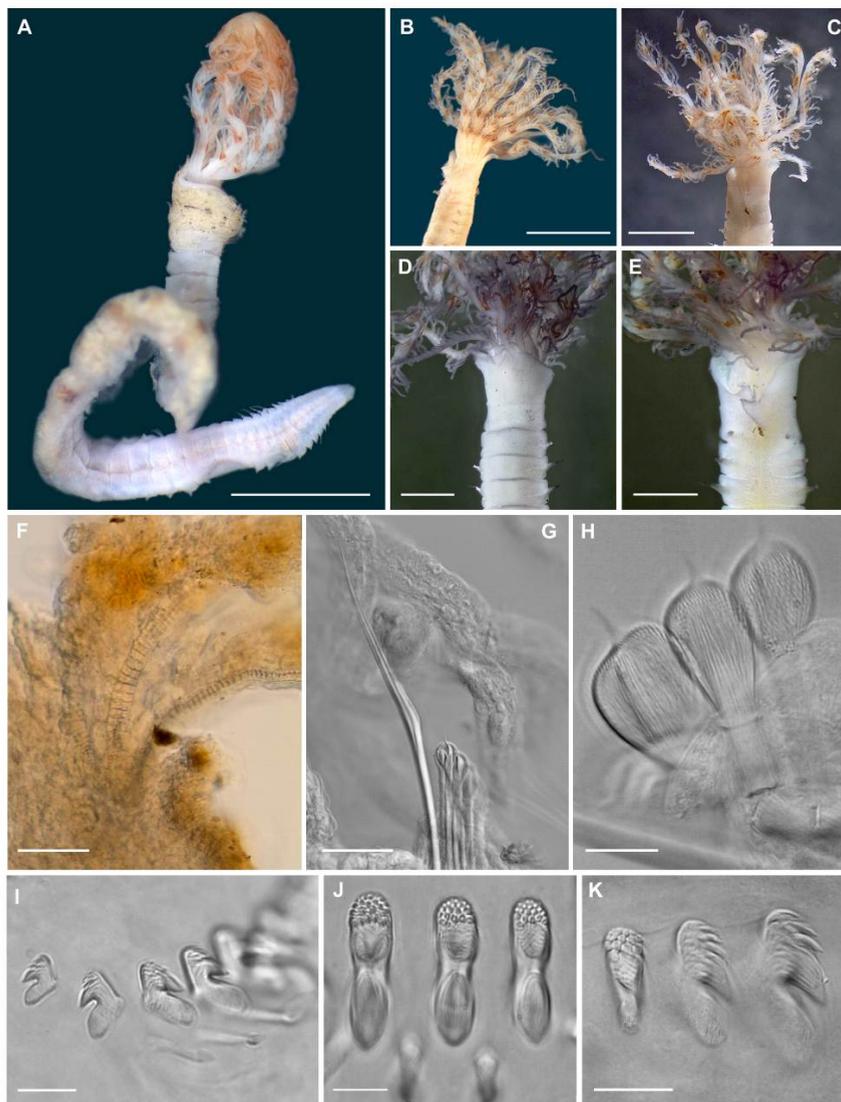


Figure 3. *Laonome calida* Capa, 2007, photographs from specimens collected in the Netherlands: (A) complete specimen; (B) anterior end, lateral view; (C) same, dorsolateral view; (D) same, ventral view, stained specimen; (E) same, dorsal view, stained specimen; (F) radioles and axial skeleton (two rows of vacuolated cells); (G) chaetal fascicle, second thoracic segment; (H) paleate chaetae, same segment; (I) thoracic uncini, side view; (J) thoracic uncini, frontal view; (K) abdominal uncini. Scale bars: A–C: 1mm; D, E: 0.5mm; F: 100 μ m; G: 50 μ m; H, J, K: 10 μ m; I: 20 μ m. Photomicrographs by David Tempelman.

length of collar; lateral collar margins smooth, lacking lateral incisions (Figures 3B–E; 4A–C). First chaetiger separated from collar by pale transverse ridge. Thorax 3–4 times longer than wide. Ventral shields inconspicuous, quadrangular and in contact with uncinal tori. First chaetiger with two oblique rows of elongate narrowly-hooded chaetae (Figure 4D). Following thoracic chaetigers with two rows of chaetae as well; superior row with elongate narrowly-hooded chaetae and inferior row with one or two tiers of paleate chaetae (Figures 3G, H; 4E, F). Thoracic uncini about five rows of several teeth each above main fang (Figures 3I, J; 4G, H), breast

well developed, no handle but a small knob instead (Figure 3I). Companion chaetae present, with thin distal asymmetrical membrane with proximal small denticles on less than a quarter of their surface (Figure 4G, I). Abdominal chaetigers with broadly-hooded neurochaetae in anterior and posterior chaetigers. Abdominal uncini with approximately five rows of 2–4 teeth each above main fang, with breast well developed and handle absent (Figures 3K, 4K, L). Last abdominal chaetigers decreasing in width to end, with a ventral anal depression in the last approximately 10–15 chaetigers, only apparent in few well-preserved specimens (Figures 3A, 4M). Pygidium as a conical

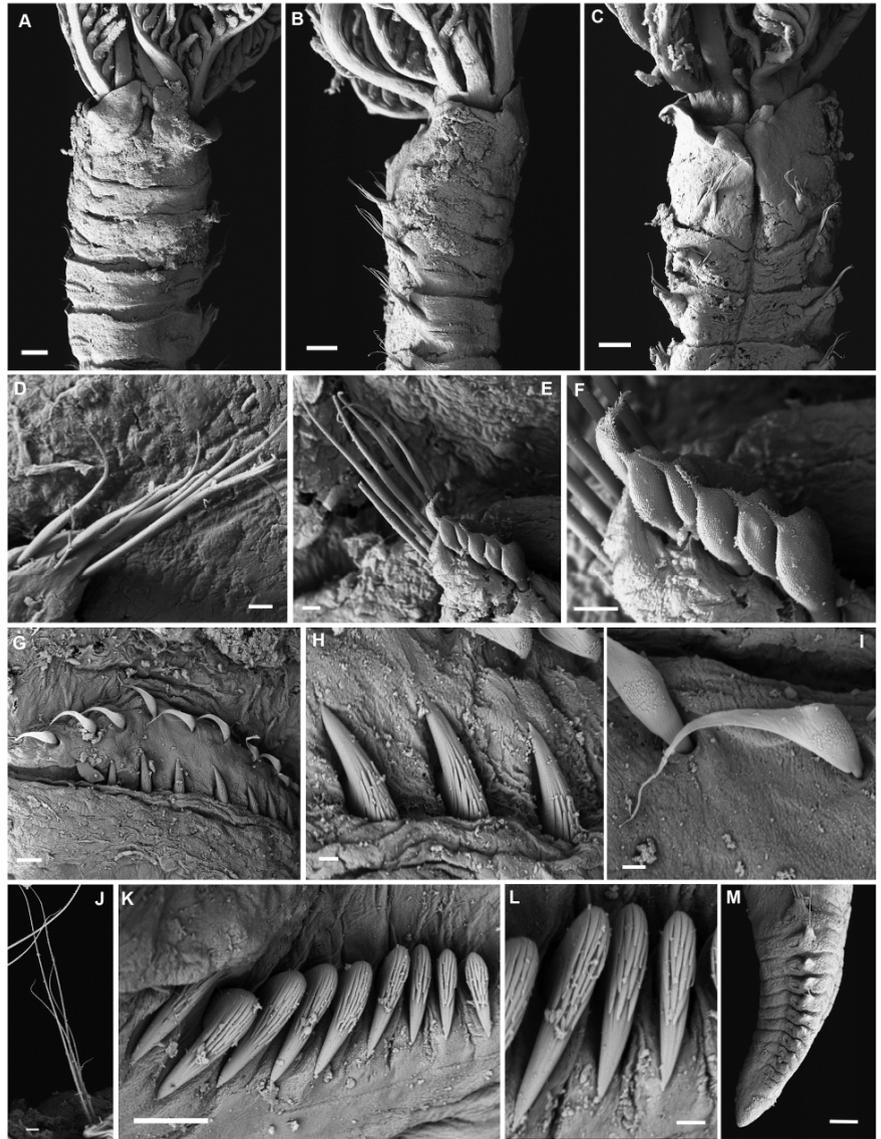


Figure 4. *Laonome calida* Capa, 2007, scanning electron micrographs (SEM): (A) anterior thoracic segments, ventral view; (B) same, lateral view; (C) same, dorsal view; (D) chaetal fascicle, first thoracic segment; (E) same, second thoracic segment; (F) paleate chaetae, same segment; (G) thoracic uncini and companion chaetae; (H) thoracic uncini; (I) companion chaetae; (J) chaetae, posterior abdominal segments; (K) uncini, anterior abdominal segments; (L) uncini, posterior abdominal segments; (M) posterior end, pygidium and anal depression. Scale bars: A–C, M: 100µm; D–G, J, K: 10 µm; H, I, L: 2 µm. Micrographs by Pat Hutchings and Sue Lindsay.

papilla (Figures 3A; 4M) with a midventral groove. Pygidial eyes absent. Tube consists of a thin layer of mucus with fine particles attached.

Comparison with Australian specimens

Specimens from the two continents were similar in shape, size and total number of segments. They shared the diagnostic features and some other attributes, such as the number of the thoracic segments (6–8) and the number of tiers of the inferior thoracic chaetae. The latter are not included in the original description of *L. calida*

but were examined for the present study and ranged from one to two in both Dutch and Australian specimens.

Some minor differences were found between the specimens from the Netherlands and those from Australian waters. Pigmented bands in the radiolar crown were more numerous in the European specimens, showing 4–8 transverse bands instead of the 1–4 in the Australian material. In some Australian specimens, incipient pinnular appendages were observed; inconspicuous or absent in the specimens from the Netherlands. Although, in some of the European specimens the

pale transverse ridge and the anal depression were not noticeable, they were observed in at least some individuals, so these attributes were considered to be present in this population.

Comparison with similar and sympatric congeners

According to Capa (2007), this species is distinguished from congeners by a unique combination of characters: the absence of dorsal and ventral radiolar appendages, the presence of a collar with a smooth edge and without dorsolateral notches, the absence of paleate chaetae on the first chaetiger, the presence of companion chaetae on the thorax and an anal depression. The Dutch specimens presented all diagnostic features of *L. calida*, although the presence of an anal depression has only been verified in few specimens. Several specimens were incomplete, lacking posterior segments or were not in good enough condition to confirm this character.

The species most similar to *L. calida* is *Laonome albicingillum* Hsieh, 1995 from Taiwan. It shares the presence of companion chaetae, the absence of dorsal radiolar appendages, and the absence of paleate chaetae on the collar fascicle. However, *L. calida* is distinguished from *L. albicingillum* by the presence of an anal depression encompassing ~15 posterior chaetigers, the absence of dorsolateral notches in the collar, and the presence of pigmented bands in the radiolar crown, as well as other characteristics (Hsieh 1995; Fitzhugh 2002; Capa 2007).

Only two *Laonome* species have been reported outside the Indo-Pacific, *Laonome kroyeri* Malmgren, 1866 and *Laonome triangularis* Hutchings and Murray, 1984. *Laonome kroyeri*, the type species of the genus, is common in the North East Atlantic and the Arctic Ocean (Malmgren 1866; Jirkov 2001; Read and Fauchald 2014). It differs from *L. calida* in the presence of paleate chaetae in thoracic segments, absence of companion chaetae and anal depression, and other features (Fitzhugh 2002; Capa 2007). *Laonome triangularis*, originally described from Australia, was recently reported as an introduction to the Mediterranean (Çinar 2009). *Laonome calida* and *L. triangularis* differ in the shape of dorsal lips (rounded in *L. calida*, and with dorsal radiolar appendages in *L. triangularis*); distribution of paleate chaetae in thoracic segments (absent in first chaetiger in *L. calida* and present in *L. triangularis*); arrangement of rows of teeth of

thoracic uncini (five transverse rows of several teeth each in *L. calida* and 3–4 rows of one tooth each in *L. triangularis*) (Hutchings and Murray 1984; Capa 2007; Çinar 2009).

Discussion

Evidence of an unintentional introduction into the Netherlands

After detailed examination of specimens from Australian (Queensland, Northern Territory and North Western Australia) and Dutch origin, the morphological differences between populations were found insufficient to consider them separate species. However, Australia and the Netherlands are at opposite sides of the planet and their populations are isolated geographically. The successful translocation of a species from tropical marine and estuarine waters to a temperate estuarine and fresh-water environment is very unusual. Therefore, we cannot exclude the possibility that additional information, e.g. from genetic techniques, will eventually prove the *Laonome* specimens reported in this paper from the Netherlands to be a new species with an almost identical morphology to *L. calida*.

With the information presently available, we assume that specimens have been unintentionally translocated from Australia or a different, as yet unknown origin, to the Netherlands. This introduction has probably occurred recently because this species was not found before 2009 in this well-surveyed delta region of Rhine, Meuse and Scheldt, and it was suddenly discovered within a three-year time period at twenty different locations in the Netherlands. The majority of these sampling stations were sampled earlier repeatedly, some even annually since 1997, using the same sampling protocol. Therefore, the sudden appearance of *L. calida* cannot be explained by a change in sampling. We refute the possibility that earlier *Laonome* records were attributed to other species, since records of sabellids have not been reported from this inland area. *Laonome calida* may be small, but its general appearance and colour pattern are unique for Dutch inland waters. Within a short time span, we received specimens of *L. calida* from several independent workers in the Netherlands, all requesting the identity of this species. In conclusion, we can only assume an alien origin of this species in the Netherlands. Considering the large number of non-indigenous species in these waters (Wolff 2005; Leuven et al. 2009), this is a feasible explanation.

Table 1. List of translocated and cryptogenic sabellid species.

Species	Origin	Introduced to	Proposed vector	References
<i>Amphicorina pectinata</i> (Banse, 1957)	Pacific	W and central Mediterranean	?	Zenetos et al. 2005, 2010
<i>Bispira polyomma</i> Giangrande & Faasse, 2012	?	The Netherlands	aquaculture	Faasse and Giangrande 2012; Haydar 2012
<i>Branchiomma bairdi</i> (McIntosh, 1885)	Caribbean	Gulf of California, E Mediterranean	ship hulls	Tovar-Hernández et al. 2009 a, b, 2011; Çinar 2009; Zenetos et al. 2010; Giangrande et al. 2012; Arias et al. 2013.
<i>B. curtum</i> (Ehlers, 1901)	Chile?	Caribbean	?	Tovar-Hernández and Knight-Jones 2006; Tovar-Hernández and Dean 2010
<i>B. luctuosum</i> (Grube, 1870)	Red Sea	Mediterranean	Lessepsian migration or ballast water	Bianchi 1983, Licciano et al. 2002; Zenetos et al. 2005, 2010; Çinar et al. 2006, El Haddad et al. 2008
<i>Desdemona ornata</i> Banse, 1957	Indo-Pacific	Mediterranean	?	Zenetos et al. 2005, 2010
<i>Euchone limnicola</i> Reish, 1959	N Pacific	SE Australia and New Zealand	?	Hewitt et al. 2004; Inglis et al. 2006; Wilson and McArthur 2008
<i>Laonome calida</i> Capa, 2007	?	The Netherlands	?	present study
<i>L. triangularis</i> Murray and Hutchings, 1984	Australia	E Mediterranean	? ballast water	Çinar 2009
<i>L. elegans</i> Gravier, 1906	Red Sea	E Mediterranean	?	Zenetos et al. 2005, 2010
<i>Megalomma claparedi</i> Gravier, 1908	Red Sea	W Mediterranean	?	Gravili et al. 2010
<i>Myxicola infundibulum</i> (Montagu, 1808)	Mediterranean	California, S Australia	?	Poore et al. 1975; Boyd et al. 2002; Hewitt et al. 2004
<i>Parasabella pallida</i> Moore, 1923	Caribbean	E tropical Pacific	ship hulls	Tovar-Hernández et al. 2009a
<i>Sabella spallanzanii</i> (Gmelin, 1791)	Mediterranean	Brazil, Australia, New Zealand	ballast water and/or ship hulls	Carey and Watson 1992; Clapin and Evans 1995; Patti and Gambi 2001; Read et al. 2011
<i>Sabellastarte spectabilis</i> (Grube, 1878)	Indo-Pacific	?Hawaii	? ship hulls	Eldredge and Smith 2001; Capa et al. 2010
<i>Terebrasabella heterouncinata</i> Fitzhugh and Rouse, 1999	South Africa	California	aquaculture	Culver et al. 1997; Fitzhugh and Rouse 1999; Kuris and Culver, 1999; Moore et al. 2007 (and references therein)

Several criteria have been used to distinguish non-indigenous species from native species in marine and estuarine waters (e.g. Chapman and Carlton 1991; Boudouresque et al. 1994; Ribera and Boudouresque 1995; Wolff 2005). Some of these criteria are fulfilled by the population of *L. calida* in the Netherlands: 1) the species is new to Dutch waters, even though the Rhine delta area has been well surveyed in the past (Wolff 1973; annual surveys of the *Monitoring van de Waterstaatkundige Toestand des Lands* - MWTL programme); 2) there is a considerable discontinuity between the Dutch and Australian populations; 3) there is insufficient natural dispersal to account for the observed distribution; 4) the Dutch population is localized in a limited area, which could be an indication of a recent introduction; 5) the population in the Netherlands has a stronger development (more abundant) compared to the Australian ones. This could be attributed to the release from natural predators and parasites, but also to occupation of formerly empty niches; 6) the only natural environment where this species has been recorded until now is the Dampier Archipelago,

in northern Western Australia, whereas most of the remaining collection sites are disturbed environments near international ports and harbours in Australia (such as Darwin Harbour, Calliope River and Brisbane waters) and the Netherlands (Rhine Delta).

Introduction of species of the family Sabellidae (*sensu stricto*) as non-natives is not unusual; including *L. calida*, there are sixteen cases (Table 1). The majority of these species is known as being introduced directly or indirectly by human vectors to areas that lay outside the area where natural range extension could be expected, and have become established in the wild as self-maintaining populations (Eno et al. 1997). Some species, like *Bispira polyomma* Faasse and Giangrande, 2012, have been recounted as cryptogenic (Faasse and Giangrande 2012; Haydar 2012). Therefore, the status as native or introduced of these species remains unclear (see Table 1). For some of these taxa, the transport vector has been identified and this includes fouling of ship's hulls or mooring devices. Attached to these surfaces, several sabellids, such

as *Branchiomma bairdi* (McIntosh, 1885), *Bispira manicata* (Grube, 1878), and *Parasabella* spp., may have travelled long distances (Tovar-Hernández et al. 2009a, b; Capa, unpublished data). Other species have colonized other geographic areas travelling as larval stages in ballast water held in tanks and cargo holds of ships; for example *Sabella spallanzanii* (Gmelin, 1791), translocated from the Mediterranean Sea to several locations in Australia and New Zealand (Clapin and Evans 1995; Andrew and Ward 1997; Patti and Gambi 2001; Read et al. 2011). Another vector of introduction is in association with the transport of species for maricultural purposes. This is the case of *Terebrasabella uncinata* Fitzhugh and Rouse, 1999, introduced to California from South Africa together with abalone (Ruck and Cook 1998; Kuris and Culver 1999).

Reproductive strategies and dispersal of *Laonome* species are poorly known, but they have been studied in *L. albicingillum*, a simultaneous hermaphrodite from estuaries in Taiwan. Larvae are lecithotrophic, with rapid development and settlement is completed within 26–33 h after fertilization; they thus have low long-distance dispersal ability (Hsieh 1995, 1997). Assuming *L. calida* shows similar characteristics, translocation as larvae in ballast water is improbable for Australia-European distances. However, it is possible that larvae have settled in ballast tanks (either at the still inner hull or in accumulating mud in corners of ballast tanks) and made the crossing as post-larval stages.

Ecological features of Laonome calida: a highly tolerant species?

The closely-related introduced species *Laonome triangularis* Hutchings and Murray, 1984 made a crossing over a similar distance, from Australia to the Mediterranean, in ballast tanks (Çinar 2009). Both *L. calida* and *L. triangularis* are euryhaline and eurythermal, inhabiting sediments of shallow-water estuarine or oceanic environments (Hutchings and Murray 1984; Capa 2007; Çinar 2009). Some of these conditions may be found in ballast tanks.

If *L. calida* is able to settle and survive in soft mud and in euryhaline and eurythermal conditions, this indicates a huge potential habitat in the Rhine delta and other European waters. Its rapid expansion in the Netherlands also points in that direction. However, whether *L. calida* will become invasive in Europe is as yet unknown.

Introduction of marine species from Australia to the North East Atlantic does not occur often. Moreover, cases known, e.g., the barnacle *Austrominius modestus* (Darwin, 1854) (Crisp 1958; Buckeridge and Newman 2010) or the sabellid *L. triangularis* (Çinar 2009) present translocations between temperate areas. The establishment of a tropical marine/estuarine species into the Netherlands is very unusual. Immigration of temperate species from the Pacific to the North East Atlantic is more customary (Wolff 2005, Leuven et al. 2009). We do not exclude the possibility for a non-Australian origin of *L. calida* and a wider and possibly also more temperate distribution of this species than currently reported. There are two undescribed *Laonome* species from China and California (Fitzhugh 2002) also in possession of companion chaetae, which may include *L. calida*. Therefore, it is not impossible for (some Australian) populations of *L. calida* to originate from elsewhere.

Ecological risk?

Several introduced sabellids (Table 1), like other non-native marine invertebrates, have become invasive or pests, i.e. playing a conspicuous role in the recipient ecosystems, taking the place of keystone species and/or being economically harmful (Clapin and Evans 1995; Culver et al. 1997; Eno et al. 1997; Culver and Kuris 2004). Early discovery of introduced and alien species is a priority for biosecurity reasons and for this purpose, several methodologies have been proposed to identify potential introduced species (e.g. Campbell et al. 2007; Keller et al. 2011) and to prevent marine invasions (e.g. Hewitt and Campbell 2007).

Conclusion

The reasons described above allow us to hypothesize about the potential translocation of this species to European waters, with its still elusive origin. Although the species was described from Australia, its natural distribution is incompletely known. The analyses of the genetic variability of this species in its geographic extent could elucidate its introduced status, since an introduced species is expected to have the same genetic identity as part of its ancestral population. At present, unfortunately, no material is available from the Australian populations to perform such investigations (all material fixed in formalin). In case the introduction is confirmed, shipping might be the vector of translocation, and a probe

could be designed to test the presence of larvae or adults in ballast tanks.

Although our taxonomic research clearly indicates the discovery of *L. calida* in Europe, we cannot exclude the possibility that genetics will eventually prove the *Laonome* species reported for the Netherlands in this paper to be a new species with an almost identical morphology to *L. calida*. Nonetheless, we decided not to wait for new information before to bring to notice the appearance of this species in Europe. Continuous monitoring of the introduced population in the Netherlands and beyond is recommended.

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Supplementary material

The following supplementary material is available for this article:

Table 1S. Geographic coordinates of the sampling sites in Figure 1B.

Table 2S. Records *Laonome calida* in the Netherlands from 2009 to 2012.

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