Non-indigenous marine and estuarine species in The Netherlands

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An overview is presented of non-indigenous marine and estuarine plant and animal species recorded from The Netherlands. In this list both exotic species from outside NW Europe and non-indigenous species from elsewhere in NW Europe are enumerated. Species that have been suggested to be non-indigenous in The Netherlands but for which insufficient evidence could be found are discussed shortly as well. The list is based mainly on literature data supplemented by own observations of the author. At least 99 plant and animal species have been introduced from elsewhere in the world. Another 13 species have been introduced from other parts of NW Europe. The third category of dubious non-indigenous species enumerates 37 species. The list is preceded by an introduction describing the history of Dutch research on introduced species, the origin of the marine and estuarine flora and fauna of The Netherlands, natural and human-induced dispersal processes, and a summary of the geographic patterns of introduced species.

Contents

1. Introduction

Ever since I found the first Dutch specimens of the polychaete *Mercierella enigmatica* Fauvel, 1923 (now *Ficopomatus enigmaticus*) in the brackish lake Veerse Meer (fig. 1) in 1968 (Wolff, 1968, 1969), I have had an interest in non-indigenous marine and estuarine species in The Netherlands. In my PhD thesis (Wolff, 1973) I enumerated the non-indigenous benthic animal species occurring in the estuarine area of the rivers Rhine, Meuse, and Scheldt (also known as the Delta area) in the SW Netherlands. From that time on I have kept track of publications on non-indigenous species in the Dutch marine and estuarine environment and I have presented lists of non-indigenous species in the Dutch Wadden Sea (Wolff, 1992, 1996, 1999; Wolff et al., 1994). Also the enumeration by Vaas (1975) of introduced species in the Delta area was largely based on my data. Korringa (1951) and Den Hartog & Van der Velde (1987), however, provided their own lists of non-indigenous marine and estuarine species in The Netherlands. Stegenga (2002a, b; see also Stegenga & Prud'homme van Reine, 1998) provided a list of introduced seaweeds.

This paper attempts to bring together all published evidence on human-caused introductions of marine and estuarine species in The Netherlands. It is based on my personal experience with many of these species in Dutch coastal waters and on white and grey literature. I did not study any collections to check identifications by others. Instead I relied on critical evaluations of collected material and the literature by taxonomic experts and myself.

But why does it make sense to collect such data for the territory of a country? Would a listing for an ecological unit, such as the North Sea (see Reise et al., 1999), not make much more sense? The answer is in the nature of the data. These are mainly found in a large variety of local publications, in many cases in the Dutch language, making them inaccessible for most foreign scientists. In the end, however, such national lists, such as the one presented, and those by Eno et al. (1997) for Great Britain and Nehring & Leuchs (1999) for Germany, should be combined in surveys of ecological units.

After a general introduction on non-indigenous species in The Netherlands, this publication contains a list of Dutch species that have been considered to be

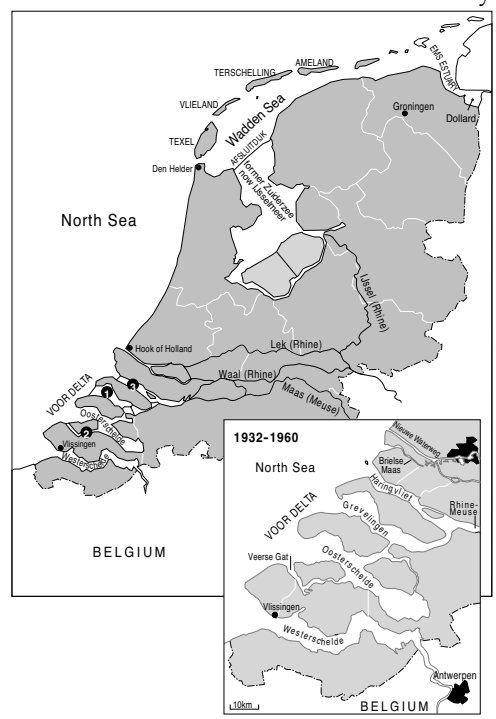

Fig. 1. Map of The Netherlands for the period 1987-present. Inset: situation in the period 1932-1960. Names indicate seas, estuaries, rivers, and other major water bodies; towns and villages are mostly not shown. 1 = Lake Grevelingen (saline); 2 = Lake Veerse Meer (brackish); 3 = Lake Haringvliet (fresh).

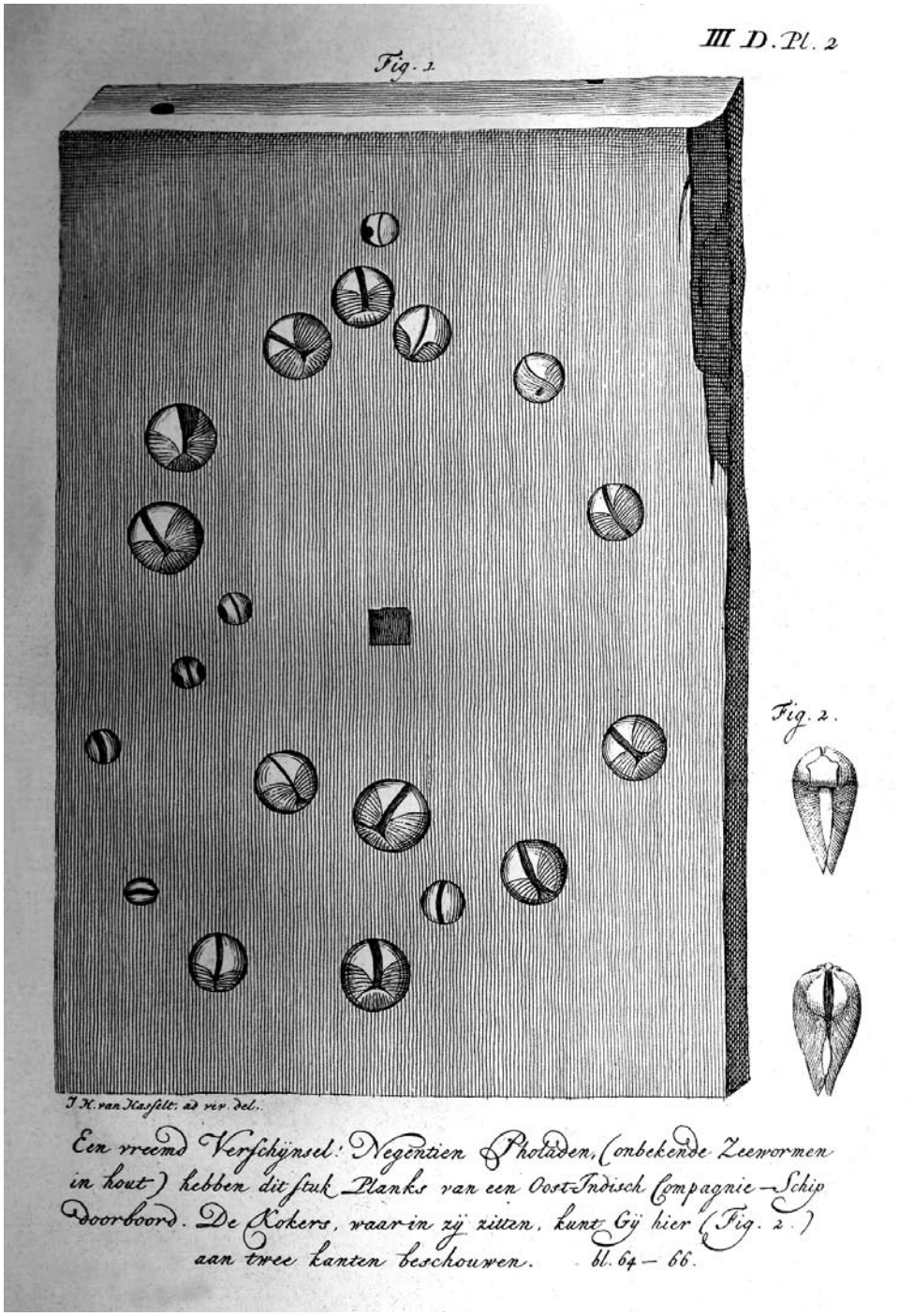

Fig. 2. Piddocks in the wooden hull of an East-Indiaman as illustrated by Martinet (1778).

non-indigenous species by me or by other authors. In this list I have distinguished between species that are truly non-indigenous in my opinion and species for which in my opinion we have insufficient evidence for a non-indigenous origin. In preparing this list I have collected information on all species found in salinities over 0.5 psu. This means that a few euryhaline freshwater species have been included.

2. History of Dutch research on non-indigenous species

The recognition that particular marine or estuarine species occurring in Dutch waters had been introduced into The Netherlands from other parts of the world came only gradually. Of course, 17th and 18th century observers will have noted the many fouling species on ships returning from other parts of the world. For example, an unknown author described in 1764 the occurrence of *Balanus tintinnabulum* (Linnaeus, 1758) on a stranded vessel coming from West Africa (Holthuis & Heerebout, 1972). Martinet (1778) suggested that East-Indiamen had introduced shipworms (*Teredo navalis* Linnaeus, 1758), and he showed an illustration depicting wood from such a vessel infested by (unidentifiable) piddocks (fig. 2). Darwin's (1854) publication suggesting that *Balanus amphitrite* Darwin, 1854, *B. improvisus* Darwin, 1854 and a few other barnacle species had been transported to parts of their reported range as fouling on ships, will have been read in The Netherlands. Hoek (1882) was asked to investigate whether the predatory gastropod *Ocenebra erinacea* Linnaeus, 1758 had been introduced into The Netherlands with French oysters. But it probably was the bivalve *Petricola pholadiformis* Lamarck, 1818 which was the first non-indigenous species in The Netherlands recognised immediately as such at its first Dutch find in 1905 (Denker, 1907). Next year, Ostenfeld (1908) came to the conclusion that the planktonic diatom *Odontella sinensis* (Greville) Grunow had been introduced into the North Sea from East Asia by ship transport, perhaps with ballast water. Kerbert (1918) believed that the nudibranch gastropod *Corambe batava* Kerbert, 1886, nowadays known as *C. obscura* (Verrill, 1870), might have been introduced into the Zuiderzee (fig. 3) from the Sargasso Sea on a ship's hull (Butot, 1984). Also the gastropod *Crepidula fornicata* (Linnaeus, 1758) was immediately recognised as a non-indigenous species upon its arrival in The Netherlands in 1924 (Oorthuys, 1924). Korringa (1951) was the first author who systematically considered whether the species he found on oysters in the Oosterschelde estuary around 1940, could have been introduced. On the

Fig. 3. Map of The Netherlands in the period 1867-1932. Names indicate seas, estuaries, rivers, and other major water bodies; towns and villages are mostly not shown.

other hand Den Hartog (1959), in his extensive dissertation on epilithic algae in The Netherlands, was unable to recognise more than one introduced macroalgal species in The Netherlands, viz. the green alga *Codium fragile* (Suringar) Harriot. However, he suspected that also a few other species had been introduced with oysters. My earlier list of non-indigenous benthic animal species in the Delta area (Wolff, 1973) was the first attempt to bring together many scattered observations on non-indigenous marine and estuarine species.

The earliest observations of non-indigenous species have been reconstructed from the literature and museum collections. Originally such species were not recognised as foreigners and it is only with hindsight that we conclude that those species must have been introduced. This applies, for example, to *Teredo navalis* (first recorded in 1730 or earlier), *Molgula manhattensis* (De Kay, 1843) (1762), *Mya arenaria* (Linnaeus, 1758) (1765), *Rhithropanopeus harrisii* (Gould, 1841) (first recorded in 1874), *Corambe obscura* (1879 or 1881), and *Cordylophora caspia* (Pallas, 1771) (1884). Perhaps *Balanus improvisus* (1827, but in Antwerp, Belgium, in 17th century) should be added.

3. Origin of the marine flora and fauna of The Netherlands

For the purpose of this publication the history of the marine fauna and flora of The Netherlands is supposed to start at the maximum of the last (Weichselian) glaciation about 18,000 years ago. At that time ice caps covered Scandinavia and Scotland and because sea level was over 100 m lower than now, the southern North Sea was dry land (fig. 4). The coastal marine fauna and flora at the northern shore of the dry basin of the present North Sea will have been similar to that of the present Arctic seas with no or very few species occurring nowadays in the coastal waters of The Netherlands (Jansen et al., 1979). The ancestors of the present biota of the North Sea will have been living West and South of what is now known as the Western Approaches to the Channel (Wolff, 1972).

With the rising sea level after the last glaciation the sea penetrated again from the West into the Channel and from the North into the North Sea basin. The horizontal rate of advance will have been dependent on the vertical speed of sea level rise and the slope of the land. Based on the vertical rate of rise and the horizontal distance to be covered between the Western Approaches and the present Dutch coast, the horizontal advance will not have been more than a few hundreds of meters per year at maximum. It is not difficult to conceive

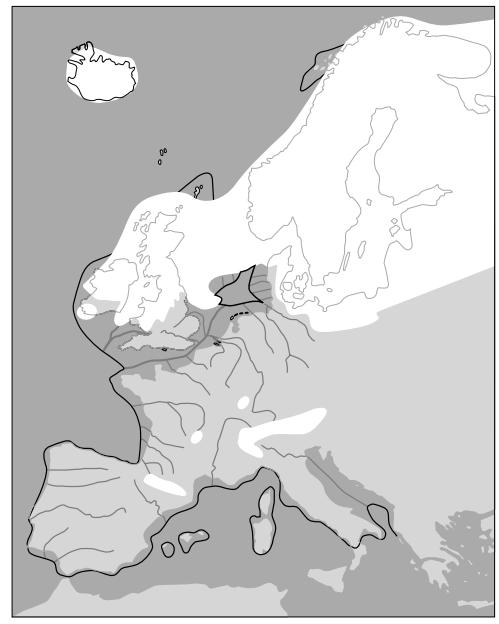

Fig. 4. Topography of NW Europe during the maximum of the Weichselian glaciation (18,000 years B.P.). After Valentin (1957) and Siegert (2001).

that the distribution of most marine organisms will have been able to track this relatively small annual expansion of the marine realm. Hence, I conclude that the present flora and fauna of Dutch coastal and offshore waters in the first place have been derived from the glacial biota living West and South of the entrance of the Channel during the last glaciation.

The fossil record might inform us about the species involved in this post-glacial migration. Jansen et al. (1979), Denys et al. (1983), and Vos & Baardman (1999) show that many present-day mollusc species as well as a few other species with calcareous parts occur in Holocene sediments from the North Sea and the Wadden Sea. A conspicuously absent species during most of the Holocene is the bivalve *Mya arenaria* (Hessland, 1946).

For benthic species this post-glacial migration process will have depended on the presence of suitable substratum. West of the Strait of Dover this might not have been a problem, but once the southern North Sea was reached rocky-shore species were confronted with an absence of suitable habitat. Only when humans constructed artificial rocky shores in the form of moles, jetties and sea walls this situation changed (Den Hartog, 1959; Wolff, 1999a; Stegenga, 2002b). Since this is a relatively recent development, it is possible that not all rocky-shore species that potentially might live in this artificial environment have reached this new habitat.

4. Natural dispersal processes

Marine organisms possess natural mechanisms of dispersal. This is immediately clear for planktonic and nektonic organisms (Shanks et al., 2003). Plankton is carried with sea currents. This also holds true for ebb and flood currents transporting water and suspended material back and forth. The length of this tidal excursion can be up to 10-20 km per tide. Due to turbulent mixing processes part of the water transported on the ebb will not return all the way on the flood (and vice versa) and may be transported further with the next ebb. Thus the combination of tidal currents and turbulent mixing can result in a directed transport of part of the material suspended in the water mass and, hence, also of phytoplankton and planktonic stages of benthic organisms. This process at least partly explains how newly introduced benthic organisms with meroplanktonic larvae can show dispersal against the direction of the residual current. The residual current is the net difference between the distance and amount of water moved during ebb and that during flood. Along the Dutch coast the residual current on average moves from SW to NE (fig. 5) with about 100-150 km per month. On a larger scale, Kautsky (1988) measured the dispersal of radionuclide wastes released at Cap de la Hague in Normandy (fig. 6). He shows that the residual current moves the water masses in the Channel and the southern North Sea in about a year from Cap de la Hague to the German Bight, resulting in an average speed of about 60 km per month. However, one has to take into account the relatively slow residual current in the German Bight. Doing so, the distance from the Channel Islands to the Dutch Delta area would be covered in about 3-4 months and the Dutch Wadden Sea would be reached in about 5-6 months. With strong westerly winds such transports can go faster, whereas strong northeasterly winds are able to reverse the direction of the current (Prandle, 1978, 1984; Salomon et al., 1993). Anyhow, drifting as well as planktonic organisms

Fig. 5. Residual currents in the North Sea and the Channel. After Pernetta (1994).

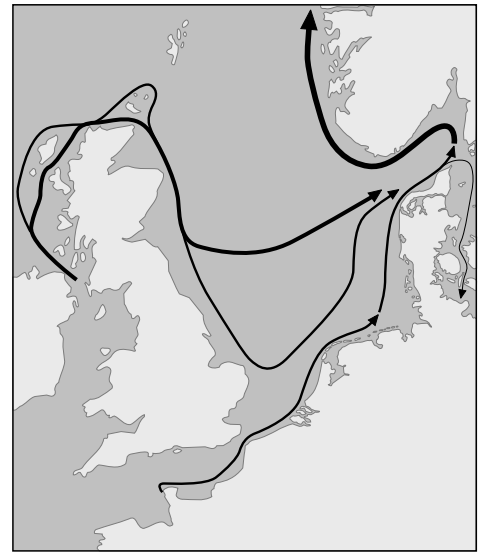

Fig. 6. Residual currents around Great Britain, in the Channel and in the North Sea as derived from the concentration and distribution of radionuclides discharged at Sellafield, United Kingdom, and Cap de La Hague, France. After Kautsky (1988).

occurring in the western part of the Channel potentially may be transported to the southern North Sea and the Dutch coastal area. This also applies to meroplanktonic species. However, in the latter case we have to assume that these planktonic stages of benthic organisms have stopover sites as adults at intermediate locations.

Another path of transport finds its origin in Atlantic water moving into the North Sea north of Scotland after which part of this water mass moves southward along the British coast until the latitude of The Netherlands (fig. 5, fig. 6).

Nektonic species can move both through transport by currents and by active swimming. Some species have been shown to selectively use tidal currents running into the 'right' direction. For many species annual migrations are known between breeding and feeding or wintering areas. This has been demonstrated in the North Sea area for cetaceans, fish, decapod crustaceans, and squid.

A few species have arrived naturally in Dutch waters as commensals or parasites of other marine organisms straggling into this area from Arctic or Atlantic areas of distribution. This applies, for example, to the barnacles and other crustaceans arriving on marine turtles and whales (Holthuis, 1969). Such species usually do not establish themselves in Dutch waters, hence, these have not been considered in this paper.

Currents can transport also benthic organisms. Almost annually large quantities of macro-algae wash ashore on the sandy Dutch coast; species include *Fucus* spp., *Ascophyllum nodosum* (Linnaeus) Le Jolis, *Himanthalia elongata* (Linnaeus) S.F. Gray, *Halidrys siliquosa* (Linnaeus) Lyngbye, *Laminaria* spp., *Cystoseira* spp., and *Sargassum muticum* (Yendo) Fensholt (Den Hartog, 1959; Prud'homme van Reine, 1977, 1980). Lucas (1950) listed no less than 171 different algal species washed ashore and nine years later Den

Hartog (1959) stated that this number had nearly doubled. Conspicuous species such as *Himanthalia, Halidrys,* and *Cystoseira* do not grow attached to benthic substrates along the Dutch coast and they must have arrived from elsewhere. Other plant and animal species occur on these large algae and in particular on the holdfasts of *Himanthalia*; these will be transported as well. This agrees with the findings of Hobday (2000, 2000a) who showed that in Californian waters kelp (*Macrocystis pyrifera* (Linnaeus) Agardh) could drift with the currents for about 100 days while transporting a large variety of organisms.

The most likely area of origin of the benthic algae washed ashore on the Dutch coast is the Channel area (Den Hartog, 1959; Prud'homme van Reine, 1977, 1980). *Himanthalia elongata* even occurs only along the shores of the western part of the Channel. The likelihood of this area of origin is supported by other observations. Bunches of cork used by French and British fishermen to mark their lobster pots have been found washed ashore on the Dutch coast, often with benthic organisms not know from The Netherlands attached. IJzerman (1937) identified rock fragments attached to algae washed ashore in The Netherlands as originating from Normandy and southern England. Lacourt (1949) listed 38 bryozoan species washed ashore and not known to occur in Dutch coastal waters. Den Hartog (1959) listed 57 plant and animal species washed ashore on Dutch beaches which at that time never had been found as indigenous organisms in Dutch coastal waters and which he deduced to have arrived from the Channel coasts. Den Hartog (1959) also recorded seven species he considered likely to have arrived from the (British?) shores of the northern North Sea. Another four species, viz. the brown alga *Sargassum natans* (Linnaeus) Gaillon, the shipworms *Bankia fimbriatula* Moll & Roch, 1931 and *Neoteredo reynei* (Bartsch, 1920), and the Columbus crab *Planes minutus* (Linnaeus, 1758), he believed to have arrived from the central Atlantic or even the West Indies. The finds of the West-African *Crassostrea denticulata* (Born, 1791), washed ashore in 1990 and later years (Rizzi, 1992; Verkuil, 1992, 1998), and the Caribbean *Pinctada imbricata* (Röding, 1798) found on the beach in 2002 (Cadée, 2003) might also be cases of long-range transport. Cadée (2000) discussed tropical drift seeds on the Dutch coast, another indicator of long-range transport by marine currents. So, apparently there is a continuous natural immigration of 'foreign' plants and animals into the coastal waters of The Netherlands. Since part of these species arrives in reproductive condition, it may be assumed that several indigenous species have established themselves on the Dutch coast as descendants of floating individuals. This applies especially to the species that have colonised the artificial rocky shores of The Netherlands (Den Hartog, 1959; Wolff, 1999a; Stegenga, 2002b).

It should be noted that man has increased the possibilities for transport by drifting. Originally, drifting material will have consisted mainly of macroalgae, shells of cuttlefish, and wooden logs. Man has added many other varieties of wood, glass objects, metallic floats, plastics etc. Especially plastics nowadays constitute a large share of drifting material. This material partly originates from river discharge, but also from waste thrown over board from ships.

Drifting material transported by currents is also under the influence of the wind. For oil slicks at sea it is known that they are transported in the direction of the wind with a velocity of about 3% of the wind speed. For example, 3% of a steady 10 m. sec^{-1} wind (Beaufort 5) would result in a displacement of nearly 800 km per month. Although

the effect of the wind on other drifting materials is not exactly known, this example shows that the effect of wind can be very important. It means that with favourable winds drifting material from Normandy may reach the Dutch coast in perhaps 1-2 months.

I conclude that there is ample evidence that marine organisms living elsewhere along the Atlantic coasts of Europe may be transported to the Dutch coast by natural processes.

5. Biogeographic position of Dutch coastal waters in Europe

Given the natural dispersal processes identified above we should be able to define an area from which marine organisms can easily reach the coastal waters of The Netherlands by natural processes. The data of Den Hartog (1959) cited above make clear that this area includes at least the Channel area and the North Sea. However, assuming stepwise dispersal in which one established population serves as the source of the next dispersal event, this area may be much larger. How much larger is difficult to decide, however. Would, for example, Brittany be a boundary because it's SW coast is characterised by a South-going current? Billot et al. (2003) demonstrated that this is not the case for the kelp *Laminaria digitata* (Hudson) Lamouroux that in Brittany shows gene flow against the direction of the currents.

Longhurst (1998) identifies the Northeast Atlantic Shelf Province as an ecological and biogeographical unit for the pelagic ecosystem. It comprises the continental shelf of Western Europe, from Northern Spain to Denmark and includes the Baltic Sea. However, this biogeographical unit is based on observed distribution patterns, not on dispersal processes. The same is probably true for earlier biogeographic subdivisions. I assume that the best approximation of the area from which organisms can reach the coast of The Netherlands by natural processes has to be based on wind and current patterns (Pernetta, 1994). This defines an area including the northern coast of the Iberian peninsula, the Bay of Biscay, the waters around the British Isles, the Channel, the North Sea and the Baltic (fig. 7). A non-indigenous organism introduced anywhere in this area has a fair chance to ultimately reach and establish itself at the coast of The Netherlands, unless other environmental factors (temperature, day-length, salinity etc.) prohibit its occurrence. It is possible that the southern boundary of this area occurs even farther to the South since in winter a northward current occurs along the Portuguese coast. Due to the continuous eastward surface current through

Fig. 7. Area from which marine organisms may reach The Netherlands by natural transport processes.

the Strait of Gibraltar the Mediterranean probably is not part of this area. The implication of this latter conclusion is that the Mediterranean can be a source of non-indigenous species for the seas of NW Europe.

The boundaries of the area defined in the previous paragraph should not be understood as absolute boundaries, however. The ecological characteristics of the organisms to be transported play a part as well. A mud-burrowing isopod without a pelagic stage no doubt will show less dispersal than a planktonic diatom.

6. Introduction processes

6.1. Dispersal by natural processes

Natural processes support the further dispersal of non-indigenous species once they have established themselves somewhere along the European coasts. Ironically, this can best be demonstrated by the range extension of non-indigenous species. The brown alga *Sargassum muticum*, which floats after detachment, spread along the European coasts after its discovery in southern England in 1973 (Boudouresque, 1994), and covered annually on average about 100 km in north-easterly direction and on average about 50 km in south-westerly direction (fig. 8). However, the dispersal of this species may have been aided by human transports of oysters. This is unlikely for the bivalve *Ensis directus* (Conrad, 1843) discovered in 1979 in the German Bight. This species disperses through planktonic larvae; it moved annually about 150 km in a northerly direction and about 50 km against the predominating current direction towards the southwest (Luczak et al., 1993; Armonies, 2001) (fig. 9). Shanks et al. (2003) review pelagic dispersal of larvae of fish and invertebrates and conclude that in many species larvae

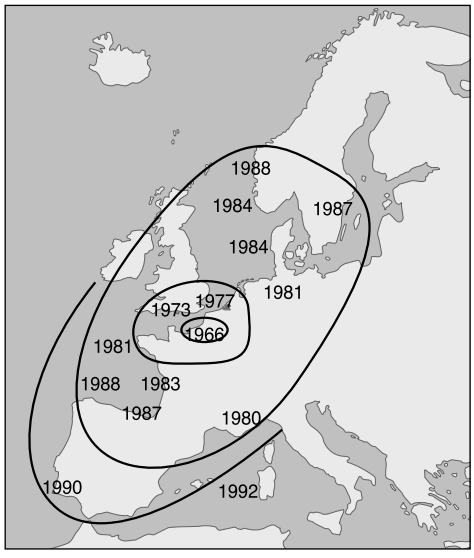

Fig. 8. Expansion of the introduced brown alga *Sargassum muticum*. After Boudouresque (1994).

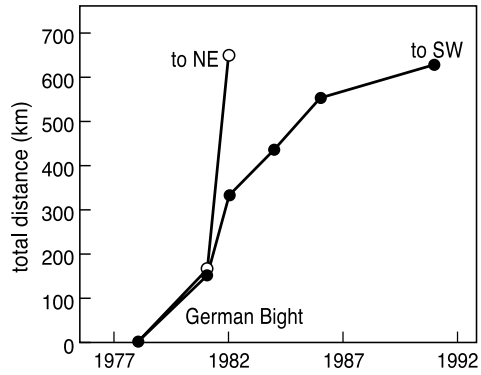

Fig. 9. Expansion of the introduced bivalve *Ensis directus*. NE indicates dispersal from the German Bight to the North East, SW to the South West. After Luczak et al. (1993).

can cover tens, if not hundreds, of kilometres. Other species, however, cover only a few metres. So, we may conclude that introduction and establishment of a non-indigenous species somewhere along the European coast can be followed by dispersal through natural processes over a much larger area.

6.2. Introduction of fouling species on ships' hulls

Ships' hulls are well known as a vector for long-range transport of fouling species. This means that one has to consider shipping between the Mediterranean and NW Europe as the first possible vector bringing non-indigenous species to the latter area. Historical information is available that the ancient Phoenicians and Greeks already sailed through the Strait of Gibraltar from the Mediterranean towards the Atlantic (Cunliffe, 1997). The Phoenicians are said to have founded a trading post near Cadiz, Spain, in 1104 BC, although there is no archaeological evidence for this. In later centuries they probably have moved northward along the Iberian coast. In about the sixth century BC also the Greek entered the Atlantic. In about 325 BC Pytheas of Massalia (Marseilles) reached the British Isles or even beyond and returned! On the other hand the Greek extensively colonised the shores of the Black Sea where their vessels could pick up Ponto-Caspian species. It is conceivable that thus the first Mediterranean and Ponto-Caspian species reached the shores of Atlantic Europe. It might be argued that ancient vessels hardly carried any fouling organisms because they were drawn onto the beach every night or at least frequently. However, archaeological finds and pictures of anchors from the same period make this unlikely. The capture of Cadiz by the Romans in 206 BC was the start of Roman contacts between the Atlantic coasts of West and NW Europe, the Mediterranean, and the Black Sea. Prins (1994) records that such contacts by Roman and other ships between the British Isles and the eastern Mediterranean basin lasted until about 500 AD. However, we have no biological information on the influence of these ancient trading and naval contacts on the dispersal of marine and estuarine species. Nevertheless, human-aided exchange of species between the Mediterranean and Black Seas on the one hand and the Atlantic coasts of Europe on the other hand may well have started in antiquity.

The next major step was made by the Vikings (Marcus, 1980). Although Irish seafarers first established contacts between Ireland and Iceland in 795 AD or earlier, they were followed soon by the Vikings. Direct contacts between Iceland and Norway existed since the Norse colonisation of Iceland in about 870. From that year until about 1400 annually several vessels made the crossing. In about 982 the Vikings discovered Greenland and a few years later vessels plied between Greenland and Iceland almost annually. In 999 the first direct crossing was made from Greenland to Norway and this direct connection was maintained to at least 1385. From about 1001 the Greenlanders regularly visited North America, the last record dating from 1347. A Norse settlement has been unearthed at Newfoundland. However, there are no historical data indicating direct contacts between North America and Europe; Greenland seems to have been the obligate stopover except perhaps for an occasional vessel driven by gales to Iceland or Europe.

It has been made probable that the Vikings were responsible for the first introduction of a North American species (*Mya arenaria*) into Europe (Petersen et al., 1992). It has

Figure 10. The Dutch colonial and trading empire during the 17th and 18th centuries, showing the potential origins of fouling species brought to The Netherlands by Dutch vessels. After Wilson (1968), Gaastra (1991) and Den Heijer (1994).

been suggested that this species was transported as food in the bilge water of a vessel and thrown overboard after arrival in Europe. Transport of fouling species by Viking vessels cannot be excluded, however, since these vessels stayed in the water during the entire summer season (Marcus, 1980). Anyhow, we have no direct evidence for introduction of North American (including species from Greenland) fouling species by Norse vessels.

In the Middle Ages shipping contacts between Atlantic Europe and the Mediterranean were restored. The Vikings entered the Mediterranean through the Strait of Gibraltar for the first time in 859. During the crusades from the 1096 to the 13th century Dutch and other NW-European vessels sailed to the eastern Mediterranean and back (Prins, 1994). Italian merchant vessels, on the other hand, came to Bruges, Belgium. These mediaeval vessels potentially re-established the transport of fouling species between the Mediterranean and Atlantic Europe.

In the 15th century the Portuguese started to explore the western coast of Africa. Cape Bojador in Morocco was reached in 1432 and step by step the western coast of the African continent and its offshore islands were discovered. In 1488 Bartolomeo Diaz rounded the Cape of Good Hope at the southern tip of South Africa. Finally Vasco da Gama sailed to India in 1497-98. After the Portuguese discovery of India the East Indies were reached in 1511-13, China in 1514-15, and Japan in 1542. Probably the introduction of the Pacific oyster (*Crassostrea gigas* (Thunberg, 1793)) strain from Taiwan into Portugal

('*Crassostra angulata*') (Boudry et al, 1998; O'Foighil et al., 1998) dates back to this period. If so, the species must have been transported as fouling on a ship's hull since the journey lasted much too long for transport on board.

In the meantime Christopher Columbus, supported by the Spanish crown, had discovered America in 1492, followed by intensive Spanish contacts with especially the Caribbean. In 1497 John Cabot, sailing from England, discovered Newfoundland and other North American territories. In 1500 the Portuguese Cabral discovered Brazil and from 1519 to 1522 the ships of the Portuguese navigator Ferdinand Magellan sailed around the world via Argentina, the Philippines and the Cape of Good Hope.

Direct contacts between The Netherlands and other continents started at the end of the 16th century. The Dutch reached the East Indies in 1596 and this heralded the start of a global trading network. Regular trading contacts existed for shorter or longer periods during the 17th and 18th centuries with North America (Nieuw-Amsterdam = New York), the West Indies, Venezuela, the Guyanas (e.g. Surinam), NE Brazil, the West African coast (Mauritania, Senegal, Ghana to Nigeria, Angola), South Africa, the Persian Gulf, Pakistan, India, Sri Lanka, Malaya, Indo-China, Indonesia, China, including Taiwan, and Japan (Wilson, 1968; Gaastra, 1991; Den Heijer, 1994) (fig. 10).

Hence, from early in the 16th century organisms from all continents could have reached Europe as fouling on ships' hulls (see also Carlton & Hodder, 1995). The same applies to wood-boring organisms (e.g., *Teredo, Limnoria, Chelura*). Direct transport to The Netherlands became possible from early in the 17th century. Transport of fouling species on ships' hulls will have continued well into the 20th century until the use of effective anti-fouling paints (since the early 1970s tributyl tin) has decreased the importance of transport on ships' hulls. Nevertheless, also today this form of transport still occurs, *e.g.*, on drilling rigs moved from one location to another.

Finally, the role of pleasure craft has to be considered. Although I do not know of intercontinental transport of fouling species by small craft, these seem to play a role in short-distance transports. This has been made plausible for the arrival of brown alga *Undaria pinnatifida* (Harvey) Suringar in the United Kingdom (Fletcher & Farrell, 1999) and for the bryozoan *Tricellaria inopinata* d'Hondt & Occhipinti Ambrogi, 1985 in The Netherlands and Belgium (De Blauwe & Faasse, 2001).

6.3. Introduction of non-indigenous species in dry ballast

Empty ships need ballast for overseas voyages. Until the 20th century ballast could be any convenient more or less dry material. Sand, gravel, and rocks from the shore, including intertidal material, have been used as ballast when they were at hand, although terrestrial material seems to have been used more often (Lindroth, 1957). With ballast from the shore coastal organisms inevitably will have been transported to new destinations and species such as littorinid gastropods and talitrid amphipods will have had a fair chance to survive the journey. However, for the trade between Great Britain and North America much more ballast was transported westward than eastward due the nature of the trade (Lindroth, 1957). Based on the pattern of the trade it may be assumed that also in The Netherlands more ballast was used on out-going intercontinental voyages than in incoming vessels. Hence, dry ballast should not be overrated as a transport medium towards The Netherlands for marine and estuarine organisms.

6.4. Introduction of non-indigenous species in ballast water

Dry ballast was replaced by ballast water from the late 1870s onward (Carlton, 1985). Nowadays, millions of tons of ballast water are transported around the globe annually (Carlton and Geller, 1993). The first recognition that a marine organism could have been introduced in ballast water applies to the diatom *Odontella sinensis* (= *Biddulphia sinensis*). Ostenfeld (1908) suggested that its appearance in the North Sea in 1903 was caused through transport by ship by 'for instance ... growing in the water of the hold'. Recent studies of the contents of ballast water tanks have shown that ballast water indeed is an important transport medium. This is especially true for planktonic organisms (both holoplankton and planktonic phases of benthic species) (Carlton, 1985, Carlton & Geller, 1993; Hallegraeff, 1998; Lavoie et al., 1999; Wonham et al., 2001; Gollasch et al., 2002).

6.5. Introduction of non-indigenous species through shellfish imports

There is a long history of oyster transfers in northwestern Europe (see also Wolff & Reise, 2002). Already in 1570 a vessel carrying flat oysters (*Ostrea edulis* Linnaeus, 1758) from France paid dues in Zeeland in The Netherlands (De Jonge, 1990), although it is not clear whether these oysters were to be relaid. As early as 1714 imports of seed oysters from Denmark to be cultivated in the western Dutch Wadden Sea were reported (Hoek, 1911; van der Vlis, 1975). At least since that year flat oysters were exchanged frequently between culture areas in The Netherlands, Denmark, Scotland, England, Ireland, and France (Brittany). Dijkema (1992) reported that shortly before 1992 oysters were imported into The Netherlands from Ireland, the United Kingdom, Greece, Turkey, the United States, Canada, and even Chile. Several European species from the coasts of Normandy and Brittany, which temporarily occurred in Dutch coastal waters and especially in the Oosterschelde estuary, have been introduced through these oyster imports (e.g., *Polydora hoplura* Claparède, 1870, *Calyptraea chinensis* (Linnaeus, 1758), *Anomia ephippium* Linnaeus, 1758) (Korringa, 1951). Critchley & Dijkema (1984) found *Sargassum muticum* attached to European flat oysters *Ostrea edulis* imported in The Netherlands.

Late in the 19th and early in the 20th century American Atlantic oysters (*Crassostrea virginica* (Gmelin, 1791)) were imported from English oyster beds into The Netherlands in several years (Van Benthem Jutting, 1943). These oysters were American stock from the USA and Canada introduced into Britain from the 1870s to 1939 (Eno et al., 1997). These oyster transports coincided in time with the introduction of species as *Petricola pholadiformis* and *Crepidula fornicata*, although it has not been established that the transport of the latter two species from England to The Netherlands was also through oyster shipments.

From 1902 on, the Pacific oyster (*Crassostrea gigas*) was imported into the northwestern United States (Seattle) and into British Columbia, Canada (Drinkwaard, 1999). Natural spat settlement occurred there in 1930. In 1964 spat from British Columbia was imported into The Netherlands, in 1965 into Great Britain for controlled breeding of a hatchery stock (Walne & Helm, 1979; Drinkwaard, 1999) and from 1966 on into France (Boudouresque et al., 1994). In 1966 spat was introduced into The Netherlands directly from Japan (Wolff & Reise, 2002). In 1971 also adult specimens were introduced into

The Netherlands from British Columbia. In 1971-1977 (Maurin & LeDantec, 1979; Boudouresque et al., 1994) *C. gigas* was also introduced into France directly from Japan. After these initial long-range introductions of *C. gigas* the same species was transferred many times between different European countries (Drinkwaard, 1999). The import of this species has been related to the introduction of many NW Pacific species, either directly from Japan or via British Columbia.

The Portuguese oyster (*Crassostrea angulata* (Lamarck, 1819)), which is actually a strain of *C. gigas* from Taiwan (Boudry et al., 1998; O'Foighil et al., 1998), was described from Portugal in 1819. It is unknown how and when it was introduced into that country. Most likely it arrived as a fouling organism somewhere between the early 16th century and the end of the 18th century. In this respect it should be noted that the Portuguese maintained a presence at Taiwan until early in the 17th century. In the second half of the 19th century *C. angulata* were imported from Portugal into France and later also into The Netherlands, Germany, Great Britain, and Ireland. Due to diseases the species disappeared again around 1970 (Drinkwaard, 1999). No clear examples of introductions of other species with Portuguese oysters are known.

Shellfish introductions have occurred mainly in the Oosterschelde estuary where the focus of Dutch shellfish cultivation and trade is situated at Yerseke (De Jonge, 1990). No wonder that many non-indigenous species in The Netherlands are known only from this estuary. This situation also explains why empty shells of several non-indigenous molluscs, e.g. *Oenopota rufa* (Montagu, 1803) (Borghouts-Biersteker, 1969), *Gibbula pennanti* (Philippi, 1846) and *G. umbilicalis* (da Costa, 1778) (Moolenbeek, 2000), have been found in the Oosterschelde estuary near Yerseke.

6.6. Introduction of Mediterranean and Ponto-Caspian species via freshwater shipping canals

Mediterranean species expanded to the North, mainly from southwestern Europe, through the canal network of France since the 18th century. One of the species believed to have been thus introduced into The Netherlands was the amphipod *Orchestia cavimana* J. Heller, 1865 (Kinzelbach, 1995).

The freshwater tolerant species of the Ponto-Caspian fauna were able to reach northwestern Europe when the Ponto-Caspian rivers were connected to the drainage system of northwestern Europe by canals. The first connection was the Oginsky canal, connecting the Pripyat-Dnjepr system with the Neman, opened in 1768 (Kolupaila, 1953; Olenin, 2002). Arbaciauskas (2002) and Nehring & Leuchs (1999) mention opening in 1803, however. Second came the opening of the Pripyat-Bug canal, connecting the Dnjepr with the Vistula, in 1775 (Jadzewski & Konopacka, 2002; Olenin, 2002) or 1780 (Kinzelbach, 1995). Third and fourth were the opening of the Mariinskij Waterway in 1810, connecting the Caspian Sea with the Baltic via the Volga and the Neva, and the construction of the Severo-Dvisnkiy Waterway in 1829, connecting the Caspian Sea with the White Sea (Olenin, 2002). More recent was the construction of the Main-Danube canal, connecting the Danube with the Rhine, in 1992. (A 19th century forerunner proved relatively unimportant and was finally cut off during the Second World War) (Bij de Vaate et al., 2002). Of course, these freshwater canals aided the expansion only of

species tolerating freshwater which is the case for a fair number of Ponto-Caspian brackish-water species (Ricciardi & MacIsaac, 2000). Examples are *Cordylophora caspia* and *Chelicorophium curvispinum* (G.O. Sars, 1895). However, several of such Ponto-Caspian species so far have been found mainly or only in Dutch rivers but not in brackish water. This is true for *Limnomysis benedeni* Czerniavsky, 1882 (Kelleher et al., 1999), *Chelicorophium curvispinum* (Van den Brink et al., 1993), *Echinogammarus ischnus* (Stebbing, 1898) (van den Brink, Paffen et al., 1993), *Dikerogammarus villosus* (Sowinsky, 1894) (Bij de Vaate & Klink, 1995), *Jaera istri* Veuille, 1979 (Kelleher et al., 2000), and *Hypania invalida* (Grube, 1860) (Klink & Bij de Vaate, 1996).

6.7. Intentional introductions

A small number of species has been introduced intentionally. This applies to the oyster species listed above and the clam *Mercenaria mercenaria* (Linnaeus, 1758) directly introduced into The Netherlands (Drinkwaard, 1999, 1999a). It also applies to a seaweed species (*Undaria pinnatifida*) introduced into Brittany for aquaculture and later reaching The Netherlands through natural expansion (Fletcher & Farrell, 1999). It is true also for the amphipod *Gammarus tigrinus* Sexton, 1939 introduced as fish food (Pinkster, 1975). In Eastern Europe many Ponto-Caspian species of invertebrates were intentionally introduced in lakes and reservoirs in the catchment area of the Baltic (Arbaciauskas, 2002); from there these species may have reached The Netherlands. The salt-marsh cordgrass (*Spartina anglica* Hubbard / *S. townsendii* H. et J. Groves) (Adema & Mennema, 1979; Thijsse, 1924) was introduced to stimulate land accretion. Rainbow trout (*Oncorhynchus mykiss* (Waldbaum, 1792)) was introduced for angling.

6.8. Other ways of import of non-indigenous species

Finally, some species did arrive in peculiar ways. The brackish-water tolerant freshwater snail *Potamopyrgus antipodarum* (Gray, 1843) arrived in England in drinking water barrels from Australia (Ponder, 1988; Eno et al., 1997). Guppies (*Lebistes reticulatus* (Peters, 1859), nowadays occurring in brackish water, have no doubt escaped from aquaria. Also the horseshoe crab *Limulus polyphemus* (Linnaeus, 1758) was introduced into the North Sea as a leftover from the aquarium trade (Nehring & Leuchs, 1999).

7. How to recognise a non-indigenous species?

Based on Chapman & Carlton (1991), Boudouresque (1994) and Ribera & Boudouresque (1995) I have used the following criteria to distinguish non-indigenous species from native species in the marine and estuarine waters of The Netherlands.

1. New species in Dutch waters. This conclusion can be drawn easily for conspicuous species from taxonomic groups that are well researched before and after the appearance of the new species. The slipper limpet *Crepidula fornicata* is a clear example. This criterion is less easily applied to small species from relatively unknown groups.
2. A geographic discontinuity between the Dutch (European) occurrence and the remainder of the distribution area. An example is the barnacle *Elminius modestus*

Darwin, 1854; its European occurrence is widely separated from its occurrence in the SW Pacific.

3. Localised occurrence. Occurrence of a species only in a small area in Dutch (European) waters may be considered as an indication of a recent introduction. Before 1930 this applied to the Zuiderzee crab *Rhithropanopeus harrisii.*
4. Expansion of an initially localised range. Expansion of an initially localised range has been observed in many introduced exotics in European waters, e.g. *Sargassum muticum* and *Ensis directus*.
5. Insufficient natural dispersal to account for observed distribution. For example, a bottom-dwelling isopod species of coastal waters is unlikely to cross an ocean basin, since it has no life stage suitable for long-range transport.
6. A population explosion. Several non-indigenous species show a very strong population development after their initial introduction. This phenomenon has been attributed to release from their original predators and parasites, but also to occupation of formerly empty niches.
7. Association with artificial means of transport, *e.g.*, occurring in ship fouling, in ballast water, or on oyster beds.
8. Associated with or dependent on non-indigenous species. This applies especially to parasites of other non-indigenous species.
9. Incomplete genetic variability. A population of a non-indigenous species may be assumed to have a lower genetic variation than the ancestral population(s) due to the founder effect.
10. Distant populations are genetically identical. An introduced species is expected to have the same genetic identity as (part of) its ancestral population.
11. Taxonomic relationship to other non-indigenous species. A species belonging to a taxonomic group of which the other members are restricted to a different part of the world may be suspected to originate from the same area.

8. Cryptogenic species

For many species we have no firm evidence that they have been introduced although this may be suspected from a number of characteristics. (1) They belong to groups that are a normal part of the fouling community on ships or the ballast water contents in ships. (2) They show a more or less cosmopolitan distribution pattern or at least they occur in more than one ocean basin, or on either side of an ocean. (3) They belong to groups that in former years were not well-known taxonomically. Examples are sponges, hydroids, entoprocts of the genera *Pedicellina* and *Barentsia* (Nielsen, 1989), bryozoans, barnacles, tube-building amphipods, and tunicates. Such species have been termed 'cryptogenic' (Carlton, 1996). These species have not been included in my lists unless an author has claimed that they had been introduced. In that case this claim has been investigated. My conclusions follow from the species list following this introduction.

9. Exotic and Northeast Atlantic non-indigenous species

In the list presented I have distinguished between Northeast Atlantic species, introduced into The Netherlands from the coasts of Atlantic Europe between northern

Norway and Portugal (and including the Baltic) on the one hand (fig. 7), and introduced exotic species from all other parts of the globe (including the Mediterranean, the Black Sea, and the Caspian Sea). Exotic species are those which were prevented by natural barriers to invade and colonise European (including Dutch) waters although apparently they are able to live in these waters. Northeast Atlantic species could have arrived in Dutch waters by natural processes but apparently were unable to establish themselves because of unsuitable environmental conditions now or in the past. The latter species may be introduced by human activities in Dutch coastal waters from elsewhere in Europe and they may even thrive for a number of years, but ultimately they disappear again. It should be noted that before the widespread construction of sea walls with artificial rocky shores along the Dutch coast, many rocky-shore species would have belonged to this category as well.

10. Establishment of exotic non-indigenous species

For non-indigenous benthic species a distinction is made between species only washed ashore and those found attached to or buried in a substrate, and likely to maintain a self-sustaining population. The former category is considered to be "non-indigenous, not established". The latter category is recorded as "established", but a distinction is made between "temporarily established", "permanently established" and "recently established". Temporarily established benthic species are those which have disappeared again after a number of years, whereas the permanently established ones apparently have become part of the Dutch marine or estuarine flora and fauna. The third category, "recently established", concerns species established less than 10 years ago, which period is considered too short to determine whether an establishment is permanent.

For neritic species I have distinguished similarly between "non-indigenous, not established" for species found only once, "temporarily established" for species found only a number of years, "permanently established" for those occurring (almost) every year and longer than 10 years, and "recently established" for those found less than 10 years ago. Species found only in ballast water of vessels in Dutch ports have not been included.

11. Origin of non-indigenous species

I list 99 exotic non-indigenous species, whereas 13 records are made of non-indigenous species originating from elsewhere in Atlantic Europe.

The most likely areas of origin of the 99 exotic non-indigenous species are shown in fig. 11. The most important donor regions are the Atlantic coast of North America and the NW Pacific, including Japan, Korea, and China. The Ponto-Caspian area delivers especially brackish-tolerant freshwater species. The majority of species originates from temperate areas, thus matching the climate of The Netherlands. The same observation applies also to *all* abundant exotic species. Most tropical species either occur in thermally polluted waters (*Hydroides elegans* (Haswell, 1883), *Balanus amphitrite, Lebistes reticulatus*) or have a doubtful origin (*Pleurosigma simonsenii* Hasle, *Garveia franciscana* (Torrey, 1902), *Janua brasiliensis* (Grube, 1872), *Megabalanus cocco-*

poma (Darwin, 1854), *M. tintinnabulum*). Table 1 shows the periods when NW Atlantic and NW Pacific species, respectively, reached Europe. Of the species derived from the Atlantic coast of North America 54% has arrived in the period 1851-1950 when American Atlantic oysters (*Crassostrea virginica*) were imported in Europe. Of the NW Pacific species 74% arrived in the period 1951-2000 when Pacific oysters (*Crassostrea gigas*) were imported in Europe.

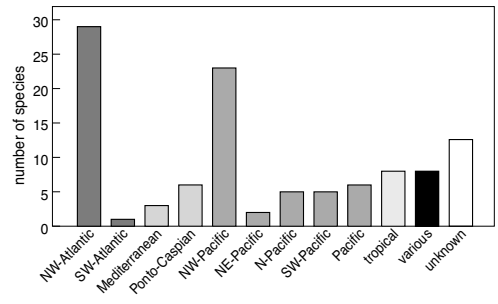

Figure 11. Most likely area of origin of exotic non-indigenous species found in The Netherlands based on the information presented in the list of species.

Table 1. Periods when exotic non-indigenous species observed in The Netherlands and originating from the NW Atlantic or the NW Pacific, respectively, were first recorded in Europe.

Period	NW Atlantic species	NW Pacific species
N	28	23
Before 1800	7%	0%
1801-1850	7%	9%
1851-1900	36%	13%
1901-1950	18%	4%
1951-2000	32%	74%

12. First observation of exotic non-indigenous species

12.1. First observation in Europe

12.1.1. Country

The exotic non-indigenous species listed as occurring in The Netherlands made their first appearance in different European countries. 31 Species were found first in The Netherlands, but another 66 species were first introduced into another European country and subsequently moved to The Netherlands, either by natural processes (currents), or through human activities. For 2 species I do not know their first occurrence.

The distribution over Europe of the first observations is shown in fig. 12. Next to a fair number of species introduced directly into The Netherlands, it appears that Great Britain and France are the major gateways for exotic non-indigenous species in The Netherlands. This survey also shows the importance of intra-European transport: nearly 70%

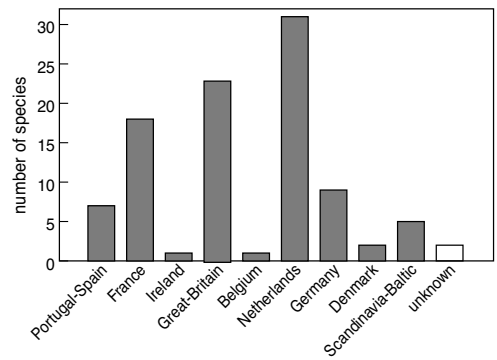

Fig. 12. Geographical distribution over Atlantic Europe of first observations of exotic non-indigenous species found in The Netherlands. After information presented in the list of species.

of the non-indigenous exotic species in The Netherlands initially established itself elsewhere in Europe. The differences between the countries will have been caused by many factors: better coverage of the literature in this study (The Netherlands), higher share of shipping transport (Great Britain, France, The Netherlands), no regulations for oyster imports (The Netherlands, France), differences in observer effort etc. I have no explanations for the very low share of Belgium and the relatively low contribution from Germany.

12.1.2. Year

The first years of observation anywhere in Atlantic Europe of the exotic non-indigenous species occurring in The Netherlands are shown in fig. 13. The figure makes the impression that the rate of introduction increases towards the end of the 20th century. It cannot be excluded, however, that this picture is due to increased observer effort. On the other hand, many forms of worldwide transport have increased during this period. Low observer effort also can explain the very low number in the period 1941-50. The low value in the period 1981-90 may reflect a time lag between introduction elsewhere in Europe and arrival in The Netherlands. This hypothesis is reinforced by the observation that 11 of the 13 species in the period 1991-2000 had their first European occurrence in The Netherlands.

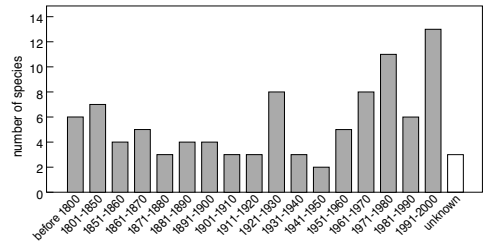

Fig. 13. Years of first observation in Atlantic Europe of exotic non-indigenous species found in The Netherlands. After information presented in the list of species.

12.2. First observation in The Netherlands

The first years of observation in The Netherlands of the exotic non-indigenous species occurring in The Netherlands are shown in fig. 14. Again an increase of the invasion rate is noted towards the end of the 20th century. Again, an increased observer effort is the first factor to be considered. However, measurements of observer effort are not available. The clear increase in observations in the period 1871-80 coincides with the building of a transportable "Zoological Station" by The Netherlands Zoological Society in that period to enable Dutch zoologists to study marine organisms. Starting in 1876 the building was erected at Den Helder (1876, 1880, 1886, 1887), Vlissingen (1877, 1884), Terschelling (1878, 1879), Tholen (1881-83), and Delfzijl (1885). In 1890 a permanent building was opened at Den Helder (Van Bennekom, 2001).

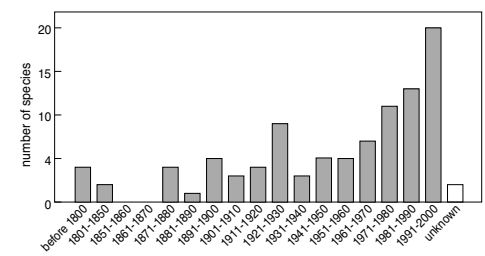

Fig. 14. Years of first observation in The Netherlands of exotic non-indigenous species found in The Netherlands. After information presented in the list of species.

13. Vector for transport of non-indigenous species

13.1. Vector for transport to Europe

The most likely vectors for the transport to Europe of exotic non-indigenous species occurring in The Netherlands are shown in fig. 15. For more than 20% of the species I cannot determine the vector that brought them to Europe. Also among the remaining species there exist many uncertainties; the columns reflect the most likely vectors in many cases. Hull fouling (28%) and introduction of shellfish (21%) are the most important vectors. Interesting is that, based on the observations until now, ballast water seems to be relatively unimportant. On the other hand, ballast water is the major factor for transport operational nowadays (Carlton & Geller, 1993); due to changed practices in shipping and shellfish culture the other major factors are of reduced importance. Deliberate introductions cover 7% of all introductions; this figure is relatively certain. More Ponto-Caspian species may be expected to reach Atlantic Europe along freshwater shipping canals and rivers. Van der Velde et al. (2002) describe introductions of freshwater species in more detail.

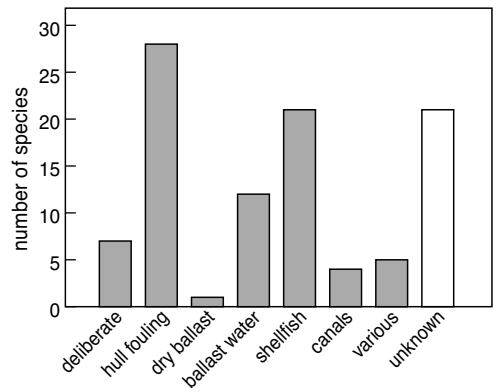

Fig. 15. Most likely vectors for the transport into Europe of exotic non-indigenous species occurring in The Netherlands. After information presented in the list of species.

13.2. Vector for transport to The Netherlands

The most likely vectors for transport to The Netherlands of exotic non-indigenous species, either directly from other biogeographic areas, or directly from elsewhere in Europe, are shown in fig. 16. At least 20% of the species arrive in The Netherlands by natural expansion, in most cases probably aided by marine currents. The two other major vectors are hull fouling and introduction of shellfish, whereas ballast water seems relatively unimportant. However, I was unable to to determine a vector for 28% of all introductions of exotic non-indigenous species.

The vector for transport to The Netherlands of Northeast Atlantic non-indigenous species is shellfish import in 9 out of 13 cases. Hull fouling may have been the vector in three cases, and in one case I have no indication.

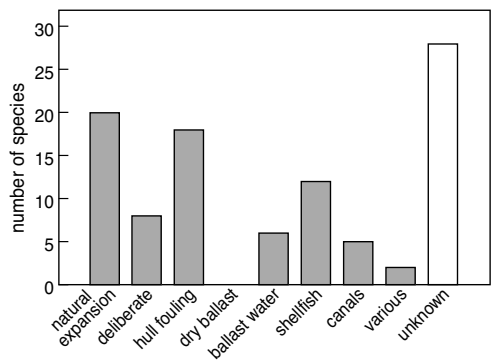

Fig. 16. Most likely vectors for transport into The Netherlands of exotic non-indigenous species, either directly from other biogeographic areas, or indirectly from elsewhere in Europe. After information presented in the list of species.

14. Status in The Netherlands

The current (2004) status in The Netherlands of the exotic non-indigenous species is summarised in fig. 17. At least 68% of all exotic non-indigenous species are permanently established. About 16% of all introduced exotic species appeared to be temporarily established; another 10% have become established less than 10 years ago. Most likely, judging from the ratio between the two former categories, most of these recently established species will become permanent members of the Dutch flora and fauna. The category 'introduced, but not established' counts only 5% of the species. This is no doubt a strong under estimate; according to the empirical 'tens rule' formulated by Williamson (1996) only about 10% of all introduced species would become established.

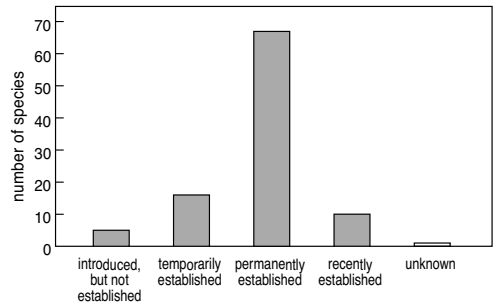

Fig. 17. Current (2004) status in The Netherlands of exotic non-indigenous species. After information presented in the list of species.

15. Distribution of non-indigenous species in The Netherlands

The present geographical distribution of the different exotic non-indigenous species within The Netherlands is shown in fig. 18. This distribution pattern shows two hot spots, viz. the Oosterschelde estuary and the brackish waters. About 14% of all species have been found in the Oosterschelde estuary only. Moreover, about 55% of all introduced species occur in this estuary whereas the much larger Wadden Sea counts only 30%. The prominence of the Oosterschelde estuary is ascribed to the fact that this estuary is the centre of the Dutch shellfish culture. Importation of foreign shellfish is a common event at Yerseke, the trading centre situated on this estuary. The high numbers of species in brackish waters were mentioned before by Wolff (1973, 1999) and, among other factors, ascribed to the undersaturation of brackish waters with regard to species numbers. Wolff (1999) also considered the possibility that the high number of brackish-water species is due to the fact that ports are often situated in brackish water. He concluded that this is not impossible but that on the other hand it should be noted that many ports have shifted nowadays to more marine conditions.

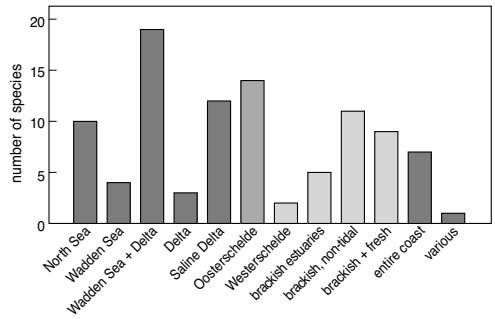

Fig. 18. Present (2004) geographical distribution of exotic non-indigenous species within The Netherlands. Each column represents species occurring in that particular area only. After information presented in the list of species.

16. Acknowledgements

In order to prepare this publication I have brought together the work of a very large number of colleagues who published their observations in many different papers. I thank them collectively for answering my questions, sending me reprints or drawing my attention to publications I otherwise might have missed. Drs. M.K. de Boer (Haren), K. Essink (Haren), M.A. Faasse (Arnemuiden), R. Leewis (Bilthoven), L. Peperzak (Middelburg), W.F. Prud'homme van Reine (Leiden), H. Stegenga (Leiden), G. van der Velde (Nijmegen) and E.G. Vrieling (Haren) read the final manuscript or parts of it. This resulted in several additional species included and many new observations of species recorded before. I am very grateful for their help and suggestions. D. Visser prepared the drawings.

17. List of non-indigenous marine and estuarine species in The Netherlands

17.1. Explanation

On the following pages I present a systematic list of all non-indigenous marine and estuarine species for which sufficient evidence is available that they have been introduced into The Netherlands. Species recorded as introduced, but for which no or insufficient evidence for introduction has been found, have been listed as well.

It has been attempted to collect the following information per species.

Status in The Netherlands.— For each species I have summarised the status of its introduction; in all cases this is my conclusion after studying the relevant data and the literature. Species introduced into The Netherlands from the Atlantic coasts of Europe have been called 'Northeast (NE) Atlantic non-indigenous species', the ones introduced from all other parts of the world 'exotic non-indigenous species.' For benthic species a distinction is made between specimens only washed ashore and those found attached to or buried in a substrate. The former category is considered to be "non-indigenous, not established". The latter category is recorded as "established", but a distinction is made between "temporarily established" and "permanently established". Temporarily established species are those which have disappeared again after a number of years, whereas the permanently established ones apparently have become part of the Dutch marine or estuarine flora and fauna. For neritic species I have distinguished between "non-indigenous, not established" for species found only once, "temporarily established" for species found only for a number of years, and "permanently established" for those occurring (almost) every year. Species established less than 10 years ago have been labelled "recently established". Between brackets the criteria used to determine whether a species is introduced are enumerated (see page 17).

Vector.— It is indicated how a species probably has been introduced, both from its area of origin into Atlantic Europe and from other European countries into The Netherlands.

Area of origin.— The (supposed) area of origin is indicated.

Introduction into Atlantic Europe.— Year (or first record) and circumstances of introduction into Atlantic Europe.

Introduction into The Netherlands.— Year (or first record) and circumstances of

introduction into The Netherlands as well as initial dispersal in Dutch waters.

Present occurrence in The Netherlands.— Description of the present occurrence of a species in The Netherlands.

17.2. Rhodophyta

Acrochaetium densum (Drew) Papenfuss
(Syn. Chromastrum densum (Drew) Stegenga & Mulder)

Status in The Netherlands.— Exotic non-indigenous species (criterion 11). Established species.

Vector: Unknown.

Area of origin.— Probably Pacific (Stegenga & Vroman, 1976).

Introduction into Atlantic Europe.— First European observation in The Netherlands.

Introduction into The Netherlands.— First observed in 1967 (Stegenga & Vroman, 1976).

Present occurrence in The Netherlands.— Apparently established in the Wadden Sea, Lake Grevelingen and the Oosterschelde estuary (Stegenga & Mol, 1980; Stegenga, 2002a). Dr. H. Stegenga (pers. comm.) also found a few times *A. catenulatum* Howe in the same area; this 'species' is considered to be the gametophyte of *A. densum.*

Agardhiella subulata (C. Agardh) Kraft & Wynne

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3). Recently established.

Vector.— It arrived in Europe perhaps with introduced shellfish (W.F. Farnham in Eno et al. (1997)); because of the location of its first occurrence in The Netherlands the same vector may be suspected for this country.

Area of origin.— Atlantic coast of North America from the tropics to Massachusetts or even Canada (Stegenga, 1999a).

Introduction into Atlantic Europe.— First observed in the Solent, England, before 1973 (Farnham, 1994; Farnham & Irvine, 1979)

Introduction into The Netherlands.— *A. subulata* was not observed during the thorough surveys of the algal flora of the Dutch Delta area by Den Hartog (1959a) and Nienhuis (1980). Observed floating in the Oosterschelde estuary near Yerseke on 27.vii.1998; on 8.xii.1998 growing attached to a hard substrate near Yerseke (Stegenga, 1999a).

Present occurrence in The Netherlands.— See above; observed in fair amounts growing in former oyster ponds near Yerseke, Oosterschelde estuary in 1999 and 2000 and abundantly at Tholen, Oosterschelde estuary in 2003 (Stegenga, pers. comm. and 2004). It still has to be demonstrated whether this species has established itself permanently.

Anotrichium furcellatum (J. Agardh) Baldock
(Syn. Griffithsia furcellata J. Agardh)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3). Temporarily established.

Vector.— It is neither known how it arrived in Atlantic Europe, nor how it reached The Netherlands, although transport with shellfish may be suspected.

Area of origin.— Mediterranean (Maggs & Stegenga, 1999).

Introduction into Atlantic Europe.— Believed to have been introduced from the Mediterranean to northern France prior to 1922. In the North Sea only known from The Netherlands (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— *A. furcellatum* was not observed during the thorough survey of the algal flora of the Dutch Delta area by Den Hartog (1959a). The first observation was made in the Oosterschelde estuary in 1968 (Stegenga & Prud'homme van Reine, 1998). However, Dr. H. Stegenga (pers. comm.) found another specimen in the Rijksherbarium, Leiden, collected, but not recognised, by Den Hartog in the oyster ponds at Yerseke on 5.viii.1950.

Present occurrence in The Netherlands.— Occurred at Yerseke and Sas van Goes in Oosterschelde estuary between 1950 and 1977. Apparently only temporarily established.

Antithamnionella spirographidis (Schiffner) Wollaston

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4). Permanently established.

Vector.— Wollaston (1968, cited in Otten & Stegenga, 1995) records a relationship with harbours and suggests dispersal to Atlantic Europe by ships. Eno et al. (1997) also suspect dispersal on ships' hulls and mooring ropes. However, it may have come to The Netherlands with shellfish.

Area of origin.— North Pacific (Maggs & Stegenga, 1999)

Introduction into Atlantic Europe.— 1906: Plymouth; 1911: Mediterranean (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— *A. spirographidis* was not observed during the thorough surveys of the algal flora of the Dutch Delta area by Den Hartog (1959a) and Nienhuis (1980)**.** Introduced around 1974 in the Oosterschelde estuary near Yerseke (Stegenga & Prud'homme van Reine, 1998; Maggs & Stegenga, 1999).

Present occurrence in The Netherlands.— Stegenga & Mol (1983): Rare in the Oosterschelde estuary. Otten & Stegenga (1995) mention a few observations in the Oosterschelde estuary until 1994, where it was not rare in the oyster ponds ('buitenputten') near Yerseke. Maggs & Stegenga (1999): 'From 1993 onwards rather common in the Oosterschelde estuary, with a few collections from the ... Grevelingen.'. Dr. H. Stegenga (pers. comm.) found it abundantly at the entrance of the Sloe harbour in the Westerschelde estuary in 2000. It is assumed that *A. spirographidis* now is a permanently established species.

Antithamnionella ternifolia (J.D. Hooker & Harvey) Lyle
(Syn. Antithamnionella sarniensis Lyle)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3). Temporarily established.

Vector.— It was probably carried to Atlantic Europe (Channel area) on the hulls and mooring ropes of ships (Eno et al., 1997). From the Channel area it may have reached

The Netherlands either transported by currents (see Otten & Stegenga, 1995), or with introduced oysters, since the first Dutch observation was at the centre of the Dutch shellfish trade.

Area of origin.— Southern Hemisphere, perhaps Australia (Eno et al., 1997).

Introduction into Atlantic Europe.— First European record in 1906 at Plymouth, UK (Eno et al., 1997, citing Maggs & Hommersand, 1993). 'The first European record was from northern France in 1910: it was found in the Channel Islands in 1921....' (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— Collected by C. den Hartog near Yerseke in the Oosterschelde estuary on 21.x.1951 (Maggs & Stegenga, 1999).

Present occurrence in The Netherlands.— Single record of an attached plant from Yerseke on the Oosterschelde estuary in 1951 (Maggs & Stegenga, 1999). Otten & Stegenga (1995) were not aware of this observation and stated that *A. ternifolia* had only been found in The Netherlands washed ashore on the beach. Athanasiadis (1990, cited by Otten & Stegenga, 1995), records that *A. ternifolia* (as *A. sarniensis*) occurs along the West European coast from Portugal to The Netherlands. The latter locality in this record must be erroneous, since he bases himself on the re-identification of a drawing of *A. spirographidis* in Stegenga & Mol (1983). This drawing most likely has been made after a specimen of *A. ternifolia (*as *A. sarniensis)* washed ashore. Probably Eno et al. (1997), who recorded this species from The Netherlands, made the same mistake. Apparently this species was only temporarily established in The Netherlands.

Asparagopsis armata Harvey

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), not established.

Vector.— It was introduced into Atlantic Europe possibly with oysters, but its subsequent spread occurred probably largely by rafting and floating (Eno et al., 1997). Apparently it is transported to The Netherlands by marine currents.

Area of origin.— Australia (Maggs & Stegenga, 1999).

Introduction into Atlantic Europe.— The first Atlantic population appeared in 1925 at Guéthary in the Bay of Biscay, and it was discovered almost simultaneously at two Mediterranean localities (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— Washes ashore fairly frequently (Stegenga & Mol, 1983; Maggs & Stegenga, 1999). Most of this material belongs to the sporophytic generation ('*Falkenbergia rufolanosa* (Harvey) F. Schmitz') (Dr. H. Stegenga, pers. comm.).

Present occurrence in The Netherlands.— Not established.

Bonnemaisonia hamifera Hariot

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), not established.

Vector.— Unknown how this species arrived in Atlantic Europe, although it is suggested to have been introduced with shellfish (Eno et al., 1997). Apparently it is transported to The Netherlands by currents.

Area of origin.— Pacific, Japan (Stegenga & Mol, 1983; Eno et al., 1997).

Introduction into Atlantic Europe.— First found in England in 1890 (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— Only known from material washed ashore on the beach (Stegenga & Mol, 1983; Maggs & Stegenga, 1999). Most of this material belongs to the sporophytic generation ('*Trailliella intricata* Batters.') (pers. comm. Dr. H. Stegenga).

Present occurrence in The Netherlands.— Not established.

Colaconema dasyae (Collins) Stegenga, Mol, Prud'homme van Reine & Lokhorst
(Syn. Acrochaetium dasyae Collins)

Status in The Netherlands.— Exotic non-indigenous species (criterion 8), probably permanently established.

Vector.— Unknown, but likely to have been introduced with its host *Dasya baillouviana*.

Area of origin.— Atlantic coast of North America (Stegenga & Borsje, 1976).

Introduction into Atlantic Europe.— The Dutch observations apparently were the first ones in Europe (Stegenga & Borsje, 1976).

Introduction into The Netherlands.— First observed in the non-tidal brackish Gat van Ouwerkerk (= Inlaag 1953) near the Oosterschelde estuary (Nienhuis, 1968; see also Stegenga & Borsje, 1976).

Present occurrence in The Netherlands.— Oosterschelde estuary near Yerseke and in the brackish Lake Veerse Meer (Stegenga, 2002b). The earlier localities Gat van Ouwerkerk and Kanaal door Zuid-Beveland (Stegenga & Borsje, 1976) do not harbour this species any longer. The species was not found any more after 1996 (pers. comm. Dr. W.F. Prud'homme van Reine).

Dasya baillouviana (S.G. Gmelin) Montagne
(Syn. Dasya pedicellata (C. Agardh) C. Agardh)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3, 7). Permanently established.

Vector.— Unknown, although Den Hartog (1964) noted that the first record of a sessile specimen originated from a locality only a few km from oyster ponds.

Area of origin.— '.... widely distributed in the Mediterranean, westwards to Cadiz, and on the Atlantic coast of North America...; it appears to be native to both of these areas.' (Den Hartog, 1964; Maggs & Stegenga, 1999)

Introduction into Atlantic Europe and in The Netherlands.— The first European and Dutch record concerns a plant washed ashore at Rockanje in 1948 (Stegenga, 2003). It had not been found attached in The Netherlands before 1950, although it is a very conspicuous species growing to 1.75 m in length. It was found in the Kanaal door Zuid-Beveland, connected to Oosterschelde estuary, in 1950. In 1953 it was observed in Sweden and in 1961 in Denmark (Den Hartog, 1964). Den Hartog (1959a) did not recognise it as a non-indigenous species.

Present occurrence in The Netherlands.— *Dasya* occurred in the Kanaal door Zuid-

Beveland in the period 1950-1959, and in the Inlaag 1953 near Ouwerkerk from 1959-1961 (Den Hartog, 1964 (as *Dasya pedicellata*)). Other authors record it from the Kanaal door Zuid-Beveland, the Inlaag 1953 near Ouwerkerk, the Veerse Meer, the Oosterschelde estuary, and Lake Grevelingen (Stegenga & Mol, 1983; Stegenga & Prud'homme van Reine, 1998; Maggs & Stegenga, 1999; Stegenga, 2003). According Stegenga (2003) known from the Kanaal door Zuid-Beveland up to 1967 and in 2003, from the Inlaag 1953 near Ouwerkerk up to 1980 and more recently from Kanaal door Walcheren, Arnemuidens Kanaal, Havenkanaal van Stavenisse. Furthermore abundant in the inner part of the Oosterschelde estuary in 2003 (Stegenga, 2004). Den Hartog & Van der Velde (1987) believe that *Dasya* is a thermophilous species, which is not able to maintain itself without human modification of the environment. Maggs & Stegenga (1999), however, consider absence of wave-action the principal factor governing its distribution.

'Dasysiphonia sp.'

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3, 4), permanently established.

Vector.— Perhaps introduced with oysters, both into Europe and into The Netherlands.

Area of origin.— NE Asia (Maggs & Stegenga, 1999).

Introduction into Atlantic Europe.— First observed in 1994 in former oyster ponds in Oosterschelde estuary near Yerseke, The Netherlands. The initial introduction may have been into France, perhaps with oysters. An apparently identical alga occurs in Galicia, Spain, since 1990 (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— First observed in 1994 in former oyster ponds in the Oosterschelde estuary near Yerseke (Stegenga & Prud'homme van Reine, 1998; Maggs & Stegenga, 1999).

Present occurrence in The Netherlands.— Common, sometimes abundant, species in most of the Oosterschelde estuary and occasionally in Lake Grevelingen (Maggs & Stegenga, 1999).

Grateloupia turuturu Yamada
(Syn. Grateloupia doryphora (Mont.) M. Howe)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), permanently established. Earlier known in Europe as *G. doryphora* (Gavio & Fredericq, 2002).

Vector.— It is suggested that this species has been transported with commercial molluscs, both to Atlantic Europe and to The Netherlands (Maggs & Stegenga, 1999).

Area of origin.— Pacific (Maggs & Stegenga, 1999); Japan, Korea (Gavio & Fredericq, 2002).

Introduction into Atlantic Europe.— Discovered in 1969 in the Solent, England (Maggs & Stegenga, 1999).

Introduction into The Netherlands.— Found in oyster ponds ('buitenputten') in the Oosterschelde estuary near Yerseke in August 1993 (Stegenga & Otten, 1997; Stegenga & Prud'homme van Reine, 1998; Maggs & Stegenga, 1999).

Present occurrence in The Netherlands.— Found in oyster ponds in the Oosterschelde estuary near Yerseke in 1993 and 1996 (Maggs & Stegenga, 1999). Many large (up to 1 m) plants in Havenkanaal van Stavenisse and nearby tidal pools in 1999 and 2000 (Dr. H. Stegenga, pers. comm.), abundant in the inner part of the Oosterschelde estuary in 2003 (Stegenga, 2004).

Polysiphonia harveyi Bailey

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 9, 10), permanently established.

Vector.— It is neither known how it arrived in Europe, nor how it reached The Netherlands.

Area of origin.— Japan (McIvor et al., 2001).

Introduction into Atlantic Europe.— Possibly in Brittany, France, in 1832; in 1908 in Dorset, England (Maggs & Stegenga, 1999; McIvor et al., 2001).

Introduction into The Netherlands.— First observed in the Kanaal door Zuid-Beveland in 1960 (Stegenga, 1998; Stegenga & Prud'homme van Reine, 1998; Maggs & Stegenga, 1999).

Present occurrence in The Netherlands.— Very common and often abundant in the Oosterschelde estuary and Lake Grevelingen (Stegenga, 1998). Also found at Texel (Maggs & Stegenga, 1999).

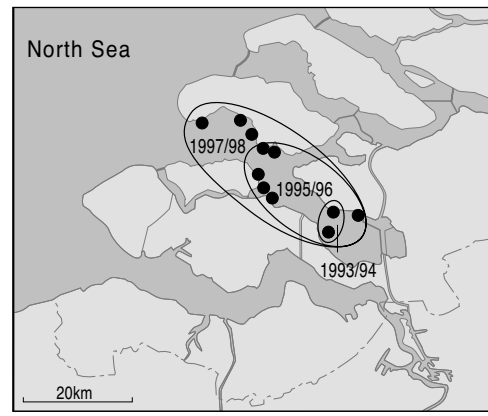

Fig. 19. Expanding distribution of *Polysiphonia senticulosa* in the period 1993-1998. After Stegenga & Prud'homme van Reine (1998).

Polysiphonia senticulosa Harvey

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— It is neither known how it arrived in Europe, nor how it reached The Netherlands.

Area of origin.— North Pacific (Maggs & Stegenga, 1999).

Introduction into Atlantic Europe and The Netherlands.— First observed in 1993 at Gorishoek in the Oosterschelde estuary, The Netherlands (Stegenga, 1998; Stegenga & Prud'homme van Reine, 1998; Maggs & Stegenga, 1999).

Present occurrence in The Netherlands.— Common in a large part of the Oosterschelde estuary, locally abundant in the oyster ponds at Yerseke (Stegenga, 1998; Stegenga & Prud'homme van Reine, 1998 (with distribution map; fig. 19); Maggs & Stegenga, 1999). Abundant in the inner part of the Oosterschelde estuary in the sublittoral fringe and in tidal pools in the colder period of the year (November – April) (pers. comm. Dr. W.F. Prud'homme van Reine).

17.3. Heterokontophyta

17.3.1. Bacillariophyceae

Asterionella glacialis Castracane
(Syn. Asterionella japonica Cleve et Möller)

Wolff (1992, 1996) and Wolff et al. (1994) erroneously consider this species (as *A. japonica*) to be introduced. There are no indications that this common species has been introduced from elsewhere into The Netherlands**.**

Coscinodiscus wailesii Gran & Angst

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 4), permanently established.

Vector.— Unknown (Eno et al., 1997). 'Probably introduced to northern Europe from the Indo-Pacific when French oyster farms began to cultivate the infection-resistant *Crassostrea gigas'* (Nehring, 1998). Introduced in ballast water or imported with oysters (Edwards et al., 2001). Assumed to have arrived in The Netherlands with sea currents.

Area of origin.— Indian and Pacific Oceans (Eno et al., 1997); northern Pacific (Edwards et al., 2001).

Introduction into Atlantic Europe.— Observed in the Western Approaches of the English Channel near Plymouth, UK, in January 1977 (Boalch & Harbour, 1977). Spread rapidly to Atlantic coast of France by 1978 and Norway by 1979 (Laing, 1999).

Introduction into The Netherlands.— Occurs along the Dutch coast since 1978 (Tripos, 1995).

Present occurrence in The Netherlands.— This species is now present in North Sea plankton throughout the year (Nehring, 1998; Edwards et al., 2001). Very common along the Dutch coast since 1978 (Tripos, 1995).

Odontella sinensis (Greville) Grunow
(Syn. Biddulphia sinensis Greville)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 4), permanently established.

Vector.— Has been introduced into Atlantic Europe probably with ballast water (Ostenfeld, 1908). Assumed to have arrived in The Netherlands with marine currents.

Area of origin.— Chinese waters? Indian Ocean or Red Sea? (Eno et al., 1997).

Introduction into Atlantic Europe.— First observation in Europe in 1889. First observation in the North Sea (German Bight) in 1903 (Ostenfeld, 1908; Eno et al., 1997).

Introduction into The Netherlands.— In 1905 observed in Dutch waters (Van Breemen, 1906; Van der Werff & Huls, 1959).

Present occurrence in The Netherlands.— Fairly common in the North Sea (Van Breemen, 1906; Van der Werff & Huls, 1959; Leewis, 1985)

Pleurosigma simonsenii Hasle
(Syn. P. planctonicum Simonsen)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 4), temporarily established.

Vector.— Unknown how it reached Atlantic Europe. Assumed to have arrived in The Netherlands by marine currents.

Area of origin.— Was described from the Indian Ocean by Simonsen in 1974 (Eno et al., 1997)

Introduction into Atlantic Europe.— In Europe it was first found near Ushant (= Ouessant), France, in 1966, but not immediately identified. Later it was found near Plymouth in 1972, 1973, and 1974 where it was the dominant species in the net phytoplankton (Boalch & Harbour, 1977).

Introduction into The Netherlands.— Kat (1982a) described the species as occurring along the Dutch coast in November 1974. She nor Leewis (1985) found the species since then.

Present occurrence in The Netherlands.— Apparently absent.

Rhizosolenia indica Peragallo

Rhizosolenia indica is listed as an introduced species in The Netherlands by Wallentinus (2002). However, according to my definitions it is an indigenous species of European seas extending into the North Sea in warm periods (Nehring, 1998).

Thalassiosira punctigera Castr.
(Syn. Thalassiosira angstii (Gran) Makarova)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 4), permanently established.

Vector.— 'it is assumed that this species was introduced [into Atlantic Europe] from the Indo-Pacific along with breeding oysters...' (Nehring, 1998). Introduced into The Netherlands with marine currents.

Area of origin.— Unknown, observed before in the North Pacific and the South Atlantic, a single observation in the Caribbean (Eno et al., 1997). Indo-Pacific (Nehring, 1999).

Introduction into Atlantic Europe.— In 1978, *T. punctigera* was found for the first time in European waters in the English Channel near Plymouth (Kat, 1982) and near Helgoland (Eno et al., 1997). In 1979 its presence in the Skagerrak was proven (Hasle, 1983).

Introduction into The Netherlands.— It was found along the Dutch coast in 1981 (Kat, 1982; Eno et al., 1997; Nehring, 1998).

Present occurrence in The Netherlands.— Present (Tripos, 1995). Nehring (1999) states that it is a frequent species in the (German?) Wadden Sea.

17.3.2. Phaeophyceae

Botrytella sp.
(Syn. Sorocarpus micromorus (Bory) Silva)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3, 8, 11), seems to be established.

Vector.— Unknown.

Area of origin.— The material seems closely related to some Pacific species (Stegenga & Mol, 1996).

Introduction into Atlantic Europe.— Unknown.

Introduction into The Netherlands.— Van Goor (1923): on a buoy in the harbour of Nieuwediep in 1919 (as *Sorocarpus uvaeformis* (Lyngb.) Pringsh.).

Present occurrence in The Netherlands.— Stegenga & Mol (1996) record the same species also from 't Horntje (NIOZ harbour) at Texel in 1981 and on *Sargassum muticum* from the saline Lake Grevelingen in 1993 and 1995. Apparently it is a rare species.

Colpomenia peregrina (Sauvageau) Hamel
(Syn. Colpomenia sinuosa (Roth) Derb. & Sol.)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), permanently established.

Vector.— Fletcher & Farrell (1999) consider it likely that this species was introduced into Atlantic Europe from the Atlantic coast of North America with juvenile American oysters. It is unknown how it arrived in The Netherlands.

Area of origin.— Atlantic coast of North America.

Introduction into Atlantic Europe.— Van Goor (1923): in Europe originally only in Mediterranean and Atlantic coast of Spain, but since 1906 along the French and English coasts. Goulletquer et al. (2002): established in France by 1905. Fletcher & Farrell (1999): arrived in southern England in 1907.

Introduction into The Netherlands.— Van Goor (1923) records that *Colpomenia sinuosa* (Roth) Derb. & Sol. was washed ashore in large quantity but also was fixed on *Fucus* at the island of Terschelling in May 1921. Recorded by Lucas (1950) as *C. sinuosa*. Stegenga & Mol (1983) knew this species only as washed ashore on the beach. De Graaf (1989) found attached plants near Dreischor in Lake Grevelingen in 1986. Stegenga & Prud'homme van Reine (1998) state that it was introduced in The Netherlands around 1989.

Present occurrence in The Netherlands.— Common and sometimes abundant in Lake Grevelingen, also in tidal pools of the Oosterschelde estuary (Dr. H. Stegenga, pers. comm.).

Elachista sp.

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3, 8), permanently established.

Vector.— Unknown how this species arrived in Atlantic Europe; it arrived in The Netherlands possibly with drifting *Sargassum muticum*.

Area of origin.— Stegenga (2000c) supposes an origin in the NW Pacific, but is unable to connect this species to a described species.

Introduction into Atlantic Europe.— Not known from elsewhere in Europe.

Introduction into The Netherlands.— First observed in 1993 as an epiphyte of *Sargassum muticum* (Stegenga & Prud'homme van Reine, 1998).

Present occurrence in The Netherlands.— Common in Lake Grevelingen, also in a tidal pool at Neeltje Jans, Oosterschelde estuary, and in Havenkanaal van Goes. It seems to prefer non-tidal salt water (Stegenga, 2000c).

Leathesia verruculiformis Y.P. Lee & I.K. Lee

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 8), permanently established.

Vector.— Unknown how this species arrived in Atlantic Europe; it possibly arrived in The Netherlands with drifting *Sargassum muticum*.

Area of origin.— NW Pacific (Stegenga, 2000a).

Introduction into Atlantic Europe.— The Dutch record apparently is also the first one in Europe.

Introduction into The Netherlands.— Stegenga & Prud'homme van Reine (1998) and Stegenga (2000a): epiphyte of *Sargassum muticum*, first observed in Lake Grevelingen near Bruinisse in 1994.

Present occurrence in The Netherlands.— Frequently found in Lake Grevelingen, also in tidal pools at Sas van Goes and at the storm surge barrier in Oosterschelde estuary.

Myriactula sp.
(Syn. Myriactula rivulariae (Suhr) Feldmann)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 8), permanently established.

Vector.— Unknown how this species arrived in Atlantic Europe; it is assumed to have arrived in The Netherlands with drifting *Sargassum muticum*.

Area of origin.— Unknown.

Introduction into Atlantic Europe.— Known only from The Netherlands (Wallentinus, 2002).

Introduction into The Netherlands.— Stegenga & Prud'homme van Reine (1998): epiphyte of *Sargassum muticum*, observed on drifting *Sargassum* in 1980; around 1983 found on attached plants.

Present occurrence in The Netherlands.— Observed in Lake Grevelingen in 1994-98 and 2003, fairly common in some years (Dr. H. Stegenga, pers. comm.).

Sargassum muticum (Yendo) Fensholt

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 5, 6), permanently established.

Vector.— Believed to have been introduced into Atlantic Europe with Pacific oysters (Critchley et al., 1990). It is likely to have reached The Netherlands by drifting

with the currents (Prud'homme van Reine, 1977, 1980). However, Critchley & Dijkema (1984) observed young plants on commercially shipped oysters *Ostrea edulis* in 1982; they nevertheless assume that *Sargassum* in The Netherlands derives from drifting specimens.

Area of origin.— Northwest Pacific: Japan, Russia, Korea, China (Wallentinus, 1999a).

Introduction into Atlantic Europe.— Observed in 1971 near Bembridge, Isle of Wight, UK; probably originally introduced to the French side of the Channel around 1966 (Eno et al., 1997). Around 1980 I observed large quantities (tons) of drifting *S. muticum* at various places in the southern North Sea.

Introduction into The Netherlands.— Prud'homme van Reine (1977) and Coppejans et al. (1980) record the first plants washed ashore at the beaches of Renesse, Monster, Katwijk and Den Helder, on Texel in April-May 1977, and on Terschelling in 1978. First attached plants found in 1980 on Texel, in Lake Grevelingen, Havenkanaal van Goes, and in Oosterschelde estuary near Burghsluis (Prud'homme van Reine, 1980; Nienhuis, 1982; Prud'homme van Reine & Nienhuis, 1982) (Critchley & Dijkema (1984) mention 1978 as the first find of attached plants; this is incorrect). Critchley et al. (1987) described the colonisation of Lake Grevelingen between 1980 and 1983 as well as the initial colonisation of the Oosterschelde estuary in the same period.

Present occurrence in The Netherlands.— Stegenga & Mol (1983): Texel, Grevelingen and Oosterschelde estuary. Presently it is an abundant species, especially in Lake Grevelingen (Dr. H. Stegenga, pers. comm.). Also at Europoort (Paalvast, 1998).

Undaria pinnatifida (Harvey) Suringar

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), recently established.

Vector.— Has been imported in Europe with oysters, but it was also deliberately introduced (Floc'h et al., 1991). It is unknown how it arrived in The Netherlands.

Area of origin.— Northwest Pacific (China, Japan, Korea, SE Russia) (Stegenga, 1999b; Wallentinus, 1999b).

Introduction into Atlantic Europe.— *Undaria* was first observed in Europe in Étang de Thau at the French Mediterranean coast in 1971, probably imported with Pacific oysters. It was deliberately introduced for cultivation purposes into Brittany in 1983. In 1987 it was found in the wild at Ouessant (= Ushant). From there it expanded along the European coasts: northern Spain (1988), southern England (1994), Strait of Dover (1998), Zeebrugge, Belgium (1999) (Floc'h et al., 1991; Stegenga, 1999b; Fletcher & Farrell, 1999; Wallentinus, 1999b).

Introduction into The Netherlands.— About 15 attached plants were found in the Oosterschelde estuary near Yerseke in 1999. The plants, about 60 cm long, grew on shells in former oyster ponds (Stegenga, 1999b).

Present occurrence in The Netherlands.— Yerseke, Oosterschelde estuary (Stegenga, 1999b). In the same estuary in 2003 it is dominant in the inner parts, especially in the sublittoral fringe (Drs. W.F. Prud'homme van Reine and H. Stegenga, pers. comm.).

17.3.3. Raphidophyceae

Chattonella marina (Subrahmanyan) Hara & Chihara

In the grey literature (e.g., Tripos, 1997) it has been stated that '*Chattonella*' is an exotic non-indigenous species in Dutch waters. *C. marina* apparently is an established species, which is perhaps identical to *C. antiqua* (Connell, 2000). The first observation occurred in 1991, but it is unclear if the species was overlooked in earlier years, because the first find was made with a newly applied immuno-chemical technique. Since that year observed in North Sea, Wadden Sea, Oosterschelde estuary, and Westerschelde estuary (Vrieling et al., 1995).

Chattonella antiqua (Hada) Ono

In the grey literature (e.g., Tripos, 1997) it has been stated that '*Chattonella*' is an exotic non-indigenous species in Dutch waters. *C. antiqua* apparently is an established species, which is perhaps identical to *C. marina* (Connell, 2000). The first observation occurred in 1991, but it is unclear if the species was overlooked in earlier years because the first find was made with a newly applied immuno-chemical technique. Since that year it was observed in a small number of samples from North Sea, Wadden Sea, Oosterschelde estuary, and Westerschelde estuary (Vrieling et al., 1995).

Fibrocapsa japonica Toriumi & Takano

It is unknown if this is an exotic non-indigenous species in Dutch waters (Kooistra et al., 2001), or that it was overlooked before 1991. Apparently it is an established species. Vrieling et al. (1995) state that Reid et al. (1990) record *F. japonica* from the Belgian coast, but the only rhaphidophycean species mentioned by the latter authors is *Olisthodiscus luteus* N. Carter. Vrieling et al. (1995) record *Fibrocapsa* from samples taken between April and September 1991 from Dutch coastal waters, whereas Billard (1992) found *Fibrocapsa* off Saint-Luc-sur-Mer, Calvados, France in October 1991. Elbrächter (1999) states 'As the species was detected nearly simultaneously and independently at three European coasts, it is not very likely that the species was earlier present in our region. .... Also the gradual increase in its abundance supports the view that it was introduced.' However, the first observation in The Netherlands in 1991 was made with immuno-chemical techniques that were applied for the first time in that year. Since that year it was observed almost annually in samples from North Sea, Wadden Sea, Oosterschelde estuary, and Westerschelde estuary (Vrieling et al., 1995). On the other hand, Kooistra et al. (2001) suggest that *F. japonica* is an introduced Pacific species which recently spread across the world after hybridisation events, possibly in the North Pacific, which led to enhanced hybrid vigour.

Heterosigma akashiwo (Hada) Hada
(Syn. Heterosigma carterae (Hulburt) Taylor)

According to Tripos (1997) a non-indigenous species in The Netherlands. However, this claim is not substantiated. There is even no clear evidence that it has been intro-

duced anywhere (Elbrächter, 1999). Connell (2000), however, found that isolates from all over the world did not differ genetically, indicating recent and probably human-assisted dispersal. This does not exclude the possibility that *H. akashiwo* is a European species. The first find in the Dutch Wadden Sea was made in 1992 (Tripos, 1993; Nehring, 1998).

17.4. Dinophyta

Alexandrium leei (Balech) Balech

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 2). If so, permanently established.

Vector.— Unknown (Elbrächter, 1999).

Area of origin.— Korea, Gulf of Thailand, Philippines (Elbrächter, 1999).

Introduction into Atlantic Europe and in The Netherlands.— 'Biological monitoring in Dutch coastal waters between 1989 and 1995 revealed the occurrence of ... *Alexandrium leei* ... new for this region' (Koeman, 1997). First observation in 1991 (Tripos, 1995).

Present occurrence in The Netherlands.— *Alexandrium leei* was mainly found offshore (Koeman, 1997).

Alexandrium tamarense (Lebour) Balech

Unclear if this is an exotic non-indigenous species. Apparently, it is a permanently established species in Dutch waters. It was described as a new species from the Tamar estuary, England, in 1925. However, PSP intoxication of humans, considered a characteristic effect of this species, has been described from England already in 1827 (Peperzak, 1994). Medlin et al. (1998) found that populations from the Orkney Islands are more similar to North American populations of this species than to other European populations. First observations in Dutch waters were made in 1989 (Peperzak, 1994). Cysts of *Alexandrium* spp. were found in the North Sea on a transect from Terschelling to Oyster Grounds in 1991 (Peperzak et al., 1996).

Gymnodinium catenatum Graham

This possibly non-indigenous species does not occur in The Netherlands, although some authors make contrasting claims. Elbrächter (1999): 'Since 1993, Nehring has reported on the occurrence of *Gymnodinium catenatum* cysts from German coastal waters and succeeded in germinating them (Nehring 1993, 1994, 1995). He speculated that the species, which had been introduced into Spanish waters around 1976, was transported by currents into the North Sea and the Baltic. As shown by Ellegaard et al. (1998), the species of North European waters is not conspecific to the toxic *Gymnodinium catenatum*, but is a newly described non-toxic species - *Gymnodinium nolleri* Ellegaard & Moestrup - which only forms chains of two cells. It is also known from subfossil and fossil sediments in the Skagerrak and Kattegat. Therefore the reports of '*Gymnodinium catenatum*' in North European waters do not represent an exotic, recently introduced species but a misidentification of a genuine but overlooked compo-

nent of our waters.' Cysts of presumably *G. nolleri* (not *G. catenatum*) have been found in the North Sea on a transect from Terschelling to the Oyster Grounds/Doggers Bank (Peperzak et al., 1996).

Gymnodinium mikimotoi Miyake & Kominami ex Oda
(Syn. Gyrodinium aureolum Hulburt)

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 2, 4), permanently established.

Vector.— Braarud & Heimdal (1970) state that this species may have been introduced into Atlantic Europe, but do not identify a vector. 'How this species was introduced into European waters is unknown.' (Elbrächter, 1999). It may have been introduced in ballast water. Minchin & Sheehan (1999) believe that it arrives at new localities by spreading at coastal fronts. It probably arrived in The Netherlands by marine currents.

Area of origin.— Elbrächter (1999): 'Morphological and molecular genetic studies showed that the European bloom-forming species called *Gymnodinium aureolum, Gymnodinium cf. nagasakiense* or *Gymnodinium nagasakiense* Takayama & Adachi, by various authors is conspecific with *Gymnodinium mikimotoi* Miyake & Kominami ex Oda from Japanese waters (Gentien, 1998; Hansen, 1998).' Vrieling et al. (1994) share this opinion. MacDonald (1999), however, believes that *G. mikimotoi* and *G. aureolum* are different species and that the European material belongs to the latter species.

Introduction into Atlantic Europe.— First recorded by Braarud & Heimdal (1970) on the SW coast of Norway in 1966. 'The species is now a regular component of neritic waters of the North Sea.' (Elbrächter, 1999).

Introduction into The Netherlands.— The species was first discovered in the Dutch sector of the North Sea in 1989 (Peperzak, 1990, 1994). De Groot & Van Banning (1998): 'In the North Sea area the dinoflagellate *Gyrodinium aureolum* is considered as having been introduced in 1968 (pers. comm. Wanda Zevenboom, Directie Noordzee), although the wide distribution in the North Atlantic and even world-wide (Tomas, 1997) causes doubt about this.'

Present occurrence in The Netherlands.— In the last few years in the entire Dutch sector of the North Sea. Highest concentrations in the pycnocline at the Oyster Grounds (Peperzak, 1994).

Prorocentrum triestinum Schiller
(Syn. Prorocentrum redfieldii Bursa)

It is unclear whether this is an exotic non-indigenous species in The Netherlands. It is established permanently in Dutch waters. *P. redfieldii* has been described from the Atlantic coast of North America, but according to Nehring (1998) it is distributed world-wide in coastal waters. Kat (1979) has reported *P. triestinum* (as *P. redfieldii*) as bloom-forming from the Dutch coastal area since 1961.

17.5. Chlorophyta

Codium fragile (Suringar) Harriot **ssp. tomentosoides** (van Goor) Silva

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 11), permanently established.

Vector.— Introduced into The Netherlands by shipping (Den Hartog, 1959). Trowbridge (1998) concludes that the primary vectors of spread of this subspecies are shellfish and ships' hulls; she considers ballast water transport highly unlikely. Chapman (1999): 'the original vector of transport to Europe is unknown. ... transport on oysters within Europe is considered most likely.' Because the first find outside the NW Pacific was in The Netherlands at a time when Pacific oysters were not yet commercially transported to Europe, transport on a ship's hull seems most likely.

Area of origin.— Pacific (Van Goor, 1923); Pacific around Japan (Trowbridge, 1998; Chapman, 1999).

Introduction into Atlantic Europe.— Minchin & Sheehan (1999) state that this subspecies has been known from Ireland since 1833. However, Trowbridge (1998) concludes that *Codium fragile* ssp. *tomentosoides* was introduced into Ireland in 1941, whereas the subspecies *C. fragile* ssp. *atlanticum* (A.D. Cotton) Silva first appeared on Irish shores about 1808. Probably, Minchin & Sheehan (1999) have used the wrong name. So the first European find is at Huisduinen in The Netherlands (Van Goor, 1923; Trowbridge, 1998; Chapman, 1999).

Introduction into The Netherlands.— First found washed ashore at Huisduinen in 1900, later (1904) also found growing at the shore near Den Helder (Van Goor, 1910, 1920, 1923; Stegenga & Prud'homme van Reine, 1998). Dorsman (1914): 'This plant did not occur before, and is introduced from America. Often in the basins of the Aquarium of Artis at Amsterdam.'

Present occurrence in The Netherlands.— Van Goor (1923): Den Helder, Texel, Zeeland. Stegenga & Mol (1983): Occurs in a large part of the Oosterschelde estuary, at the entrance of the Westerschelde estuary, along the Marsdiep and at West-Terschelling. Abundant in Lake Grevelingen (Dr. H. Stegenga, pers. comm.).

Ulva pertusa Kjellman

Status in The Netherlands.— An exotic non-indigenous species (criteria 1, 2), permanently established.

Vector.— Unknown.

Area of origin.— Northern Pacific (Stegenga & Mol, 2002).

Introduction into Atlantic Europe.— First recorded from the Dutch Delta area in 1993 (Stegenga & Mol, 2002).

Introduction into The Netherlands.— The first observations in Atlantic Europe were made in the Dutch Delta in 1995, but later the species was recognised in herbarium material collected in the same area in 1993 (Stegenga & Mol, 2002).

Present occurrence in The Netherlands.— In 2002 one of the most common species of *Ulva* in the Delta area in the SW Netherlands, especially in the Oosterschelde estuary and Lake Grevelingen; also found at Texel in the western Wadden Sea (Stegenga & Mol, 2002).

17.6. Tracheophyta (Vascular Plants)

Cotula coronopifolia L.

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 11), permanently established.

Vector.— Unknown.

Area of origin.— South Africa (Cohen & Carlton, 1995). However, already found in New Zealand during Cook's discoveries.

Introduction into Atlantic Europe.— Known from NW Germany since 1739 (Mennema et al., 1980).

Introduction into The Netherlands.— The first observation in The Netherlands was made on the seawall of the brackish Zuiderzee near Amsterdam in 1846. In 1975 the species occurred also in the brackish marshes of the Dollard near Nieuwe-Statenzijl and in the reclaimed Lauwersmeerpolder (Mennema et al., 1980).

Present occurrence in The Netherlands.— *Cotula* occurs both in brackish and in freshwater marshes; it disappeared near Amsterdam, recent finds have been made in Zuid-Flevoland, Lauwersmeer (1975, 2002) and Dollard (1975, 2002) (Mennema et al., 1980; own observations).

Spartina maritima (Curt.) Fernald

Perhaps an exotic non-indigenous species in The Netherlands, permanently established at least since 1834. Chevalier (1923) suggests that it had been introduced into Atlantic Europe from Africa by shipping. If introduced, it is unknown how it arrived in The Netherlands. The species is known from the West Coast of Africa and Europe from the Cape of Good Hope to The Netherlands (Chevalier, 1923). The first record in Britain is from northern Kent in 1629 (Gray et al., 1991). It was first collected in The Netherlands in 1834, both at Walcheren and at Zuid-Beveland (Mennema et al., 1980). It was formerly a common species in the estuaries of the Delta area, North to the southern shore of Goeree-Overflakkee, but it did not occur in the Wadden Sea. However, already in 1951 the species had nearly vanished (Jansen, 1951). In 1976 and 1978 it still occurred on only one saltmarsh in the Oosterschelde estuary (Mennema et al., 1980)

Spartina anglica Hubbard

Status in The Netherlands.— Non-indigenous new species (criteria 1, 3, 4, 6, 7), permanently established.

Vector.— Deliberately introduced for stimulating land accretion.

Area of origin.— England

Introduction into Atlantic Europe.— The American *Spartina alterniflora* Loisl., introduced into South England, interbred with native (?: see above) *S. maritima* (Curt.) Fernald, resulting in the bastard *Spartina townsendii* H. & J. Groves around 1870. The first material was collected in 1877, but already in 1870, and perhaps 1861, similar material had been collected. *S. neyrautii* Foucauld from the Spanish-French border (1892) belongs to the same species. Chromosome doubling in *S. townsendi* around

1890 resulted in the fertile new species *S. anglica* Hubbard (Gray et al., 1991).

Introduction into The Netherlands.— In 1924 50 plants have been imported from England to be planted in the Zuid-Sloe estuary. In 1924/25 and later years also imported from England into other estuaries. Later plants from Zeeland localities have been planted elsewhere in The Netherlands. Since that time the species has established in other suitable areas very rapidly (Thijsse, 1924; Jansen, 1951; Wilderom, 1968; Adema & Mennema, 1979).

Present occurrence in The Netherlands.— The true *S. townsendii* has been found four times (Texel, Oostvoorne, Braakman, Axelse Gat); all other collected plants belong to *S. anglica (*Adema & Mennema, 1979). Van der Meijden et al. (1989) present a distribution map (page 152): *S. anglica* occurs along the shores of the entire Wadden Sea and Delta area.

17.7. Protista

Bonamia ostreae Pichot, Comps, Tigé, Grizel & Rabouin, 1979

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3, 4, 6, 7), permanently established.

Vector.— *Bonamia* is a parasite, imported with oysters from Brittany into The Netherlands (Van Banning, 1988).

Area of origin.— California (Cigarria & Elston, 1997); NE Pacific (Goulletquer et al., 2002).

Introduction into Atlantic Europe.— Introduced into Brittany at the end of the seventies (Pichot et al., 1979) and into Asturia, Spain, in 1977 (Cigarria & Elston, 1997).

Introduction into The Netherlands.— The species was imported with oysters from Brittany into the Oosterschelde estuary in 1980 (Van Banning, 1988).

Present occurrence in The Netherlands.— *Bonamia o*ccurs in the Oosterschelde estuary since 1980 and in Lake Grevelingen since 1988 (Van Banning, 1991). It caused the nearly complete disappearance of the Dutch culture of the European flat oyster (*Ostrea edulis* Linnaeus, 1758).

Haplosporidium armoricanum (Van Banning, 1977)
(Syn. Minchinia armoricana Van Banning, 1977)

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 3, 7), not established.

Vector.— This is a parasite. It is unknown how it arrived in Atlantic Europe, but probably it was imported with oysters. In The Netherlands it was imported with oysters (Van Banning, 1977).

Area of origin.— Unknown.

Introduction into Atlantic Europe and in The Netherlands.— Van Banning (1977) described this species as *Minchinia armoricana.* It occurred in oysters (*Ostrea edulis*) from the Oosterschelde estuary, The Netherlands, imported from Brittany, France, in 1974.

Present occurrence in The Netherlands.— Occurred exclusively in imported oysters. After removing all infected oysters not observed after 1978 (Van Banning, 1988).

Marteilia refringens Grizel, Comps, Bonami, Cousserans, Duthoit & Le Pennec, 1974

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 3, 4, 6, 7), not established.

Vector.— *Marteilia* is a parasite; it is unknown how it arrived in Atlantic Europe, although it was probably imported with oysters. In The Netherlands it was imported with oysters (Van Banning, 1988).

Area of origin.— Unknown.

Introduction into Atlantic Europe.— The first observation was in Brittany in 1968 where it caused the 'Aber' disease in European flat oysters (Grizel et al., 1974; Van Banning, 1988).

Introduction into The Netherlands.— *Marteilia* was observed in *Ostrea edulis* on the Yerseke Bank, Oosterschelde estuary, since 1974, but exclusively in oysters imported recently from France (Van Banning, 1988).

Present occurrence in The Netherlands.— *Marteilia* has been eradicated by removing all infected oysters. It was not observed any longer after 1978 (Van Banning, 1988).

17.8. Porifera

Haliclona loosanoffi Hartman, 1958

Perhaps an exotic non-indigenous species, permanently established. In The Netherlands so far found only in the Oosterschelde estuary where it is not uncommon (Van Soest, 1976, 1977; De Weerdt, 1983). It is also known from America and Ireland (De Weerdt, 1983). Its restricted distribution suggests that this species has been imported from elsewhere, perhaps with oysters. However, it is not possible to distinguish between an American and a European (or another) origin (Van Soest, 1983). Van Soest (1976) states that the possibility of transport of this sponge by human means (attached to ships etc.) to either Atlantic coast seems small because material of this species dates back as far as 1880. However, he apparently does not consider the possibility that it was imported with American Atlantic oysters (see *Crassostrea virginica* on page 80) in the 19th century.

Haliclona rosea (Bowerbank, 1866)

Perhaps a NE Atlantic non-indigenous species, possibly only temporarily established. It is suspected that this species has been imported from Brittany with oysters. However, it is extremely difficult to prove an origin from elsewhere (Van Soest, 1983). It was observed in the Oosterschelde estuary at Wemeldinge (1976) and on Schouwen (Plompe toren) in 1979 (De Weerdt, 1983). Buizer (1989) found it abundantly in oyster ponds near Yerseke. Faasse (1991a) records it from the Kanaal door Walcheren near Middelburg in 1990.

Haliclona cf. simplex (Bowerbank, 1866)

Perhaps a non-indigenous species in Dutch waters, possibly established temporarily. It is suspected that this species has been imported from elsewhere, perhaps with oysters. Unknown if this is a NE Atlantic or an exotic species; perhaps it is an undescribed species (De Weerdt, 1983). However, it is extremely difficult to prove an exotic origin (Van Soest, 1983). It was first observed in the Westgat or Mosselkreek in the Oosterschelde estuary near Yerseke (De Weerdt, 1983). In 1982 it was abundant on oyster lot 264 in the Oosterschelde estuary.

Hymeniacidon perlevis (Montagu, 1812)

Perhaps a NE Atlantic non-indigenous species but probably not established. Collected in the Oosterschelde estuary near Wemeldinge in 1951 (Van Soest, 1977) and in oyster ponds at Yerseke Bank in 1989 (Buizer, 1989). It is suspected that this species has been imported from elsewhere along the Atlantic coasts of Europe (Van Soest, 1983), perhaps with oysters. However, its Dutch occurrence may also represent a marginal population.

Mycale micracanthoxea Buizer & Van Soest, 1977

Perhaps an exotic non-indigenous species, permanently established. It was described from the Oosterschelde estuary, The Netherlands, in 1977 (Buizer & Van Soest, 1977); it is not known from elsewhere. Vosmaer has collected the oldest specimens at Bergen op Zoom, Oosterschelde estuary, probably in the 19th century; it is still present in the Oosterschelde and Westerschelde estuaries (Buizer & Van Soest, 1977). If it is introduced into Atlantic Europe, it remains unknown how it arrived. Perhaps it was imported in The Netherlands with oysters (Van Soest, 1983). However, there exist no other indications for an exotic origin (Van Soest, 1983).

Scypha scaldiensis Van Koolwijk, 1982

Perhaps an exotic non-indigenous species in The Netherlands, permanently established. It was described from the Oosterschelde estuary, The Netherlands (Van Koolwijk, 1982). It is suspected that this species has been imported from elsewhere, perhaps with oysters, since it is only known from the Oosterschelde estuary where this species is fairly common (Van Koolwijk, 1983). However, there exist no other indications for an exotic origin (Van Soest, 1983).

17.9. Cnidaria

17.9.1. Hydrozoa

Cordylophora caspia (Pallas, 1771)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), permanently established.

Vector.— Dispersed through freshwater canals between the Ponto-Caspian drainage basin and the Baltic basin, probably as fouling on timber rafts or ships. Further dispersal in NW Europe probably by planktonic larvae, attached to drifting plant material and as hull fouling (Bij de Vaate et al., 2002).

Area of origin.— Ponto-Caspian area (Nehring & Leuchs, 1999).

Introduction into Atlantic Europe.— Olenin (2002) records it from the Curonian and Vistula Lagoons in the early 1800s, after the Oginsky and the Pripyat-Bug canals had been opened. Nehring & Leuchs (1999) record that Agardh probably made the first observation in Swedish coastal waters in 1816. In 1844 it was found by Allman in the Grand Canal Docks, Dublin, Ireland (Funke, 1922, referring to Allman, 1872), and in 1858 on buoys in the Elbe estuary, Germany.

Introduction into The Netherlands.— The earliest observations were made in the Rotterdam water works in 1884 and in mouth of Ems estuary (Eem river?) in 1885 (Vervoort, 1964).

Present occurrence in The Netherlands.— Funke (1922) recorded *Cordylophora* from various inland waters (a.o. Maastricht) and from the Zuiderzee in the harbour of Muiden, near Durgerdam and in the Ensgat behind Schokland. Wagenaar Hummelinck (1936) gave many more records from the Zuiderzee. Vervoort (1946) also gave a large number of records. However, Vervoort (1964) identified most of the former material as *Garveia franciscana* (see below). He presents a map showing that the true *Cordylophora* occurred in slightly brackish water in the provinces of Friesland, Noord- and Zuid-Holland, Noord-Brabant and Zeeland as well as in the IJsselmeer. Wolff (unpublished) observed the species in the freshwater tidal area of the Biesbosch (Deeneplaat) in 1964. Oosterbaan (1985) states that *Cordylophora* occurs everywhere in The Netherlands in brackish to nearly fresh waters, but not in the sea (see also Van der Velde et al., 2002).

Garveia franciscana (Torrey, 1902)
(Syn. Perigonimus megas Kinne, 1956)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently established

Vector.— Unknown.

Area of origin.— Unclear. Vervoort (1964) mentions the species from the Gulf of Mexico, the Pacific and the Atlantic coast of the USA, India, West Africa and Australia. Cohen & Carlton (1995) suggest it to be a native of northern Indian Ocean estuaries.

Introduction into Atlantic Europe and into The Netherlands.— According to Vervoort (1964) Funke (1922) found the first European specimens (as *Bougainvillia ramosa* (Wright)) in the southeastern Zuiderzee in 1920.

Present occurrence in The Nether-

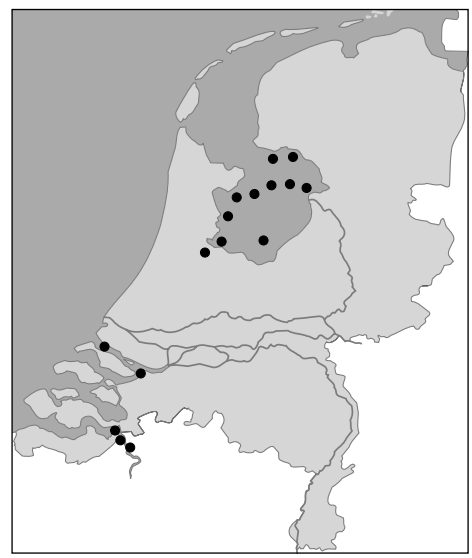

Fig. 20. Distribution of *Garveia franciscana* in the period 1926-1962. After Vervoort (1964) and Den Hartog (1959a)

lands.— *Garveia* occurred in the Zuiderzee/IJsselmeer between 1920 and 1934 (Vervoort, 1964). Den Hartog (1959a) found the species (as *Perigonimus megas*) abundantly in the Hollands Diep near Willemstad (in 1958?). Later (1959, 1962) Vervoort (1964) recorded the species from Hellevoetsluis (fig. 20). Oosterbaan (1985) gives its distribution as formerly in the Zuiderzee, and still in the Oosterschelde estuary. Faasse & Van Moorsel (2003) record the species from the brackish eastern part of the Westerschelde estuary around 2000, thus confirming earlier finds in this estuary at Doel and Liefkenshoek in Belgium (Vervoort, 1964).

Gonionemus vertens A. Agassiz, 1862

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— Broch (1929) suspected transport in ballast water, but Leloup (1948) believed that the species had been introduced with imported American oysters *Crassostrea virginica.* Tambs-Lyche (1964) and Carlton (1985) assume transport of the polyp on ship hulls. Edwards (1976) assumes introduction into Atlantic Europe with oysters (*Crassostrea gigas*). It is unknown how it arrived in The Netherlands. It has been suggested to have been introduced into Rammekenshoek creek, The Netherlands, with pontoons from Normandy, which had been used to block a gap in the seawall.

Area of origin.— Atlantic coast of North America (Werner, 1950). Pacific coast of North America, Japan, China (Edwards, 1976). Tambs-Lyche (1964) is unable to pinpoint an area of origin, but on the other hand states that it has been distributed widely by human means.

Introduction into Atlantic Europe.— Goulletquer et al. (2002) mention 19th century finds in Portugal. Tambs-Lyche (1964) and Edwards (1976) record the species from NE-England in 1913. Broch (1929) mentions the first finds of the medusa from the Oslofjord in 1921. Teissier (1932) (not seen) describes the 'first' European finds from Île Callot, Brittany, in 1929 and 1931.

Introduction into The Netherlands.— Leloup (1948) records the species from Ostend, Belgium, not far from the Dutch coast, in 1946 and 1947. In The Netherlands it was first observed in the non-tidal brackish creek Rammekenshoek at the former island of Walcheren in 1960 (Leentvaar, 1960, 1961).

Present occurrence in The Netherlands.— *Gonionemus* was observed in the Kreek Rammekenshoek in 1960 (Leentvaar, 1960, 1961). Vervoort (1964a) mentions 1 specimen from Sas van Goes, near Wilhelminadorp, on 30.vii.1963 [See also rectification in Zeepaard 25: 4]. Bakker (1980, 1981) found it in the Havenkanaal van Goes in 1976, and in Lake Grevelingen from 1976 to 1980. Verkuil (1994) records it from Lake Grevelingen in 1982, from Sas van Goes in 1987, and c. 15 exx from the Oosterschelde estuary near Lokkersnol, Zierikzee, on 14.v.1994(?). Finally the species has been found in the Goesse Meer in 1995, 1996, and 2000 (M.A. Faasse, pers. comm.).

Nemopsis bachei (L. Agassiz, 1849)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), permanently established.

Vector.— Transported into Atlantic Europe as polyps on ships' hulls (Tambs-Lyche, 1964; Nehring & Leuchs, 1999). It is unknown how it arrived in The Netherlands.

Area of origin.— North America (Tambs-Lyche, 1964); Atlantic coast of North America (Thiel, 1967). Faasse & Ates (1998) suggest that perhaps it was introduced into North America from Europe.

Introduction into Atlantic Europe.— Thiel (1967) describes introduction into Atlantic Europe. In 1851 the first observation was made at the Hebrides, in 1879 it occurred in Norway.

Introduction into The Netherlands.— The first observation was made in the former Zuiderzee in 1905 (Van Breemen, 1907).

Present occurrence in The Netherlands.— Van Breemen (1907), Tesch (1912) and Van Kampen (1922) make clear that it was common in the former Zuiderzee. Dumoulin (1997) (not seen) found it at Cadzand in 1996. Faasse & Ates (1998) record it from the Oosterschelde estuary near Burghsluis, Neeltje Jans and Zierikzee in 1993 and 1996, and from the Westerschelde estuary near the intake of the power station at Borssele in 1996 en 1997. Dekker (1998) observed *Nemopsis* washed ashore on the Balgzand in 1998; probably also in 1997 on beach of Texel. Tulp (2002) found the medusae in the Wadden Sea near Lauwersoog between June and November in 2000 and 2001; from the occurrence of very small medusae (< 1 mm) he concluded that the polyps must occur in the Wadden Sea as well.

Ostroumovia inkermanica (Paltschikowa-Ostroumowa, 1925)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), not established.

Vector.— Possibly transported into Atlantic Europe and into The Netherlands as polyp on ships' hulls (Saraber, 1962).

Area of origin.— Ponto-Caspian area (Saraber, 1962).

Introduction into Atlantic Europe and The Netherlands.— The find in The Netherlands in the North Sea Canal at IJmuiden on 23.ix.1959, was the first and only one in Atlantic Europe and The Netherlands (Saraber, 1962).

Present occurrence in The Netherlands.— Not observed again.

Thieliana navis (Millard, 1959)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3, 11), permanently established.

Vector.— Unknown.

Area of origin.— Faasse & Vervoort (2001) suggest that this might be a Ponto-Caspian species, although so far it has been found only in South Africa, the Baltic, England, and The Netherlands. However, *Cordylophora inkermanica* Marfenin, 1983, from the Black Sea may be the same species.

Introduction into Atlantic Europe.— The first observation is from the mouth of the Nordsee-Ostsee Kanal in the Kieler Förde in Germany in 1960 (Thiel, 1962).

Introduction into The Netherlands.— Faasse & Vervoort (2001) show that this species was observed for the first time in the non-tidal Gat van Ouwerkerk near the Oosterschelde estuary in 1964.

Present occurrence in The Netherlands.— The species has not been found again in the Gat van Ouwerkerk. In 2000 and 2001, however, it was observed in the Goesse Meer and in 2001 (and perhaps in 1999) in the Westkapelse Kreek. In contrast to *Cordylophora* and *Garveia*, which can be classified as freshwater-oligohaline and mesohaline species, respectively, *Thieliana* seems to be a polyhaline species (Faasse & Vervoort, 2001).

17.9.2. Anthozoa

Diadumene cincta (Stephenson, 1925)

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 2), permanently established.

Vector.— Probably imported into Atlantic Europe in fouling on the hull of ships or with oysters (Nehring & Leuchs, 1999). It is unknown how it arrived in The Netherlands, although natural range extension seems possible.

Area of origin.— Warm-temperate areas, perhaps California (Nehring & Leuchs, 1999). Cohen & Carlton (1995) assume an Atlantic origin. Manuel (1988) apparently considers this to be a native British species.

Introduction into Atlantic Europe.— Stephenson (1925) described this species from Plymouth. The species probably was found a few years earlier for the first time. I consider it to be a non-indigenous species because of its sudden appearance in Plymouth in the 1920s and its restricted European distribution.

Introduction into The Netherlands.— Found around 1925 at Schouwen and near Den Helder (Pax, 1936).

Present occurrence in The Netherlands.— Abundant.

Haliplanella lineata (Verrill, 1869)
(Syn. Diadumene luciae (Verrill, 1898))

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— Probably introduced into Atlantic Europe on ships' hulls (Gollasch & Riemann-Zürneck, 1996). Nehring & Leuchs (1999) consider introduction with oysters also possible. It is unknown how this species arrived in The Netherlands.

Area of origin.— Pacific (Eno et al., 1997). NW Pacific (Grosholz & Ruiz, 1996). Japan (Manuel, 1988).

Introduction into Atlantic Europe.— Probably introduced from Japan into the Atlantic towards the end of the 19th century (Manuel, 1988). First observed in dock at Milbay near Plymouth in 1896 (Walton, 1908).

Introduction into The Netherlands.— The oldest observation was made in 1912/1913 by Tesch (Minutes of a meeting of The Netherlands Zoological Society in Tijdschrift Nederlandsche Dierkundige Vereeniging (2) 3: VIII-IX). It seems that many later records from Den Helder refer to the same find(s) in 1912/1913.

Present occurrence in The Netherlands.— Van Urk (1956) lists (as *Diadumene luciae*)

all Dutch finds (all from Den Helder). Braber & Borghouts (1977) record it from the Veerse Meer in 1968 en 1969 at about 18 psu. Dekker (1982) found it in 1981 and 1982 in large numbers on the dike of 't Horntje, Texel. On 15 July 1982 he found the species also on the moles of Oost-Vlieland; it did not occur on the Helderse zeewering or on the dike near Oudeschild, Texel. Dekker (1982) also records an unconfirmed find from Schouwen in 1951. Dekker (1987) mentions 1984: dike Oudeschild; 1985: 't Horntje; several years before 1987: Den Helder, Fort Harssens (pers. comm. B. Schrieken); 1986: Oosterschelde estuary, Zuidbout near Ouwerkerk and Plompe Toren. Faasse (1991) observed *Haliplanella* in the Veerse Meer near Veere in 1990. Faasse (1991a) found the species in the Kanaal door Walcheren near Veere in 1990. Faasse (1996) records finds in the Oosterschelde estuary near Prommelsluis, Zierikzee, in 1991 and 1995, in the harbour of Burghsluis, and in the Boomkil in Oosterschelde estuary in 1995, and in the outlet of the power station at Borssele in 1996. Faasse (1997) gives several new localities in the Oosterschelde estuary, in Den Inkel near Kruiningen and in the Westerschelde estuary near Vlissingen. It was also found in the Westerschelde estuary near Terneuzen and Baarland (M.A. Faasse, pers. comm.).

17.10. Platyhelminthes: Turbellaria

Euplana gracilis (Girard, 1850)

Status in The Netherlands.— An exotic non-indigenous species (criteria 1, 2, 3 and 5), recently introduced.

Vector.— Suggested to have been introduced in hull fouling (Faasse & Ates, 2003).

Area of origin.— Atlantic coast of North America (Faasse & Ates, 2003).

Introduction into Atlantic Europe and into The Netherlands.— The first observations of this species were made in the Noordzeekanaal at IJmuiden in July and December 2002 (Faasse & Ates, 2003).

Present occurrence in The Netherlands.— So far, only known from IJmuiden.

Stylochus flevensis (Hofker, 1930)

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1 and 3), permanently(?) established.

Vector.— Unknown.

Area of origin.— Unknown.

Introduction into Atlantic Europe and into The Netherlands.— Hofker (1930) described this species from the brackish Zuiderzee where this species was observed from 1921 till 1932 (Hofker, 1930; Wibaut – Isebree Moens, 1954). Although the species is not known from anywhere else, it is unlikely that this concerns a native species.

Present occurrence in The Netherlands.— Faasse (2003) records similar flatworms from the brackish Veerse Meer (2001) and from the brackish Noordzeekanaal (1997).

17.11. Annelida

17.11.1. Oligochaeta

Tubificoides heterochaetus (Michaelsen, 1926)
(Syn. Peloscolex heterochaetus Michaelsen, 1926)

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 2, 3, 4), if so, permanently established.

Vector.— Unknown.

Area of origin.— Unknown. Occurs on both sides of the northern Atlantic (Giere & Pfannkuche, 1982).

Introduction into Atlantic Europe.— Described by Michaelsen as a new species from Greifswald, Germany, in the Baltic in 1926. Also found in Finland, the Elbe and Weser estuaries, Germany, and the Scheldt estuary in Belgium (Seys et al., 1999a).

Introduction into The Netherlands.— De Vos (1936) states that this species (as *Peloscolex heterochaetus*) did not occur in her many samples from the brackish Zuiderzee, The Netherlands, she collected and analysed in 1920-21. In 1927-1932, however, it was the most abundant oligochaete species in the southern and eastern part of the Zuiderzee. She considers it more than likely that this species has arrived in the Zuiderzee after 1921. This points to an exotic origin.

Present occurrence in The Netherlands.— Unknown. Verdonschot (1980) did not find this species in the brackish Haringvliet in the period 1960-1970. Seys et al. (1999, 1999a), however, record this species as *Tubificoides heterochaetus* from the Zeeschelde in Belgium between Antwerp and the Dutch border, hence in the brackish part of this estuary (fig. 21).

Fig. 21. Distribution of *Tubificoides heterochaetus* in the period 1927-1999. After De Vos (1936) and Seys (1999).

17.11.2. Polychaeta

Aphelochaeta marioni (Saint-Joseph, 1894)
(Syn. Tharyx marioni (Saint-Joseph, 1894)

It is doubtful if this is an indigenous species in The Netherlands. It is permanently established. Reise (1990; see also Nehring & Leuchs, 1999) states that this species has been introduced into Germany at the end of the 1960s. It was described from the French

side of the Channel in 1894. Oldest records outside France are from the English shore of the Channel and (as *Tharyx multibranchiis* (Grube, 1863)) from the Oosterschelde estuary, The Netherlands (Korringa, 1951). Wolff (1973) found *Tharyx marioni*, supposed to be identical to Korringa's *T. multibranchiis*, to be common in the Dutch Delta area in the period 1959-69. It is also remarkable that Horst, a well-known Dutch specialist on polychaete taxonomy in the early 20th century, did not record this common species.

Boccardia ligerica (Ferronière, 1898)
(Syn. Polydora redeki Horst, 1919)

Unclear if this is an exotic non-indigenous species. It is permanently established. Its possible area of origin is in debate: North- or South Atlantic or North Pacific (Nehring & Leuchs, 1999), or native to brackish waters of France, Holland and Germany (Cohen & Carlton, 1995). It was described from brackish waters in northern France in 1898. Later it was described as *Polydora redeki* from the brackish Alkmaarder Meer, The Netherlands, in 1919 (Horst, 1919). It occurred in The Netherlands in brackish inland waters in Noord-Holland, Zuiderzee, and Haringvliet-Hollands Diep (Horst, 1919; De Vos, 1936, 1954; Wolff, 1973), but in all these localities brackish conditions have ceased to exist. Nowadays it still occurs in the Zeeschelde between Antwerp, Belgium, and the Dutch border (Seys et al., 1999; Ysebaert et al., 2000).

Branchiomma bombyx (Dalyell, 1853)

Status in The Netherlands.— NE Atlantic non-indigenous species, established temporarily.

Vector.— Unknown.

Area of origin.— Atlantic Europe.

Introduction into The Netherlands.— Wolff (1974, 1999) collected this species on a post near Keersluis, Vlissingen, in the Kanaal door Walcheren on 9.x.1973. This location showed elevated water temperatures due to heating by a power station.

Present occurrence in The Netherlands.— Unknown, no recent records.

Ficopomatus enigmaticus (Fauvel, 1923)
(Syn. Mercierella enigmatica Fauvel, 1923)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— On ships' hulls or in ballast water (Ten Hove, 1974).

Area of origin.— Southwest Pacific (Grosholz & Ruiz, 1996). Southern Hemisphere (Eno et al., 1997).

Introduction into Atlantic Europe.— Discovered in 1921 and described from the harbour canal of Caen, France, by Fauvel (1923). In London Docks in 1922 (Eno et al., 1997).

Introduction into The Netherlands.— *Ficopomatus* was found in the Veerse Meer and the Kanaal door Walcheren in 1968. Probably it occurred in the latter locality already in 1967 (Wolff, 1968, 1969).

Present occurrence in The Netherlands.— It was observed in the Veerse Meer and the Kanaal door Walcheren from 1968 till 2000 (Wolff, 1969; Ten Hove, 1974; Vaas, 1975; Faasse, 1991a, and pers. comm.; Van der Velde et al., 1993; Ten Hove & Lucas, 1996). Vaas (1975) also mentions the Binnenhaven at Vlissingen. Van der Velde et al. (1993) record the first observation in the Noordzeekanaal near Velzen in January 1992; probably it settled there in 1991. Nehring & Leuchs (1999) observed the species in the (non-tidal) harbour of Emden, Germany (close to the Dutch border), in 1975. In 2000 *Ficopomatus* was found in the Goesse Meer (M.A. Faasse, pers. comm.).

Hydroides elegans (Haswell, 1883)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 3), temporarily established.

Vector.— On ships' hulls (Ten Hove, 1974).

Area of origin.— Found around the world in tropical and subtropical seas (Ten Hove, 1974).

Introduction into Atlantic Europe.— Not mentioned by Eno et al. (1997) for the British Isles, although Ten Hove (1974) records it as introduced into Great-Britain.

Introduction into The Netherlands.— Ten Hove (1974) found this species near the Keersluisbrug at Vlissingen in the Kanaal door Walcheren in September 1973. At that time the canal was thermally polluted by the PZEM power station at Vlissingen.

Present occurrence in The Netherlands.— After the first observation in 1973 not found again, although it was looked for several times (Ten Hove & Lucas, 1996).

Janua brasiliensis (Grube, 1872)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently(?) established.

Vector.— Unknown how it reached Europe, possibly with the Round the World Yacht Race; introduction into The Netherlands perhaps with drifting *Sargassum muticum* or with leisure craft (Critchley & Thorp, 1985).

Area of origin.— Tropical areas, including Brazil (Eno et al., 1997).

Introduction into Atlantic Europe.— In 1974 in Portsmouth Harbour, the Solent, UK (Eno et al., 1997).

Introduction into The Netherlands.— Critchley & Thorp (1985) found this species in the harbour canal of Goes.

Present occurrence in The Netherlands.— Critchley & Thorp (1985) record it, growing on *Sargassum muticum* and on native *Zostera marina* Linnaeus, from the Havenkanaal van Goes. In 2000 it was found in the Kanaal door Zuid-Beveland (M.A. Faasse, pers. comm.).

Marenzelleria cf. wireni Augener, 1913
(Syn. Marenzelleria viridis auct.)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6, 9, 10), permanently established.

Vector.— Ballast water (Essink, 1999).

Area of origin.— Barnes (1994): 'a species native to the eastern coast of North America'. Bastrop et al. (1997) and Bick & Zettler (1997): Atlantic coast of the USA. Nehring & Leuchs (1999): Arctic waters (based on Bick & Zettler (1997)!).

Introduction into Atlantic Europe.— Late 1970s found in the Tay estuary, Scotland (Atkins et al., 1987) (as *M. viridis*). Essink (1999) states 'The first records of … *Marenzelleria* are from 1982 (Forth estuary, Scotland: McLusky et al., 1993) and 1993 (sic: should be 1983) (Ems estuary, The Netherlands; Essink & Kleef, 1988)'.

Introduction into The Netherlands.— First observed in Ems estuary in 1983 (as *M. viridis*: Essink, 1987; Essink & Kleef, 1988).

Present occurrence in The Netherlands.— In 1983-1987 *Marenzelleria* was abundant in the Dollard (Essink & Kleef, 1988) and in 1986-87 in the Bocht van Watum (Essink & Kleef, 1988). Dekker (1991) found it in the western Dutch Wadden Sea in 1990-1991. Essink et al. (1998) present the population development in the Dollard in the period 1983-1994. Essink (1999) states that 'On the eastern shores of the North Sea *M. cf. wireni* dispersed further southward to the coastal waters of the SW Netherlands [according to map in 1995] and the western Scheldt estuary [according to map in 1996] (J. Craeymeersch, personal communication).' Essink (1999) presents a table and a map (fig. 22), showing the 'Present occurrence in The Netherlands'. This includes the Dollard since 1983, 'Groningen' (near Noordpolderzijl) since 1994, Piet Scheveplaat since 1994, sublittoral western Wadden Sea (near Zuidoostrak) since 1994, Balgzand since 1989, Voordelta (Brouwershavense Gat) since 1995, Westerschelde estuary (near Belgian border) since 1995 and Nieuwe Waterweg (near Maassluis) since 1997 (see also Essink & Dekker, 2000). Also just across the Dutch border in the Belgian Zeeschelde (Ysebaert et al., 2000).

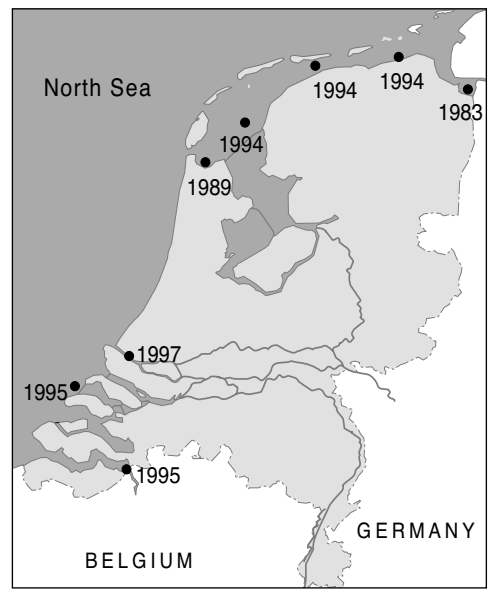

Fig. 22. Distribution of *Marenzelleria* cf. *wireni* in The Netherlands in 1999. After Essink (1999).

Microphthalmus similis Bobretzky, 1870

It is doubtful if this is an exotic non-indigenous species, although it has been suggested to originate from the Black Sea or the Mediterranean (Nehring & Leuchs, 1999). The first NW-European observation was made near Neuwerk, German Wadden Sea, in 1962. It was found later also near Sylt and Wangerooge, Germany, and in Denmark (Nehring & Leuchs, 1999). In The Netherlands Wolff (1969b, 1973) found this species at the entrance of the Brouwershavense Gat in 1962 or '63 and in the North Sea off the Delta area in 1966. It was at least temporarily established in The Netherlands; in Germany it has been found at several locations in the 1990s (Nehring & Leuchs, 1999).

Nereis virens Sars, 1835

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 4), permanently established.

Vector.— Unknown.

Area of origin.— North Atlantic or North Pacific (Nehring & Leuchs, 1999).

Introduction into Atlantic Europe.— Michaelis & Reise (1994) and Nehring & Leuchs (1999) suggest that *N. virens* might be an exotic non-indigenous species, because this large and conspicuous species was described from Norway only in 1835. Nehring & Leuchs (1999) record a number of observations in Scandinavia in the 19th century. First observations in the German Wadden Sea occurred in 1923-26 (Nehring & Leuchs, 1999). The suggestion that *N. virens* might have been introduced in Europe is supported by the genetic population structure of the species studied by Breton et al. (2003). They found that all European populations studied were genetically remarkably uniform; however, also North American and Japanese populations were similarly uniform.

Introduction into The Netherlands.— Horst (1920) observed the species for the first time near Den Helder, The Netherlands, in 1915. This is also remarkably late for this large species and for this author whom at that time had studied Dutch polychaetes for more than 30 years.

Present occurrence in The Netherlands.— A common species nowadays (Korringa, 1951; Wolff, 1973, unpublished observations).

Polydora hoplura Claparède, 1870

Status in The Netherlands.— NE Atlantic non-indigenous species. Temporarily established.

Vector.— Introduced with oysters (Korringa, 1951).

Area of origin.— Atlantic Europe, especially Western France (Korringa, 1951).

Introduction into The Netherlands.— Korringa (1951) writes '*Polydora hoplura* … has repeatedly been imported with Brittany oysters ... It did reproduce successfully in Dutch waters in 1949.' In 1950 the oyster growers attempted to control this species because of its abundance (Korringa, 1950a).

Present occurrence in The Netherlands.— An old record by Horst (1919) from the Alkmaardermeer is based on a wrong identification of the tail end of *Polydora redeki* Horst, 1920 (= *Boccardia ligerica* Ferronière, 1898) (Vorstman, 1935). Hofker (1922) 'cautiously' identifies two larvae from Den Helder as *P. hoplura.* Hoeksema (1983) records oyster shells with *P. hoplura*, possibly from Zeeland (Oosterschelde estuary or Grevelingen), but perhaps from France. Korringa (1951): '*Polydora hoplura* … does not belong to the regular fauna of Dutch waters.'

Proceraea cornuta (A. Agassiz, 1862)
(Syn. Autolytus cornutus A. Agassiz, 1862)

Perhaps a non-indigenous species in Dutch waters, possibly established permanently. Korringa (1951) considered this to be a non-indigenous species. This is based on Okada (1933), who found this species near Plymouth, UK, in 1929, but not in 1927-28.

However, this author states that the identification of the newly found species as *Autolytus cornutus* is tentative. It was suggested to have been introduced from North America into Europe with hydroids on a ship's hull (Okada, 1933), and perhaps transported with oysters to The Netherlands (Korringa, 1951). Two specimens were found on oysters from the Oosterschelde estuary on 4.iv.1941. More specimens were found in the Oosterschelde estuary in 1941, 1942, and 1943, and in the Grevelingen estuary in 1941 (Korringa, 1951). Lucas (1957) recorded 2 specimens swimming around at night caught at Zijpe, Schouwen-Duiveland, between 4 and 11.viii.1956 (Lucas made a (unpublished) taxonomic revision of this group). Van Nieukerken (1971) refers to the same find.

Sabellaria spinulosa (Leuckart, 1849)

Status in The Netherlands.— NE Atlantic non-indigenous species, temporarily established.

Vector.— Introduced with oysters (Korringa, 1951).

Area of origin.— Atlantic Europe, especially France (Korringa, 1951).

Introduction into The Netherlands.— Korringa (1951) records 'Occasionally *S. spinulosa* has been introduced alive with oysters from Arcachon, e.g. in April 1947. On 6.x.1947, I found living *Sabellaria* full of spawn on such relaid oysters.' 'Only once did I find the hard sand burrow of *Sabellaria* on a Dutch oyster, viz. 13.xii.1938.' 'In the spring of 1938 oysters from Brittany and Arcachon had been relaid in fair numbers.' 'I found another Dutch specimen on a tile collector, February 1950.'

Present occurrence in The Netherlands.— At an artificial reef in the North Sea off Noordwijk, 1991 (van Moorsel, 1993). Buitenhaven, Vlissingen, in 1996; at Westkapelle in 1996 and 2001, entrance of Oosterschelde estuary in 1992, 1995, 2000, and 2001, near Zoutelande in entrance of Westerschelde estuary in 2001 (Stikvoort & Faasse, 2001). It seems possible that more recently *S. spinulosa* has become a normal inhabitant of Dutch coastal waters, whereas it did not occur naturally in Korringa's time. This might be due to the series of mild winters since 1990.

Syllidia armata Quatrefages, 1866
(Syn. Magalia perarmata Marion & Bobretzky, 1875)

Status in The Netherlands.— NE Atlantic non-indigenous species, not established.

Vector.— Introduced with oysters (Korringa, 1951).

Area of origin.— Atlantic Europe (Korringa, 1951).

Introduction into The Netherlands.— Suggested to have been imported from Brittany, France, with oysters (Korringa, 1951).

Present occurrence in The Netherlands.— Found on an oyster in the Oosterschelde estuary on 30.viii.1943 (Korringa, 1951). No other autochthonous records.

Syllis gracilis Grube, 1840

Status in The Netherlands.— NE Atlantic non-indigenous species, not established.

Vector.— Introduced with oysters (Korringa, 1951).

Area of origin.— Atlantic Europe (Korringa, 1951).

Introduction into The Netherlands.— Suggested to have been imported from Brittany, France, with oysters (Korringa, 1951).

Present occurrence in The Netherlands.— Found on an oyster in the Oosterschelde estuary on 10.x.1940 (Korringa, 1951). No other autochthonous records.

Streblospio benedicti Webster, 1879

Horst (1910) described *Streblospio dekhuyzeni* from the brackish Zuiderzee. Redeke (1933) found it to be common in Dutch brackish inland waters and Korringa (1951) found the species in the Oosterschelde estuary. Wolff (1973) concluded that *S. dekhuyzeni* is a junior synonym of *S. shrubsolii* (Buchanan, 1899); he found the species to be common in the Haringvliet estuary. Other finds were made in the other estuaries of the Delta area and even offshore in the North Sea. Carlton (1979) suggested *S. shrubsolii* to be identical to *S. benedicti* Webster, 1879, described from North America. This suggestion apparently has been widely accepted (e.g., Schulze et al., 2000; Dauvin et al., 2003). This implies that *S. benedicti* would be a non-indigenous species in Europe. However, Dauer et al. (2003) show that morphologically *S. shrubsolii* and *S. benedicti* are two different species. *S. benedicti* does occur in Europe (Spain), but there is no reason to believe that *S. benedicti* occurs in The Netherlands.

17.12. Nematoda

Anguillicola crassus Kuwahara, Niimi & Itagaki, 1974

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 4, 7), permanently established.

Vector.— This parasitic nematode, living in the swim-bladder of eels (*Anguilla anguilla* (Linnaeus, 1758)), was imported in Europe with infected Japanese eels *Anguilla japonica* Temminck & Schlegel, 1846; probably it was introduced into The Netherlands with infected eels from elsewhere in Europe (W. Dekker, pers. comm.).

Area of origin.— Japan (Koops & Hartmann, 1989).

Introduction into Atlantic Europe.— Reported independently from Germany and Italy in 1982 (Koops & Hartmann, 1989).

Introduction into The Netherlands.— First observed in July 1985, but probably introduced in 1984, perhaps even in 1983. In July 1985 already found in a large part of The Netherlands (Van Banning et al., 1985). In 1986 at almost all locations sampled between Veerse Meer and Lauwersmeer (Dekker & Van Willigen, 1989).

Present occurrence in The Netherlands.— Common in Dutch eel from fresh and salt waters as well as from eel farms with apparently little effect on fish health (Van Willigen et al., 1987; Dekker & Van Willigen, 1989; Kamstra, 1990). Occurs also in smelt (*Osmerus eperlanus* (Linnaeus, 1758)) (Haenen & Van Banning, 1990). After 1989 the prevalence of the parasite declined (Haenen et al., 1994).

17.13. Crustacea

17.13.1. Cirripedia

Conchoderma auritum (Linnaeus, 1767)

Status in The Netherlands.— Cosmopolitan non-indigenous species, not established.

Vector.— Probably on ships' hulls (Buizer, 1978).

Area of origin.— Cosmopolitan.

Introduction into Atlantic Europe.— Unclear.

Introduction into The Netherlands.— It was found attached to a ship's hull, probably in dry dock, at Delfzijl. Buizer (1978) published an autochthonous record from a buoy N of Terschelling in 1976.

Present occurrence in The Netherlands.— Not present.

Elminius modestus Darwin, 1854

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6, 7), permanently established.

Vector.— Introduced into Europe on ships' hulls (Bishop, 1947). Dispersed in Europe by hull fouling and marine currents (Crisp, 1958).

Area of origin.— New Zealand and southern Australia (Harms, 1999).

Introduction into Atlantic Europe.— First recorded in European waters in 1945 on fouling plates in Chichester harbour in West Sussex, England (Bishop, 1947). Afterwards Stubbings (1950) had data from Chichester Harbour and Portsmouth of 1944 at his disposal and from the size of the collected specimens he concluded that *Elminius* must have occurred in Portsmouth as early as 1943. Crisp (1958) deduces that the species might have settled in Southampton Water, England, in 1939. *E. modestus* is now considered to be a permanent member of the fouling communities from the Shetland Islands down to Portugal (Harms, 1999).

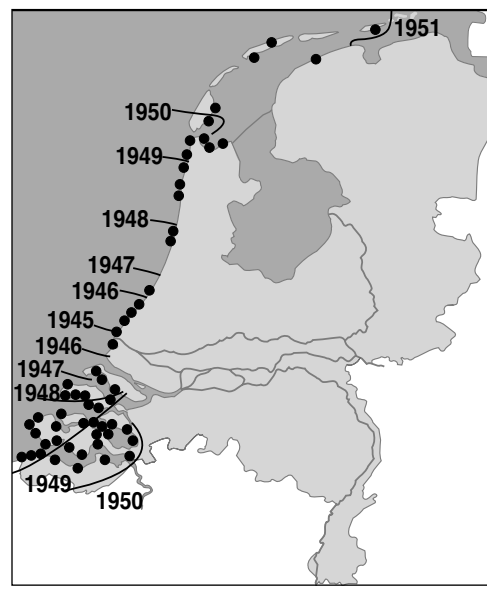

Fig. 23. Expansion of *Elminius modestus* along the Dutch coast. After Den Hartog (1953).

Introduction into The Netherlands.— Boschma (1948) recorded the barnacle from the Dutch coast where it had been found first in 1946. These specimens were found at Wassenaarse slag (unclear on what substrate) and on breakwaters at Loosduinen-Kijkduin in autumn 1946 (Den Hartog, 1953). It is probable that *Elminius* first settled at the Hook of Hol-

land in 1945 (Den Hartog, 1953). Den Hartog (1953) presents a map (fig. 23) showing that the species had colonised almost the entire Dutch coast by 1951. See also Leenhouts (1948), Stock (1949), Bloklander (1949), and Den Hartog (1953a).

Present occurrence in The Netherlands.— A very common species along the entire coast (Huwae, 1985).

Balanus amphitrite Darwin, 1854

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), permanently established.

Vector.— Probably introduced on ships' hulls (Darwin, 1854; Boschma et al., 1961), but perhaps in ballast water.

Area of origin.— This barnacle is of tropical origin. On the basis of fossil records, it is considered to be native to the south-western Pacific and Indian Oceans, and to have been introduced into the North Pacific and Atlantic Oceans, for which no fossil records exist (Eno et al., 1997). Gollasch (2002) calls it a warm-temperate species of Japan and Korea.

Introduction into Atlantic Europe.— Darwin (1854) already mentioned this species from the Mediterranean and the Portuguese coast. Found in 1914 at La Rochelle, France (Prenant, 1929), and in 1937 in Shoreham Harbour, Essex, England (Bishop, 1950). In 1952 the species was found in the harbour of Ostend and in 1995 on a groyne at Koksijde, Belgium (Kerckhof & Cattrijsse, 2001).

Introduction into The Netherlands.— Boschma et al. (1961) knew the species only from material washed ashore and from ships' hulls. Established specimens were found in a cooling water discharge canal at Vlissingen in 1962, 1965, and 1967 (Borghouts-Biersteker, 1969a). Vaas (1975) mentions that the species was found in the Veerse Meer first in 1970, in 1975 it occurred all over this lake.

Present occurrence in The Netherlands.— Seldom washed ashore on the beach, usually material from ships' hulls (Huwae, 1985). Faasse (1991a) found 2 specimens in the Kanaal door Walcheren near Middelburg in 1990. Faasse (1996) states that the species probably has disappeared from the Kanaal door Walcheren and the Veerse Meer, but records a new observation in the cooling water discharge of the power station at Borssele in 1996. Kerckhof & Cattrijsse (2001) record the species on buoys off the Belgian coast (and close to Dutch waters) in 1997-99 as well as from several localities on the Belgian coast.

Balanus balanus (Linnaeus, 1758)

Perhaps a NE Atlantic non-indigenous species, temporarily established in the Dutch coastal waters. On the other hand this may be an offshore species temporarily extending its range into coastal waters. Observed first by Faasse (1990) near the Schone Waardin, Westerschelde estuary, in 1990. Adema (1994) records that the species occurred on a lot of confiscated mussels from the Oosterschelde estuary suspected to have been introduced illegally from abroad in 1993. Adema believes that the specimens recorded by Faasse (1990) may have been descendants from similarly introduced specimens. It is fairly common in the deeper parts of the North Sea (Huwae, 1985), although not in the southern North Sea (Kerckhof, 2002).

Balanus eburneus Gould, 1841

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), temporarily established.

Vector.— On ships' hulls (Southward & Crisp, 1954).

Area of origin.— Atlantic coast of America from Boston to Rio de Janeiro (Stock, 1995).

Introduction into Atlantic Europe.— According to Southward & Crisp (1954) introduced to several countries by shipping: Spain, France, Mediterranean, Black Sea.

Introduction into The Netherlands.— Stock (1995) records that it was collected, but not recognised, by Maitland, perhaps in the 1890s, on wood, blue mussels (*Mytilus*) and zebra mussels (*Dreissena*) in the IJ inlet near Amsterdam. It was also collected in 1914 from two ferries between Middelburg and Zierikzee (which had never left Dutch waters). A dead specimen was found on a mussel shell dredged from the Middelgronden (between Breezand and Makkum) in the Zuiderzee in 1930. Huwae (1985) knew a specimen from the beach of Terschelling.

Present occurrence in The Netherlands.— No data.

Balanus improvisus Darwin, 1854

Balanus improvisus is considered by many European authors to be an exotic non-indigenous species, although others consider it to be a native species. It is permanently established. If introduced, it arrived on ships' hulls (Darwin, 1854). Kerckhof & Cattrijsse (2001) found this species in archaeological material from Antwerp, Belgium, dating back to the 17th century. However, it was not found in a 9th century excavation at Ostend, Belgium (Kerckhof, 2002). Waardenburg (1827) found this species (as *Balanus ovularis*) in The Netherlands in the North Sea and in very low salinities in the brackish River Rhine near Leiden (Hoek, 1875). The low salinity at the latter locality excludes any other barnacle species presently occurring in The Netherlands. Gislén (1950) gives the first record in the Baltic in 1844 and suggests that this reflects the colonisation of the Baltic. Darwin (1854), in his first description, mentions this species from the coasts of England, Scotland, Belgium(?), Nova Scotia, Santa Cruz in South-Patagonia and Montevideo in La Plata. He mentions a variety *assimilis* from the West Indies, viz. Charlestown (USA), and from Guayaquil, as well as from West-Colombia. Kirchenpauer observed the species in 1858 on buoys in the Elbe estuary, Germany (Nehring & Leuchs, 1999). Münter found it in the Baltic near Greifswald, Germany, in 1867 (Hoek, 1875). Cohen & Carlton (1995) consider it to be a native of the North Atlantic. Grosholz & Ruiz (1996) believe the species to have come from the North West Atlantic, whereas Nehring & Leuchs (1999) write 'Das Ursprungsgebiet liegt wahrscheinlich in subtropisch-gemässigten Gewässern.' Van der Gaag et al. (1999) state that 'The paleontological and historical records show *B. improvisus* may have originated in the Old World (Kolosváry, 1942) and could have spread extensively during the 20th century.' If Kolosváry's (1942) Tertiairy fossil records from Hungary really concern *B. improvisus,* the species may be of Mediterranean or Ponto-Caspian origin. However, according to Gomoiu et al. (2002) and Leppäkoski's (1999) review it colonised the Black Sea in 1844 or 1899 and the Caspian Sea after 1952, pointing to a non-Ponto-Caspian origin. Leppäkoski (1999) believes the species to be of West Atlantic origin. I

conclude that *B. improvisus* is either a European native species or an early immigrant. Gollasch (2002) considers it to be a cryptogenic species.

For The Netherlands Hoek (1875) lists the localities Amstel near Uithoorn and Amsterdam, Zuiderzee near Huissen, North Sea, and Haarlemmervaart near Leiden. He does not mention the possibility that *B. improvisus* is an exotic species. In the 19th and the first part of the 20th century this species occurred in The Netherlands in brackish inland waters and in the brackish former Zuiderzee (Waardenburg, 1827; Hoek, 1875; Groenewegen, 1922). Nowadays it is a common species in The Netherlands in marine, brackish, and sometimes even nearly fresh waters (Holthuis, 1961; Huwae, 1985; Paalvast, 1998; Van der Gaag et al., 1999).

Megabalanus coccopoma (Darwin, 1854)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), not permanently established.

Vector.— On ships' hulls (Kerckhof & Cattrijsse, 2001).

Area of origin.— Tropical eastern Pacific coasts of Central and South America (Kerckhof & Cattrijsse, 2001).

Introduction into Atlantic Europe.— First recorded, probably on a ship's hull, from Le Havre, France, in 1851 (Kerckhof & Cattrijsse, 2001).

Introduction into The Netherlands.— Kerckhof & Cattrijsse (2001) demonstrate that the balanids found by Buizer (1978, 1980) on buoys in the North Sea off the Dutch coast in 1976-77 and identified as *Balanus perforatus* (Buizer, 1978) and later as *Megabalanus tintinnabulum* (Buizer, 1980) in reality are *M. coccopoma.*

Present occurrence in The Netherlands.— No recent finds in Dutch waters. Kerckhof & Cattrijsse (2001), however, found the species in fair numbers on buoys off the Belgian coast, close to Dutch coastal waters, in 1997-98.

Megabalanus tintinnabulum (Linnaeus, 1758)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), not established.

Vector.— On ships' hulls (Holthuis & Heerebout, 1972).

Area of origin.— Tropical seas (Kerckhof, 2002): West Africa, Indo-Pacific.

Introduction into Atlantic Europe.— The Dutch specimens found in 1764 perhaps were the first ones recognised in Europe.

Introduction into The Netherlands.— The first known Dutch specimens were found on a vessel coming from West Africa (St. George d'Elmina in present Ghana) and stranded at Wijk bij Zee on 8.xi.1764 (Holthuis & Heerebout, 1972).

Present occurrence in The Netherlands.— After the record in 1764 recent material frequently has been found washed ashore on Dutch beaches (Holthuis & Heerebout, 1972; Huwae, 1985). Many records of this large barnacle concern material from ships' hulls to be recognised by traces of rust on the bottom part. The material found in 1976-77 on buoys in the North Sea off the Dutch coast and identified as *M. tintinnabulum* (Buizer, 1980a), concerns *M. coccopoma* (Kerckhof & Cattrijsse, 2001). Kerckhof (2002), however, found the present species on buoys off the Belgian coast in 1997-2001.

17.13.2. Copepoda

Acartia tonsa Dana, 1848

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), permanently established.

Vector.— Unknown, possibly ballast water.

Area of origin.— Unknown. Before discovery in Europe known from the Eastern coast of North America and from the Indo-Pacific (Eno et al., 1997).

Introduction into Atlantic Europe.— The first observation was made by Remy (1927) in a brackish canal between Caen, France, and the sea. Brylinski (1981) summarises the European distribution; the species is found in brackish waters between Normandy and the Gulf of Finland.

Introduction into The Netherlands.— *Acartia* was first recorded by Redeke (1934, 1935) as a new Dutch species. Redeke (1934) states that he had seen this species in older plankton samples from the former Zuiderzee taken before 1916 but after 1912.

Present occurrence in The Netherlands.— Wibaut - Isebree Moens (1954) found the species in the IJsselmeer in 1932 and 1933. Bakker (1972) observed it in the Veerse Meer from 1961 up till 1971. Bakker & De Pauw (1975) observed it also in the Westerschelde estuary in 1967-1973. Bakker et al. (1977) again records it from the Veerse Meer, also in 1974. Bakker (1978) mentions it from Lake Grevelingen after 1976.

Eurytemora americana Williams, 1906.

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently established.

Vector.— Unknown.

Area of origin.— East coast of North America (Bakker, 1972).

Introduction into Atlantic Europe.— Gurney (1933) found the species in the Channel near Plymouth and in brackish ponds in Sussex and on the Isle of Wight. Bakker (1978) believed that the Gulf Stream had introduced the species. This is unlikely for a coastal species, however.

Introduction into The Netherlands.— Bakker (1972) first observed the species in the Veerse Meer, but had no information about the way of introduction. Dr. W. Vervoort, a Dutch specialist in copepod taxonomy, did not know this species from The Netherlands. Drs. M.S. Wilson (USA) and J.P. Harding (London) confirmed the identification (C. Bakker, pers. comm.).

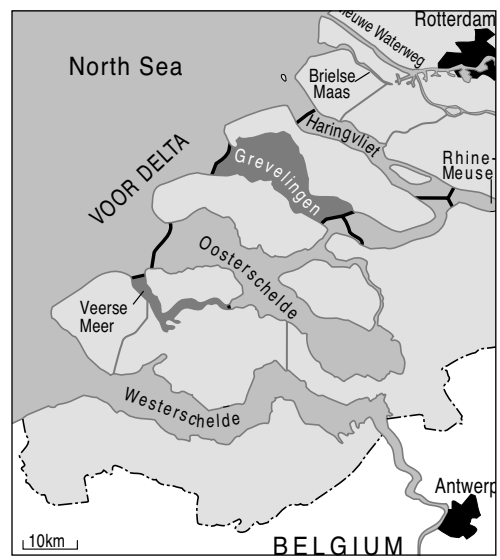

Fig. 24. Distribution of *Eurytemora americana* up to 1988 (Grevelingen, Veerse Meer). After Bakker (1978, in litt.).

Present occurrence in The Netherlands.— *E. americana* was found in the Veerse Meer from 1963 until 1988, and probably also after this year (Bakker, 1972; Bakker & De Pauw, 1975; Bakker et al., 1977; Bakker, 1978, in litt.). Bakker (1978, in litt.) records it from the Grevelingen Lake in 1976 - 1988, and probably also later. Bakker & De Pauw (1975) did not find the species in the Westerschelde estuary (fig. 24).

Myicola ostreae Hoshina & Sugiura, 1953

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 8), unknown if established.

Vector.— This copepod has no doubt been accidentally introduced into Dutch waters with Pacific oysters *Crassostrea gigas* (Stock, 1993).

Area of origin.— Japanese and Korean waters (Stock, 1993).

Introduction into Atlantic Europe.— According to His (1979) Comps (1972) found this species in Portuguese oysters at Marennes-Oléron, France, in 1972. His (1979) records the species also from the Bassin d'Arcachon and the Gironde estuary in France.

Introduction into The Netherlands.— Stock (1993) found this species from May - September 1992 at Schelphoek in the Oosterschelde estuary. This constituted the first record in the North Sea. The actual introduction may have happened many years before, because Stock apparently was the first scientist to investigate Dutch *C. gigas* for parasitic copepods.

Present occurrence in The Netherlands.— No data.

Mytilicola intestinalis Steuer, 1902

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6), permanently established.

Vector.— Introduced with mussels (*Mytilus edulis* Linnaeus, 1758) (Korringa, 1951a).

Area of origin.— Described from the Mediterranean near Trieste in 1902 (Steuer, 1902).

Introduction into Atlantic Europe.— The first record outside the Mediterranean was from the North Sea area (Caspers, 1939; Minchin & Sheehan, 1999). It was found in Germany in 1938 near Cuxhaven and in Ostfriesland, but not in Schleswig-Holstein (Caspers, 1939). In 1950 *Mytilicola* occurred only between Borkum and the Elbe estuary (Korringa, 1951a). Korringa (1951a) supposed that *Mytilicola* had been introduced into the German Wadden Sea in mussels growing on a ship's hull.

Introduction into The Netherlands.— Korringa (1951a) and Stock (1950): First observed in mussels from Zandkreek on 9.ix.1949. In autumn 1949 it was observed also in the Westerschelde estuary, the Oosterschelde estuary and the Grevelingen estuary, but not in the Haringvliet estuary, at the Hook of Holland, at Scheveningen, and in the Wadden Sea. In 1950 it occurred everywhere in Zeeland, but not in the Wadden Sea. Probably it was introduced into the Zandkreek in 1948 from the German Wadden Sea near Borkum with seed mussels. Korringa (1952) found it in the Wadden Sea in 1950 and 1951 only in the Schild, the Spruit, and at Eemswadje, but not in the Eilanderbalg and more to the West. Korringa (1953) records that in the Wadden Sea in 1952 the range expanded to the West to include the Eilanderbalg and the Zoutkamperlaag. Korringa

(1954) recorded no further expansion in the Wadden Sea in 1953. Vaas (1975) stated that *Mytilicola* is a non-indigenous species, which invaded the mussel beds of the Delta area in 1948; he referred to Korringa (1951a).

Present occurrence in The Netherlands.— Common species. Stock (1993) found the species in *Mytilus* from Schelphoek, Oosterschelde estuary, in 1992. In the first years after its introduction *Mytilicola* was considered a serious pest which even necessitated a redesign of mussel culture practices. Nowadays, *Mytilicola* is relatively harmless (Engelsman & Haenen, 2003).

Mytilicola orientalis Mori, 1935

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 8), permanently established.

Vector.— Stock (1993) states that it no doubt was introduced accidentally into Europe with Pacific oysters *Crassostrea gigas.*

Area of origin.— Originally described from Japan; Northwest Pacific (Grosholz & Ruiz, 1996). European material may originate either from Japan or from another introduction into British Columbia, Canada (Holmes, 1995).

Introduction into Atlantic Europe.— His (1977, 1979) records this species from the Bassin d'Arcachon, France, in Pacific oysters *Crassostrea gigas* in 1977.

Introduction into The Netherlands.— Stock (1993, 1993a) writes that 'During an investigation in the summer of 1992 on the large oyster beds of Schelphoek (Oosterschelde estuary, Schouwen), largely consisting of feral specimens of the oriental oyster *Crassostrea gigas*, another *Mytilicola* was found in the gut: *M. orientalis* Mori, 1935.' It occurred also in *Ostrea edulis* and *Mytilus edulis*, but in smaller numbers. The actual introduction may have happened many years before, because Stock apparently was the first scientist to investigate Dutch *C. gigas* for parasitic copepods.

Present occurrence in The Netherlands.— See above.

17.13.3. Mysidacea

Hemimysis anomala G.O. Sars, 1907

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), recently established.

Vector.— Either by natural expansion from the Danube via Main-Danube canal and the river Rhine, probably aided by shipping, or through transport with ballast water from the Baltic or the Black Sea or both (Ketelaars et al., 1999).

Area of origin.— Ponto-Caspian area (Ketelaars et al., 1999).

Introduction into Atlantic Europe.— In 1960 *H. anomala* was successfully transferred from the Dniepr hydropower reservoir to reservoirs in Lithuania. From there it spread into the Baltic Sea, where it was first recorded in 1992 (Ketelaars et al., 1999). In 1997 it was observed in the Rhine and the Neckar in Germany, probably reaching these rivers via the Main-Danube canal (Faasse, 1998a).

Introduction into The Netherlands.— Observed in the oligohaline Noorder IJ plas near the Coentunnel, Amsterdam, in June 1997 (Faasse, 1998). Kelleher et al. (1999)

found the species in stomachs of young fish caught in the river Rhine near Nijmegen in September 1997. Ketelaars et al. (1999) found the species in November 1997 in the Petrusplaat drinking water reservoir in the Biesbosch. In 1998 the species was also found in two other Biesbosch reservoirs and in the Andijk reservoir in North-Holland. In 1997 and 1998 also observed in the river Meuse near the entrance of the Maas-Waalkanaal, in the river Waal near Opijnen, in the Meuse near Keizersveer, and in stomach contents of perch from the Haringvliet (Kelleher et al., 1999).

Present occurrence in The Netherlands.— See above, mostly in freshwater. So far only once observed in brackish water, although it has been found in the vicinity of the Haringvliet sluices in 1998 and 1999 and in the Bathse Spuikanaal in 2000 (M.A. Faasse, pers. comm.).

17.13.4. Isopoda

Limnoria lignorum (Rathke, 1799)

Perhaps an exotic non-indigenous species, because neither the species nor damage caused by this species to wooden constructions was observed before the 19th century. It was described from Scandinavia in 1799, and found in the British Isles in 1811. Nineteenth-century British authors discussed the possible introduction from America, but concluded that *Limnoria* is a British species. In 1868 it was discovered in France (Hubrecht et al., 1893). *Limnoria* has not been mentioned in the references to the Dutch outbreak of the shipworm *Teredo navalis* around 1730 (Holthuis, 1956), nor do Vrolik et al. (1860) mention this species from The Netherlands. However, Hubrecht et al. (1893) make clear that the latter authors had overlooked *Limnoria*. Probably *Limnoria* was observed already in 1834 and 1861-62 in Dutch waters. The first positive observations were made in 1885-86 in the Westerschelde estuary, the Oosterschelde estuary, along the North Sea coast and in the western Wadden Sea (Hubrecht et al., 1893). If introduced, it probably was transported in wooden vessels. It is known from many places around the globe; some authors consider it to be a cosmopolitan species (Holthuis, 1956).

Limnoria quadripunctata Holthuis, 1949

Perhaps an exotic non-indigenous species, not established. Perhaps transported in wooden vessels, but driftwood may be an alternative. Holthuis (1956) considers it to be a cosmopolitan species. It was described from The Netherlands in 1949 from driftwood material washed ashore on the beach (Holthuis, 1956). It occurs also in England, South Africa, New Zealand, and California (Hayward & Ryland, 1995).

17.13.5. Amphipoda

Caprella mutica Schurin, 1935
(Syn. C. macho Platvoet, De Bruyne & Gmelich Meyling, 1995)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently established.

Vector.— Unknown.

Area of origin.— East Asia (W.J.M. Vader, pers. comm.), Sea of Japan (Cohen & Carlton, 1995).

Introduction into Atlantic Europe.— Described from The Netherlands as *Caprella macho*. This species appears to be identical to *C. mutica,* recently also found in West Norway (pers. comm. Dr. W.J.M. Vader).

Introduction into The Netherlands.— Platvoet et al. (1995) described *Caprella macho* as a new species from the entrance of the Oosterschelde estuary, The Netherlands. The species occurred abundantly at this locality already in 1993, 1994 and 1995 (Faasse, 1996a and pers. comm.).

Present occurrence in The Netherlands.— So far only known from the Oosterschelde estuary. Platvoet et al. (1995) knew it from Burghsluis en Neeltje Jans. Faasse (1999) found it in 1996 at Zierikzee (Zeelandbrug), Goesse Sas, Katse Hoek, Kattendijke, and 's-Gravenhoek; in 1997 he mentions Borssele at the Westerschelde estuary and again Zierikzee (Levensstrijd).

Chelicorophium curvispinum (G.O. Sars, 1895)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— Expanded from Ponto-Caspian area through freshwater canals and rivers (Bij de Vaate et al., 2002).

Area of origin.— Ponto-Caspian area (Van der Velde et al., 2000).

Introduction into Atlantic Europe.— *C. curvispinum* has expanded from the Ponto-Caspian area via the rivers Dnjepr, Pripyat, Vistula, Warthe and connecting canals. In 1912 it was found in the Müggelsee near Berlin. The Rhine was reached via the Havel-Spree area, Mittelland Canal and Dortmund-Ems Canal. From there it spread along the whole river and its tributaries (Van der Velde et al., 2000). In Germany it now occurs in the brackish part of the Elbe estuary (Nehring & Leuchs, 1999).

Introduction into The Netherlands.— It was first observed in the freshwater part of the Rhine in 1987 (Van den Brink et al., 1989, 1991).

Present occurrence in The Netherlands.— Van den Brink & Van der Velde (1992) found it in the River Rhine, the River Waal, the River IJssel, the River Lek, the lake IJsselmeer, the lake Markermeer and in connected canals. Van den Brink et al. (1993) found it in the Zaan (according to their fig 1.) in 1991. They also state that 'In the oligohaline parts of the Lower Rhine estuary, the species co-occurred with the related brackish-water species *C. lacustre* Vanhöffen and *C. multisetosum* Stock.' Platvoet & Pinkster (1995) found it in the lakes Brielse Meer, Haringvliet, Hollands Diep, Biesbosch, and Zoommeer and in adjoining rivers in 1992, but not in the southern part of the Delta area. Apparently in The Netherlands the species hardly penetrates into brackish water (Faasse & Van Moorsel, 2000), although Paalvast (1998) records it from the oligohaline Hartelkanaal near Rotterdam.

Gammarus tigrinus Sexton 1939

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— Introduction into Europe perhaps in ballast water (Hynes, 1955). Deliberately introduced into The Netherlands (Nijssen & Stock, 1966).

Area of origin.— Atlantic coast of North America from St. Lawrence estuary to Florida (Nijssen & Stock, 1966; Den Hartog & Van der Velde, 1987).

Introduction into Atlantic Europe.— First observation in Ireland in 1931 (Bassindale, 1946). Hynes (1955) assumes that the English(?) population of *G. tigrinus* has been introduced recently, perhaps with ballast water. Schmitz (1960) states that he introduced the species deliberately into the rivers Weser and Werra in Germany in 1957.

Introduction into The Netherlands.— Nijssen & Stock (1966) record that Dr. C.L. Deelder (Netherlands Institute of Fisheries Research - RIVO) deliberately introduced several tens of animals from Lough Neagh, Northern Ireland, into the IJsselmeer near Enkhuizen on 29.vii.1960. (Deelder him self stated that he believed that the animals had been introduced with ballast water). The species was discovered in the IJsselmeer near Enkhuizen in May 1964 (Nijssen & Stock, 1966). In 1965 *G. tigrinus* occurred all over the IJsselmeer, in the Randmeren and in a large part of the inland waters of North-Holland (Nijssen & Stock, 1966). In 1966 *G. tigrinus* was found in Oost-Flevoland and Friesland (Pinkster & Stock, 1967). Pinkster et al. (1977: this paper summarises also other papers by Dennert et al. (1968) and Gras (1971) documenting the range extension) present the range extension until 1973 (fig. 25). In that year *G. tigrinus* occurs from the Eemskanaal en West-Groningen in the NE Netherlands, via Friesland, Noord-Holland to the northern part of Zuid-Holland and the border areas of the IJsselmeer in Utrecht and Gelderland. Moreover it was found at a few places on the Zuidhollandse eilanden. The authors write that the species inhabits fresh and oligohaline waters but probably the authors used Redeke's classification of brackish waters, meaning that they did not find the species above 1.8 psu.

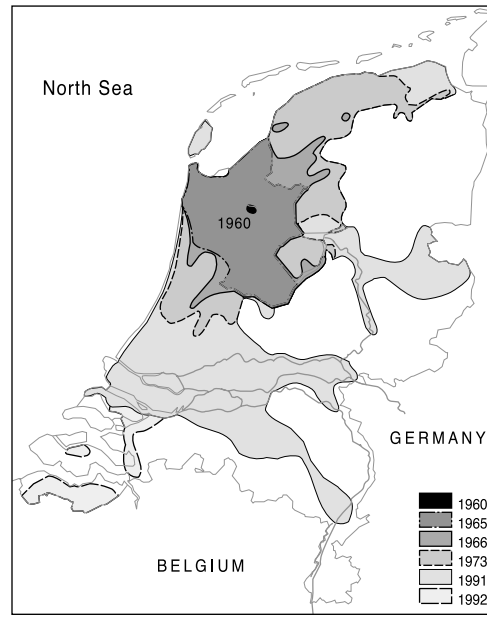

Fig. 25. Range extension of *Gammarus tigrinus* in The Netherlands up to 1995. After Nijssen & Stock (19660, Pinkster & Stock (1967), Pinkster et al. (1977, 1992) and Platvoet & Pinkster (1995).

Present occurrence in The Netherlands.— In addition to the localities cited above (see also Pinkster, 1975; Pinkster et al., 1980; Pinkster & Platvoet, 1983; Platvoet & Pinkster, 1985; Hauters & Pinkster, 1987, and Platvoet et al., 1989), Peeters (1988) found the species to be abundant in the brackish (up to 5 psu) Noordzeekanaal. Pinkster et al. (1992) record the species from non-tidal waters in the entire coastal area of The Netherlands from Goeree-Overflakkee to the Eems-Dollard estuary. It was also found on the Frisian Islands. Platvoet & Pinkster (1995) found the species to be common in the northern part of the Delta area, in the Zoommeer, and further in the Westerschenge, Zuid-

Beveland, and scattered in Zeeuws-Vlaanderen (fig. 25). It penetrated hardly into brackish water (Westerschenge, Braakman). Paalvast (1998), however, records the species from oligohaline conditions in the Hartelkanaal near Rotterdam. Faasse & Van Moorsel (2003) record this species from the mesohaline eastern part of the Westerschelde estuary around 2000.

Incisocalliope aestuarius (Watling & Maurer, 1973)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3 and 5), permanently established.

Vector.— Hull fouling or ballast water (Faasse & Van Moorsel, 2003).

Area of origin.— Estuaries on the Atlantic coast of North America (Delaware-Georgia) (Faasse & Van Moorsel, 2003).

Introduction into Atlantic Europe and The Netherlands.— First European observations (as *Parapleustes assimilis* (G.O. Sars, 1882)) in 1991 in the eastern part of the Westerschelde estuary, The Netherlands (Brummelhuis et al, 1997; Faasse & Van Moorsel, 2003).

Present occurrence in The Netherlands.— Known from Baarland, Hoedekenskerke, Walsoorden, and Bath in the brackish eastern part of the Westerschelde estuary, The Netherlands (Faasse & Van Moorsel, 2003) and from the adjacent Zeeschelde in Belgium (Ysebaert et al., 2000: as *Pleusymtes glaber* (Boeck, 1861)).

Melita nitida Smith, 1873

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), recently established.

Vector.— Either hull fouling or ballast water (Faasse & Van Moorsel, 2003).

Area of origin.— Atlantic coast of North America from Gulf of St. Lawrence to Yucatan peninsula (Cohen & Carlton, 1995; Faasse & Van Moorsel, 2003).

Introduction into Atlantic Europe and The Netherlands.— First European observations in 1998 in the Westerschelde estuary near Bath, The Netherlands (Faasse & Van Moorsel, 2000, 2003).

Present occurrence in The Netherlands.— Also found at Baarland and Walsoorden, Westerschelde estuary (Faasse & Van Moorsel, 2000, 2003) and in the Noordzeekanaal at IJmuiden (Faasse & Ates, 2003; van Moorsel, pers. comm.).

Monocorophium sextonae (Crawford, 1937)

Several authors suggest this to be an exotic non-indigenous species in European and Dutch waters; if so, it is permanently established. It is suggested to have been transported on ships' hulls (Hurley, 1954). Its area of origin is suggested to be New Zealand (Hurley, 1954; Eno et al., 1997), but the only evidence is that it has been found in that country before 1921 (Hurley, 1954), i.e. earlier than elsewhere. Crawford (1937) made the first European observation at Plymouth, England, in 1934. It was also recorded by this author from Wembury, England, and from off the mouth of the Tagus, Portugal, in 1930. Crawford states that its abundance at Plymouth in the 1930s 'is the

more surprising since it is not present in the rich collection of *Corophium* made from the same dredging grounds in 1895-1911. It seems possible, therefore, that it is not indigenous at Plymouth. ... I cannot guess at its original locality.'

In The Netherlands it was found at the inner side of the northern mole at IJmuiden on 11.v.1952 (Stock, 1952). In 1956 it was found at the Uithuizerwad (Stock & De Vos, 1960). It washed ashore on holdfasts of *Himanthalia* between Zandvoort and Noordwijk in September 1953 (Stock, 1994) and on *Buccinum* eggs between Katwijk and Wassenaar in 1960 (Lacourt, 1962). It was abundant in the Pietermankreek, in the Oosterschelde estuary near Yerseke (in 1994?) (Stock, 1994). Faasse & Van Moorsel (2000) found it everywhere on hard substrates in high salinities in Lake Grevelingen, the Oosterschelde estuary, and the entrance of the Westerschelde estuary.

Orchestia cavimana J. Heller, 1865

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— Has possibly expanded along shipping canals from the Mediterranean through France (Kinzelbach, 1972, 1995).

Area of origin.— Probably Ponto-Caspian and East Mediterranean area (Kinzelbach, 1972).

Introduction into Atlantic Europe.— *Orchestia* penetrated from the Mediterranean into France in the 18th century (Kinzelbach, 1995). In 1878 and 1879 it was found in a garden at Zaltbommel, although not close to the Waal river, The Netherlands (Hoek, 1879); it is unclear how it has arrived there. Kinzelbach (1972), referring to Hoek (1879), mentions the location Tiel; this is incorrect.

Introduction into The Netherlands.— *O. cavimana* was recorded first from a garden at Zaltbommel in 1878 (Hoek, 1879).

Present occurrence in The Netherlands.— On the shores of brackish and fresh water, locally abundant (Dekker, 1978).

Platorchestia platensis (Krøyer, 1845)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4); probably established permanently.

Vector.— Dry ballast?

Area of origin.— Described from the La Plata estuary, Argentina, but distributed world-wide (Dahl, 1946).

Introduction into Atlantic Europe.— First recorded from Amrum, Germany, in 1931, but subsequent investigations showed that it did occur in the Sound between Denmark and Sweden in the period 1860-80. In the 1940s it occurred along the Kattegat, the Sound and the western Baltic (Dahl, 1946).

Introduction into The Netherlands.— Stock (1950a) mentioned this species for the first time in his identification guide. In the main paper he states that this species is not known from The Netherlands, but in an annex he mentions *Orchestia platensis* from Wieringen.

Present occurrence in The Netherlands.— Den Hartog (1961) knew the species from De Normert (= Normerven?) and near Den Oever (1959), both at Wieringen, and from Oude Schild at Texel (1960). Den Hartog (1963) only mentions the saltmarsh near Den Oever: with numerous *O. platensis*. The species has not been found in the Delta area (Den Hartog, 1963; Platvoet & Pinkster, 1995).

17.13.6. Decapoda

Callinectes sapidus Rathbun, 1896

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), probably permanently established.

Vector.— Ballast water (Van der Velde et al., 1999).

Area of origin.— Atlantic coast of America from Nova Scotia to Uruguay (Christiansen, 1969).

Introduction into Atlantic Europe.— A live male specimen was found in the harbour of Rochefort, SW France in 1900 (Bouvier, 1901). Den Hartog & Holthuis (1951) recorded a live female in the Zaan in 1932, and another live female in the Entrepothaven, Amsterdam, in 1934.

Introduction into The Netherlands.— The first Dutch specimens were recorded by Den Hartog & Holthuis (1951) who recorded a live female in the Zaan in 1932, and another live female in the Entrepothaven, Amsterdam, in 1934. In addition they mentioned two boiled specimens on the beach near Vlissingen in 1950 (see also Holthuis, 1969). Holthuis (1969) also records a live specimen from Nauerna in 1951 as well as 4 dead specimens washed ashore at Schiermonnikoog in 1967.

Present occurrence in The Netherlands.— Adema (1982) records more boiled animals and parts of animals in 1967, a live specimen 25 miles NW of IJmuiden (1968), four live males from the Westhaven at Terneuzen (1973, twice in 1978 and 1980), and live males from Sluiskil (1980) and Walsoorden-Perkpolder (1980). Adema (1983) found a live female with eggs in the Schaar van de Spijkerplaat, NW of Terneuzen. Ates (1990) writes about a live specimen caught in the western Wadden Sea in December 1989(?) (De Typhoon: 28.xii.1989). Adema (1991) in addition mentions finds from the Noordzeekanaal near Nauerna in 1951 and 1984, at Antwerp, Belgium, in 1981, at IJmuiden and in the Wadden Sea in 1984 and near Axel in 1986. Timmermans & Melchers (1992) record the catch of five specimens in the Noordzeekanaalboezem in the period 1932-1985. No blue crabs were caught during surveys of this canal in 1985-1990. However, between 27.viii.1991 and 28.ix.1992 nine records with 14 animals were made in the Noordzeekanaal. Craeymeersch & Kamermans (1996) mention finds in the Oosterschelde estuary near Zierikzee in September 1995 and near the storm surge barrier in October 1995. Maes et al. (1998) found blue crabs between July 1994 and June 1995 in the cooling water inlet of the power station at Doel, Belgium, on the Westerschelde estuary, just across the Dutch border.

It seems that *Callinectes* occurs permanently in the Westerschelde estuary and adjacent waters as well as in the Noordzeekanaal between Amsterdam and the North Sea. Isolated finds were made in the Oosterschelde estuary and the Wadden Sea.

Eriocheir sinensis H. Milne Edwards, 1854

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6, 7), permanently established.

Vector.— Introduction into Europe in ballast water (Peters & Panning, 1933). Reached the Dutch coastal waters by walking over the river bottom from German rivers towards the estuaries and coastal North Sea for reproduction and subsequent transport of larvae into Dutch estuaries by tidal currents (Kamps, 1937).

Area of origin.— East Asia, from the Street of Taiwan, China, North to Korea (Kamps, 1937; Adema, 1991; Hänfling et al., 2002).

Introduction into Atlantic Europe.— The first European mitten crab was caught in the Aller, a tributary of the Weser, Germany, in 1912 (Peters & Panning, 1933). Hänfling et al. (2002) conclude from mt-DNA sequences that the Central European populations derive from multiple invasions.

Introduction into The Netherlands.— Kamps (1937) describes and reconstructs the introduction of this species in The Netherlands. In 1929 and 1930, mitten crabs were caught by German fishermen in the Ems-Dollard estuary. In 1930 a specimen was caught inside the sluices at Termunterzijl. In 1931 the first observation was recorded by the scientific world (Redeke, 1932; Jippes & Kamps, 1932). In 1931-32 the species was found everywhere in the area discharging towards the Lauwerszee (Kamps, 1937). The western part of Friesland was colonised in 1932. In 1931 single mitten crabs were caught also at Zaandam, Brielse Maas, Reeuwijkse plassen and Rotterdam. In 1935-36 the first specimens were caught in the Zeeland estuaries. Finally, in 1935 the Chinese mitten crab was present in almost any suitable part of The Netherlands (fig. 26).

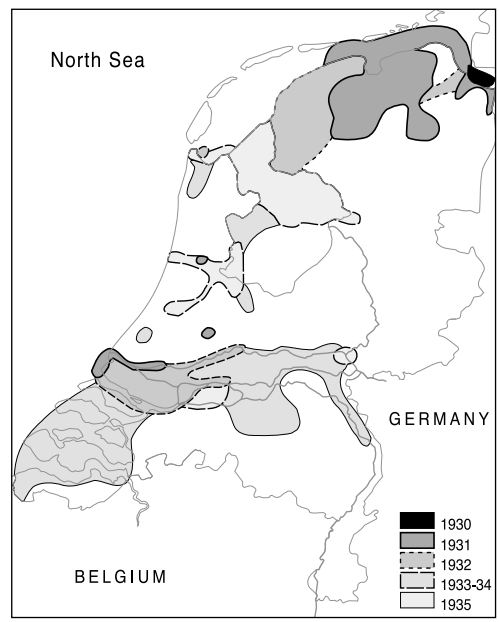

Fig. 26. Range extension of *Eriocheir sinensis* in the period 1930-1935. After Kamps (1937).

Present occurrence in The Netherlands.— Abundant species, especially in the coastal areas (Kamps, 1937; Wolff & Sandee, 1971; Adema, 1980, 1991).

Hemigrapsus penicillatus (De Haan, 1835)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), recently established.

Vector.— Introduced into Europe in ballast water or in hull fouling (Gollasch, 1999). Possibly introduced into The Netherlands with oyster imports (Anonymous, 2000).

Area of origin.— Northwestern Pacific from Sakhalin to Taiwan (Gollasch, 1999,

2002; d'Udekem d'Acoz & Faasse, 2002).

Introduction into Atlantic Europe.— Collected from the hull of a Japanese vessel at Bremerhaven, Germany, in August 1993. First observed on the shore in Charente Maritime near La Rochelle, France, in 1994 (Noël et al., 1997), where it was probably introduced in 1993 (Gollasch, 1999). In 1996 the species ranged already from South of the Loire estuary into northern Spain near Laredo (Noël et al., 1997).

Introduction into The Netherlands. — First observed at Sas van Goes, Oosterschelde estuary, on 19.iii.2000; 18 specimens were collected at the same locality in April 2000. Probably it had established itself in 1999 (Anonymous, 2000; Nijland & Beekman, 2000). In 2000 it was also observed in the Oosterschelde estuary at Yerseke, Wemeldinge, Sas van Goes, Katse Hoek, and perhaps Colijnsplaat (Nijland, 2000; Faasse et al., 2002). In 2001 it was observed in the larger part of the Oosterschelde estuary as well as at two locations in the Westerschelde estuary (fig. 27) (Faasse et al., 2002). In 2002 more localities in the Oosterschelde estuary were colonised and in the Westerschelde estuary the species penetrated further landinward (d'Udekem d'Acoz & Faasse, 2002).

Present occurrence in The Netherlands.— So far known from the Oosterschelde estuary as well as the Westerschelde estuary (Nijland, 2000, 2001; Faasse et al., 2002; d'Udekem d'Acoz & Faasse, 2002).

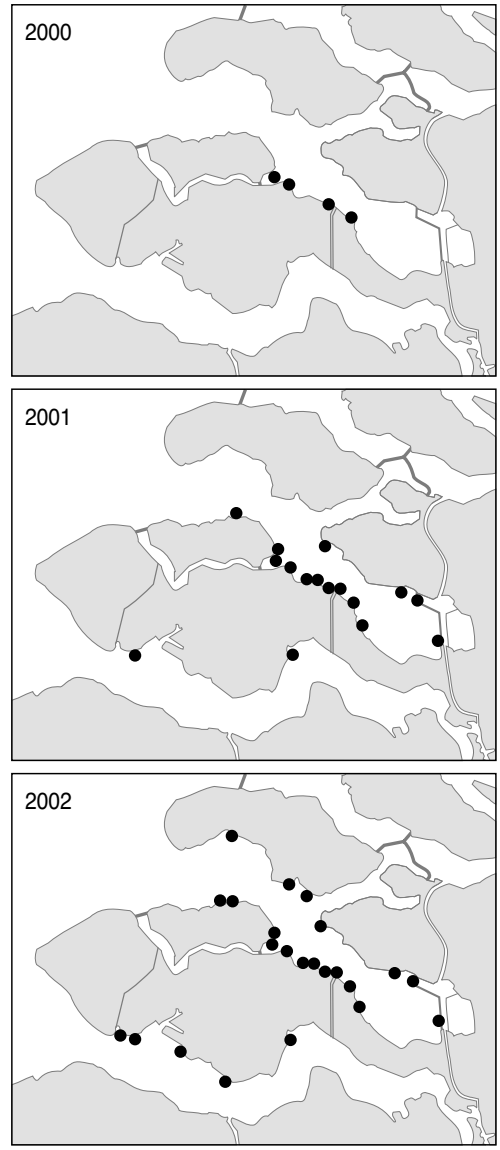

Fig. 27. Distribution of *Hemigrapsus penicillatus* in 2000 (top), 2001, and 2002 (bottom). After Faasse et al. (2002) and d'Udekem d'Acoz & Faasse (2002).

Hemigrapsus sanguineus
(De Haan, 1835)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), recently established.

Vector.— Probably introduced into Europe in ballast water (Breton et al., 2002). It

is unknown how it has been introduced into The Netherlands.

Area of origin.— Northwestern Pacific from Sakhalin to Taiwan (Breton et al., 2002, d'Udekem d'Acoz & Faasse, 2002).

Introduction into Atlantic Europe.— Collected at about the same time at Le Havre, France (29.viii.1999) and at Schelphoek, Oosterschelde estuary, The Netherlands (21. viii.1999). The animals at Le Havre must have settled in 1998 or earlier since the local population was adult and breeding (Breton et al., 2002).

Introduction into The Netherlands.— See above.

Present occurrence in The Netherlands.— Known from Schelphoek in the Oosterschelde estuary in 1999 (Breton et al., 2002) and from the mole at Hoek van Holland in 2003 and 2004 (Campbell & Nijland, 2004)

Palinurus elephas (Fabricius, 1787)

Status in The Netherlands.— NE Atlantic non-indigenous species, not established.

Vector.— Perhaps introduced in ship hull fouling (Holthuis, 1950); deliberately introduced (Heerebout, 2001).

Area of origin.— Atlantic coast of Europe from the British Isles southward (Holthuis, 1950).

Introduction into The Netherlands.— Holthuis (1950) draws attention to an observation by Slabber of a large decapod before 1769 which may have been *P. elephas*. The animal was found in the fouling of an East-Indiaman. Heerebout (2001) records the deliberate introduction of two specimens in the Oosterschelde estuary around 1910 and the subsequent catch of one specimen elsewhere in the same estuary in 1927.

Present occurrence in The Netherlands.— Not present.

Rhithropanopeus harrisii (Gould, 1841)
(Syn. Pilumnus tridentatus Maitland, 1874)

Status in The Netherlands.— Exotic non-indigenous species (criteria 2, 3, 4), permanently established.

Vector.— Unknown, but probably not in ballast water, because it was already common in the Zuiderzee in 1874 (Adema, 1991).

Area of origin.— Atlantic coast of America from New Brunswick to NE Brazil (Christiansen, 1969; Eno et al., 1997).

Introduction into Atlantic Europe and The Netherlands.— Maitland (1874) described this species from the Zuiderzee as *Pilumnus tridentatus*. At that time the species already was common in the 'Kom' of the Zuiderzee and in the IJ inlet (Adema, 1991). Buitendijk & Holthuis (1949) concluded that *Pilumnus tridentatus* is identical to *Rhithropanopeus harrisii*. After a population peak in 1933-36, occurring in the Zuiderzee after its closure, the species was found also elsewhere in Europe.

Present occurrence in The Netherlands.— Tesch (1922) recorded this species (as *Heteropanope tridentatus*) from the entire Zuiderzee, and also from Bovensluis in the Hollands Diep, the Amstel near Uithoorn and the Noord-Hollands Kanaal. Holthuis (1954) concluded that the record from Bovensluis in the Hollands Diep could not be trusted. He stated that the species increased strongly after the closure of the Zuiderzee

until a peak was reached in 1933-36. The last find in the IJsselmeer was in 1943. In the Noordzeekanaal it occurred until 1951, near Den Helder from 1948-50 and in the 1930s it lived also in Friesland and Groningen. Wolff & Sandee (1971) mention four observations from the Haringvliet - Hollands Diep area. Huwae (1977) and Jansens (1977) found the species in 1977 in the Veerse Meer near Kortgene, near Vrouwenpolder and near the Veerse-Gat dam. They mention other observations after 1950 from Niezijl, Dokkumer Ee, Den Helder (twice), in the Noordzeekanaal (twice), near Willemstad in the Hollands Diep and in the Haringvliet. Jansens (1977a) found the species to be common in the western part of the Veerse Meer in August-October 1977. Adema (1980, 1981) mentions Veerse Meer (1977, 1979, 1980) and Noordzeekanaal (early 1950s, 1952, 1980). Peeters (1988) found the species abundantly in the Noordzeekanaal. Adema (1991) presents a map of all records as well as of all records after 1960 (Noordzeekanaal, Nieuwe Waterweg, Haringvliet, Veerse Meer, Waal near Nijmegen, Schelde near Antwerp, Belgium). It was found in the River Rhine upstream until at least Rees in Germany (Van der Velde et al., 2000). Faasse (1991a) found *R. harrisii* in the Kanaal door Walcheren near Middelburg and near Arnemuiden in 1991. It was found at Bath in the Westerschelde estuary in 1998 (M.A. Faasse, pers. comm.; Faasse & Van Moorsel, 2003). The latter find should be connected to the occurrence just across the Dutch border in the Belgian Zeeschelde and adjacent waters from 1985 onwards (Maes et al., 1998; Ysebaert et al., 2000; Wouters, 2002).

17.14. Arachnida: Xiphosura

Limulus polyphemus (Linnaeus, 1758)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), not established.

Vector.— Deliberately introduced for commercial purposes (Lloyd, 1874).

Area of origin.— Atlantic coast of North America from Nova Scotia to Yucatan (Holthuis, 1950).

Introduction into Atlantic Europe.— In the 1860s the firm Hagenbeck imported an unknown number of horseshoe crabs into Germany for the aquarium trade. Because not all animals could be sold the remainder was liberated near Helgoland, Germany, in 1866 (Lloyd, 1874; Holthuis, 1950).

Introduction into The Netherlands.— Fishermen caught 4 or 5 live animals in the North Sea about 11 km off Terschelling in 1873 (Holthuis, 1950; Wolff, 1977; Nehring & Leuchs, 1999).

Present occurrence in The Netherlands.— Not present.

17.15. Mollusca

17.15.1. Polyplacophora

Lepidopleurus cancellatus (Sowerby, 1839)

Perhaps a NE Atlantic non-indigenous species, not permanently established. Van Benthem Jutting & Engel (1936) state that H.F. Nierstrasz found this species once in

Dutch waters in the Oosterschelde estuary near Yerseke in July 1897. All further records refer to these specimens, three of which are kept in the Zoological Museum at Amsterdam. This single find at Yerseke, the centre of the Dutch shellfish cultures, suggests an introduction with oysters. It is a European species which has been dredged also in the southern North Sea (Kaas, 1952).

17.15.2. Gastropoda

Calliostoma zizyphinum (Linneaus, 1758)

Status in The Netherlands.— Recently established. Unclear if this is a natural range extension of a NE Atlantic species, or that this represents a human-aided introduction.

Vector.— Perhaps introduced with oysters (Van Bragt, 2003).

Area of origin.— Atlantic coasts of Europe, from Norway to the Mediterranean.

Introduction into The Netherlands.— First observation at Sas van Goes, Oosterschelde estuary, in 2001. Another 3 records in the same estuary in 2003 (Van Bragt, 2003; http://www.anemoon.org/spuisluis).

Present occurrence in The Netherlands.— Occurs only in Oosterschelde estuary (Van Bragt, 2003).

Calyptraea chinensis (Linnaeus, 1758)

Status in The Netherlands.— NE Atlantic non-indigenous species, temporarily established.

Vector.— Introduced with oysters (Kaas & Ten Broek, 1942).

Area of origin.— Atlantic coast of Europe.

Introduction into The Netherlands.— Kaas & Ten Broek (1942) record 'A few times found in Zeeland. Probably imported with French oysters.'

Present occurrence in The Netherlands.— Not present.

Corambe obscura (Verrill, 1870)
(Syn. Corambe batava Kerbert, 1886)

Status in The Netherlands.— Exotic non-indigenous species (criteria 2, 3), temporarily established.

Vector.— Unknown.

Area of origin.— Atlantic coast of USA. Found also in Brazil (Swennen & Dekker, 1987).

Introduction into Atlantic Europe.— First European finds in the Zuiderzee, The Netherlands, in 1879 and 1881, described by Kerbert (1886) as *Corambe batava*.

Introduction into The Netherlands.— Discovered by Dr. C. Kerbert in the Zuiderzee near Durgerdam in November 1879 and August 1881; in 1886 described by him as *C. batava*. Van Benthem Jutting & Engel (1936) and Swennen (1957) do not mention that this is possibly a non-indigenous species. Butot (1984) suspected that *C. batava* is a non-indigenous species. Swennen & Dekker (1995) describe at length that the animals belong to *C. obscura*, which has been introduced from the Atlantic coast of America.

Present occurrence in The Netherlands.— Van Benthem Jutting (1922, 1936), Van Benthem Jutting & Engel (1936), Swennen (1957), Butot (1984) and Swennen & Dekker (1987) record that *C. obscura* used to be common in the former Zuiderzee from spring to autumn. It also occurred in the western Wadden Sea near Den Helder, Wieringen and Texel. A later find in a ditch at Texel in 1947 (Butot, 1984) proved to be erroneous (Kuijper, 2000). Swennen & Dekker (1995) explain that *C. batava* is a junior synonym of *C. obscura*; they consider *C. batava* to be an exotic non-indigenous species.

It was a common species in the brackish Zuiderzee and the western Wadden Sea, but it has never been found in the NE- or SW-Netherlands. After the closure of the Zuiderzee in 1932 *C. obscura* has disappeared; it has never been found again and it is probably extinct in The Netherlands (see also Butot, 1984).

Crepidula fornicata (Linnaeus, 1758)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 7), permanently established.

Vector.— Imported into Europe with American oysters (Van Benthem Jutting, 1933; Eno et al., 1997). Korringa (1942) makes probable that *Crepidula* reached the Dutch coast with drifting material.

Area of origin.— Atlantic coast of North America from Nova Scotia to Gulf of Mexico (Nehring & Leuchs, 1999).

Introduction into Atlantic Europe.— The first known occurrence in Europe was in 1872 in Liverpool Bay, England, but the populations in this area have since died out (Eno et al., 1997). Known to have been introduced into Essex, England, between 1887 and 1890 from North America (Korringa, 1942; Eno et al., 1997). Dupont et al. (2003) conclude from molecular genetic data that the French populations of *Crepidula,* established after 1940, derive from several genetically diverse source populations, either in Europe or in North America.

Introduction into The Netherlands.— Live specimens have been found at the Belgian coast in 1911 (Nehring & Leuchs, 1999). Oorthuys (1924) records empty shells attached to seaweed washed ashore on the beach near Bergen (NH) in 1924. Van Benthem Jutting (1933) mentions that first only empty shells have been found at Bergen (NH), Schoorl, Zandvoort, Katwijk and in the Grevelingen estuary. First live specimens were collected on a large piece of wreckage washed ashore at Zandvoort in October 1926 (Korringa, 1942). Living specimens occurred in May 1929 at the Bol van Lodijke in the Oosterschelde estuary (Van Benthem Jutting, 1933; Korringa, 1942). Next year hundreds were found and 'at this moment (1932?) it is a very common animal in the Zeeland estuaries' (Van Benthem Jutting, 1933). In 1941 4 million kg of *Crepidula* from the Oosterschelde estuary were processed for human food (Korringa, 1942). In the Wadden Sea introduced with oysters from Zeeland (Korringa, 1942).

Present occurrence in The Netherlands.— Common species, especially in Zeeland (Van Benthem Jutting, 1933; Kaas & ten Broek, 1942; Korringa, 1942; Wolff, 1973; De Bruyne, 1994). Also in Calandkanaal, Beerkanaal and adjacent harbour basins near Rotterdam (Paalvast, 1998).

Gibbula cineraria (Linnaeus, 1758)

Status in The Netherlands.— NE Atlantic non-indigenous species, recently established.

Vector.— Probably introduced with oysters (De Bruyne, 1994; Wolff, 2000).

Area of origin.— Atlantic coasts of Europe, from north Norway to Gibraltar.

Introduction into The Netherlands.— In the 1980s found alive twice in the Oosterschelde estuary near Yerseke (M. Faasse, pers. comm.; De Bruyne, 1994). Observed in the Oosterschelde estuary in 1994, found again in 1998, and common in 1999 (Moolenbeek, 1999; Wolff, 2000). Also found there in 2000 (Moolenbeek, 2000; R. Nijland, pers. comm.).

Present occurrence in The Netherlands.— Occurs only in Oosterschelde estuary (Wolff, 2000).

Heleobia stagnorum (Gmelin, 1791)

Wolff (1999) suggests, on account of its restricted geographical distribution, that *H. stagnorum* might be a non-indigenous species. This is apparently incorrect since Bank & Butot (1984) mention fossil records from Great Britain, The Netherlands and Germany. Gittenberger & Janssen (1998) record fossil occurrence in The Netherlands in warm periods in the Eemien and the Holocene.

Ocenebra erinacea (Linnaeus, 1758)

This species has been suggested to be a non-indigenous, not established NE Atlantic species. However, there are no data supporting this suggestion. Van Benthem Jutting (1943), basing herself on Hoek (1882, 1902), records that this species has been introduced with French oysters to the 'Herkingse banken' near Bruinisse in about 1880, but that it did not establish itself. However, Hoek (1882, 1902) himself writes that he could not find the species at Herkingen.

Potamopyrgus antipodarum (Gray, 1843)
(Syn. Hydrobia jenkinsi Smith, 1889)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently introduced.

Vector.— Introduced into England in drinking water barrels in ships from Australia (Eno et al. (1997). Unclear how it reached The Netherlands.

Area of origin.— The species originates from New Zealand from whence it was introduced into Australia (Ponder, 1988).

Introduction into Atlantic Europe.— Probably introduced as early as 1859. In Europe Smith (1889) was first to recognise it (as *Hydrobia jenkinsi*) from the Thames estuary.

Introduction into The Netherlands.— Scholten (1913) made the first Dutch find in a ditch near Amsterdam in 1913 (as *Hydrobia jenkinsi* Smith, 1889) but there is no indication about the real time of introduction. Van Benthem Jutting (1922) mentions this species (as *Hydrobia jenkinsi*) from the Zuiderzee near Blankenham. Nehring & Leuchs

(1999) state that this species was introduced into The Netherlands in 1890; they base this erroneous record on Van Benthem Jutting (1922) and Thienemann (1950).

Present occurrence in The Netherlands.— Common in a large part of The Netherlands (Van Benthem Jutting, 1933; Kaas & Ten Broek, 1942; Gittenberger & Janssen, 1998). It occurs mainly in fresh to slightly brackish non-tidal waters.

17.15.3. Bivalvia

Anomia ephippium Linnaeus, 1758

Status in The Netherlands.— NE Atlantic non-indigenous species, temporarily established.

Vector.— Introduced with oysters (Korringa, 1948, 1951).

Area of origin.— Atlantic coasts of Great Britain and France.

Introduction into The Netherlands.— Van Benthem Jutting (1936a), Kaas & Ten Broek (1942), and Van Benthem Jutting (1943) record the introduction of this species into the Oosterschelde estuary with French oysters (*Ostrea edulis*) since 1935. Korringa (1948, 1951): 'Attached to French oysters *Anomia ephippium*, known among the Dutch oystermen as the French slippers, has been introduced into Dutch waters. It does not thrive there as a rule and its reproduction is exceptional. In December 1937 I found a young specimen attached to a Dutch tile collector. After the warm summer of 1947 young specimens ..... could be found in fair numbers on mussel shells broadcast on the plots as collectors. I do not believe that the hydrographical conditions prevailing in the Oosterschelde suit *A. ephippium*.'

Present occurrence in The Netherlands.— Not present.

Corbicula fluminalis (Müller, 1774) and **C. fluminea** (Müller, 1774)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently established.

Vector.— Ballast water? (Gittenberger & Janssen, 1998).

Area of origin.— According to Kinzelbach (1991) *Corbicula* originated from SE-Anatolia and further East. However, Gittenberger & Janssen (1998) state that Kinzelbach (l.c.) confounded the various species; *C. fluminalis* should originate from SE-Asia, *C. fluminea* from southern Russia to Indonesia.

Introduction into Atlantic Europe.— Mouthon (1981) records the presence of *Corbicula* in the river Dordogne in western France and in the Tagus in Portugal in 1980. In 1984 *C. fluminalis* has been observed in the Unterweser, Germany, from the oligohaline area up river (Kinzelbach, 1991).

Introduction into The Netherlands.— Blanken (1990) records a *Corbicula* from the River Lek near Bergambacht. This is followed by numerous publications on new finds in which three different species of *Corbicula* are recorded (e.g., Bij de Vaate & Greijdanus-Klaas, 1990; Gittenberger & Van Peursen, 1992). Gittenberger & Janssen (1998), however, state that only *C. fluminea* and *C. fluminalis* occur in The Netherlands; they present distribution maps of both species with, among others, finds in the tidal freshwater of the Oude Maas. Although both species are known to tolerate higher salinities, finds in

brackish water only recently have been made (Oosterbaan, 2002).

Present occurrence in The Netherlands.— Gittenberger & Janssen (1998) present distribution maps of *C. fluminalis* and *C. fluminea* in The Netherlands with, among others, finds in the Oude Maas. Oosterbaan (2002) records *C. fluminea* from the oligohaline Hartelkanaal.

Crassostrea 'angulata' (Lamarck, 1819)

Remark.— *Crassostrea angulata* (Lamarck, 1819) has been shown to be the same species as *C. gigas* (Thunberg, 1793) (Ranson, 1948; Menzel, 1974; Boudry et al., 1998). However, due to its differing introduction history *C. 'angulata'* is treated separately.

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7, 10), not permanently established.

Vector.— Introduction into Portugal probably on ships' hulls; from Portugal deliberately introduced into The Netherlands (Wolff & Reise, 2002).

Area of origin.— Introduced into Portugal from Taiwan (Boudry et al., 1998), but in other European countries the species has been imported for cultivation from Portugal for many years ('Portuguese oyster').

Introduction into Atlantic Europe.— From Lamarck's description in 1819 follows that the species occurred in Europe at that time. Ranson (1948), Menzel (1974), Eno et al. (1997) en Boudry et al. (1998) consider *C. 'angulata'* to be identical to *Crassostrea gigas* (Thunberg, 1793). However, O'Foighil et al. (1998) consider *C. 'angulata'* to be closely related, but not identical to Japanese *C. gigas*. Nevertheless, they consider *C. 'angulata'* to be an introduction from Asia. This supports the conclusion of Boudry et al. (1998) that *C. 'angulata'* has been introduced from Taiwan.

Introduction into The Netherlands.— The species has been deliberately introduced several times into the Zeeland estuaries, but did not establish itself (Van Benthem Jutting, 1937, 1943; Kaas & Ten Broek, 1942; Korringa, 1965; Wolff & Reise, 2002). The first autochthonous individual was found in 1928 attached to a *Cerastoderma* shell, i.e. it had been born in Dutch waters. After 1936 the species was regularly imported with French *Ostrea edulis* Linnaeus, 1758. In 1947 Portuguese oysters were introduced deliberately from Brittany. In 1961-62 direct import from Portugal was registered (Korringa, 1965).

Present occurrence in The Netherlands.— Kaas & Ten Broek (1942) state that it was found a few times at Yerseke, probably imported with French oysters. Moerdijk (1986), however, records that 'It is my impression that *C. 'angulata'* has disappeared from Dutch waters at the end of the 1960s.' Boudry et al. (1998) state that between 1967 and 1972 *C. 'angulata'* has disappeared from France because of a disease. Drinkwaard (1999a) writes that 'In 1980 it was reported that virtually no *C. 'angulata'* oysters were left in Dutch waters.'

Crassostrea gigas (Thunberg, 1793)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6, 7), permanently established.

Vector.— Deliberately introduced (Drinkwaard, 1999a; Wolff & Reise, 2002).

Area of origin.— Japan and SE-Asia (Eno et al. (1997).

Introduction into Atlantic Europe.— Originally *C. gigas* was introduced into Portugal as *C. 'angulata'* (see above). Much later, *C. gigas* was deliberately introduced from the Pacific coast of the USA and Canada as well as from Japan into France (1966), the UK (1965), and The Netherlands (1964) (Ranson, 1948; Menzel, 1974; Walne & Helm, 1979; Grizel & Héral, 1991; Eno et al., 1997; Boudry et al., 1998; Drinkwaard, 1999, 1999a; Wolff & Reise, 2002; Goulletquer et al., 2002). See also O'Foighil et al. (1998).

Introduction into The Netherlands.— According to Dijkema (1997) Dutch oyster growers imported small amounts of 10 mm spat of the Kumamoto and the Myagi strains from Japan in 1964. Drinkwaard (1999a), however, writes: 'In 1964 a Dutch oyster farmer imported spat of the Pacific oyster from British Columbia.' He continues 'After the winter of 1964/1965, the oysters were ... brought to an oyster culture plot on the Yerseke Bank...' 'On this plot the growth was followed to the end of 1965, when the oysters were raked from the bottom.' 'In 1966 experiments were also carried out with the Japanese strain from the Hiroshima area, but nearly nothing is reported about the introduced quantities. In covert terms the incoming assignments of Japanese spat were 'fair' and showed a remarkable growth.' 'In the case of the Dutch *C. gigas* importations, it was not predicted that offspring were to be expected. In 1966 the oyster farmers were informed that the introduction of the Pacific oyster as seed stock was acceptable since these oysters could not reproduce at the latitude of the Dutch coastal waters.' 'Early in the 1970s, the Dutch oyster farmers were growing cupped oysters of the genus *Crassostrea* to a limited extent. These must have been of Portuguese, Japanese or mixed origin.' 'The Dutch did not expect a spatfall in their own waters. However, in 1975 this happened during a very warm summer.... The real breakthrough came with the spawning again in 1976.' '... in 1976 spat settlement on jetties and stone-covered dike-feet was obvious enough. In an official report it was concluded that 'Perhaps measures are necessary to nip this spatfall in the bud!' Political pressure stopped the importation of *C. gigas* in the following year.' 'At that time 20-30 million so-called weed oysters was the estimate. The hand-picking of oysters along the dikes was decontrolled to reduce the cupped oysters.' 'After arrival of the already ordered spat from Japan and the United States, these importations came to an end in 1977.' 'For 1979 it is reported that marketable *C. gigas* oysters were imported 'largely' from France and Belgium.' '... in 1981 the littoral zone outside the culture plots was opened to the public fishery. However, the thinking changed in 1982 with a new natural larval outburst with up to 50 cupped oyster larvae per 100 liters of Oosterschelde estuary water as against 5 *O. edulis* larvae. From that time on the new 'creuses' were accepted as belonging to the fauna of The Netherlands and the commercializing of the Dutch cupped oyster stock could really start.'

Drinkwaard (1999a) presents a graph of the production of *C. gigas* in the Oosterschelde estuary from 1976 to 1996. In 1987 settlement of Pacific oysters occurred in Lake Grevelingen. Drinkwaard (1999a) also states that 'In the Dutch Wadden Sea, only medium sized and somewhat larger cupped oysters were reported by Dutch mussel farmers who were relaying imported mussels from the Danish and northern German Wadden Sea. Transport of mussels from the Oosterschelde estuary to the Dutch Wadden Sea occurred during a short period before 1980 (Bruins, 1983) too.' 'Settlement of *C. gigas* in littoral locations of the Westerschelde estuary (sporadic during the 1980s, but increasing

during the beginning of the 1990s) may either be due to spreading from the Oosterschelde, or to the experimental nursery rearing along the sluice dock of Ostend.'

Present occurrence in The Netherlands.— Bruins (1983) recorded *C. gigas* in the cooling water basins of the Texel power station at Oudeschild and along the Wadden Sea dike at Oudeschild in August 1983. The specimens in the cooling water basins perhaps were 6-7 years old. Later, finds were reported from March 1982. However, at the nearby Shellfish Experimental Station of RIVO (National Institute for Fisheries Research) at 't Horntje, Texel, experiments with oysters were carried out from 1976 to 1978; in the first year *C. gigas* was involved as well. Dankers et al. (2004) record a Pacific oyster found at West-Terschelling in 1989. In 1995 oysters of 2-3 years age were found in the Mok Bay, Texel, and in 1997 the first oyster was observed at the Vlakte van Kerken near Texel (Dankers et al., 2004). Tydeman (1999) found thousands of specimens (2nd year animals) in the Eemshaven in October 1998. He also refers to finds of live Pacific oysters at Lauwersoog in 1998 (Nieuwe Dockumer Krant, 17 Sept. 1998), at Ameland in 1995 and at Vlieland in 1997. It is said that Pacific oysters occurred at Schiermonnikoog in 1998, perhaps in sufficient numbers to be fished. Specimens at Eemshaven in 1999 had a maximum length of about 60 mm, suggesting an age of about 4 years (Anonymous, 2000). In April 2000 young specimens were observed at Eemshaven, Hoog Watum and Termunterzijl (here also older specimens) along the Ems estuary (Wolff, unpubl. observ.). In April 2001 they occurred further landward in the same estuary at Punt van Reide and Geisedam (Tydeman et al., 2002). In October 2000 specimens occurred at the Schiermonnikoog tidal flats (J.G. Hiddink, pers. comm.). Cadée (2000a) describes occurrence in the entire Dutch Wadden Sea. Wehrmann et al. (2000) record finds in the adjacent East-Frisian Wadden Sea, Germany, with the oldest specimens probably dating from 1996. Dankers et al. (2004) summarise the distribution of the Pacific oyster in the Wadden Sea in 2003; the species occurs in the entire area and starts to develop reefs.

Along the North Sea coast specimens were found at the Hook of Holland in 1983, in 1995 live specimens at Katwijk-Noordwijk, but in 2000 the species was not yet known from the Hondsbossche Zeewering (Cadée, 2000a).

Hoeksema (1983) recorded five live specimens found in the Oosterschelde estuary near Zierikzee. Moerdijk (1986) states that the species 'felt very well at home in the Oosterschelde estuary; in no-time the entire estuary had been colonized.' This concerned several tens of millions of young oysters. Heinis et al. (1995) recorded that *C. gigas* in 1989 was established at four out of five investigated locations in the Oosterschelde estuary. Strong expansion occurred in the period 1989-1993, perhaps also due to the warm summers of 1989 and 1992 (fig. 28). In 1994 more than 2000 tons of oysters were produced in the Oosterschelde estuary (Drinkwaard, 1999a).

Around 2000 it was observed in increasing numbers in the Westerschelde estuary at Borssele, Ellewoutsdijk, Baarland, 's-Gravenpolder, and Bath (M.A. Faasse, pers. comm.; Faasse & Van Moorsel, 2003). Ysebaert et al. (2000) record this species (as *Crassostrea angulata* Lamarck, 1819, and *Ostrea* sp.) already in 1997 from the Belgian part of the Westerschelde estuary.

Also in Calandkanaal, Beerkanaal, and adjacent harbour basins near Rotterdam (Paalvast, 1998).

Fig. 28. Bed of Pacific oysters (*Crassostrea gigas*) in the Zandkreek in the Oosterschelde estuary, September 2004. Photograph courtesy Drs. K. Troost.

Crassostrea virginica (Gmelin, 1791)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), not established.

Vector.— Deliberately introduced (Wolff & Reise, 2002).

Area of origin.— Atlantic coast of North America (Miller, 2000; Wolff & Reise, 2002).

Introduction into Atlantic Europe.— First imported in Baie d'Arcachon, France, in 1861 (Goulletquer et al., 2002). Imported in England in 1871 (Miller, 2000) or around 1880 (Eno et al., 1997) (but *Crepidula* which probably arrived together with this oyster was already found in 1872!).

Introduction into The Netherlands.— Van Benthem Jutting (1943): 'via English oyster beds imported from the USA and Canada in several years.' Not established; it has disappeared after a few years (Wolff & Reise, 2002).

Present occurrence in The Netherlands.— Not present.

Dreissena polymorpha (Pallas, 1771)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 4, 6, 11), permanently established.

Vector.— Natural expansion from the Ponto-Caspian drainage basin to the Baltic basin through freshwater canals, aided by transport of fouling communities through these canals by ships and timber rafts. Overseas transport in Europe on timber on board of ships (Bij de Vaate et al., 2002).

Area of origin.— Ponto-Caspian area (Gittenberger & Janssen, 1998).

Introduction into Atlantic Europe.— Reached Atlantic Europe after the Oginsky canal was opened in 1768; first observed in the Curonian Lagoon, Lithuania, in 1803 (Olenin, 2002).

Introduction into The Netherlands.— First collected in the river Maas, nowadays the border between The Netherlands and Belgium, near Maaseik, Belgium, in 1826 (Van Beneden, 1835; Gittenberger & Janssen, 1998). According to Van Benthem Jutting (1943) *Mytilus lineatus* recorded by Waardenburg (1827) from Lake Haarlemmermeer, and in the rivers Rhine and Lee near Leiden on stones and shells must have been *Dreissena polymorpha*. As these water bodies must have been fresh to oligohaline at that time, I agree with this conclusion unless this observation constitutes the earliest record of *Mytilopsis leucophaeata* (see below).

Present occurrence in The Netherlands.— Occurs all over The Netherlands in freshwater lakes, canals and rivers. Tolerates oligohaline conditions; occurs in the Noordzeekanaal near Amsterdam together with *Mytilopsis leucophaeata* (Peeters, 1988; Gittenberger & Janssen, 1998)

Ensis directus (Conrad, 1843)
(Syn. E. americanus (Gould in Binney, 1870))

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6), permanently established.

Vector.— Probably introduced into Europe in ballast water (Von Cosel et al., 1982). Arrived in The Netherlands through larval transport by marine currents (fig. 9).

Area of origin.— Atlantic coast of North America from Labrador to North Carolina (De Bruyne & De Boer (1984).

Introduction into Atlantic Europe.— First observed in the German Bight in 1979, probably settled in 1978 (Von Cosel et al., 1982). Beukema & Dekker (1995), however, record a few small *Ensis* at the tidal flats near Terschelling, The Netherlands, in 1977; they suggest that these may have been *E. directus*.

Introduction into The Netherlands.— Empty shells washed ashore on the beach of Schiermonnikoog in 1982 (De Boer & De Bruyne, 1983). In 1983 similar finds on the beaches of Terschelling, Ameland and Schiermonnikoog (De Bruyne & De Boer, 1984). Essink (1984) found the first live *E. directus* in the Wadden Sea; he records live specimens from the Bocht van Watum in 1981 and from nearly the entire Wadden Sea in the next few years. Swennen (1984) found a live specimen in the North Sea off Texel. Essink & Tydeman (1985) record live specimens from the year-class 1984 on 7 localities in the western Wadden Sea. Essink (1986) mentions shells washed ashore at IJmuiden, Bloemendaal/Zandvoort, Katwijk / Noordwijk in 1985. Van Urk (1987) state that it also washed ashore at Scheveningen, Kijkduin, Terheyde, and Hoek van Holland in 1986 and 1987. It is assumed that large numbers of shells washed ashore on the North Sea beaches imply living populations off the beach (Essink, 1985).

Present occurrence in The Netherlands.— Common species occurring in wave- and current-swept clean sands (De Bruyne, 1994; Beukema & Dekker, 1995).

Mercenaria mercenaria (Linnaeus, 1758)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), but unclear if established.

Vector.— Deliberately introduced in Europe (Goulletquer et al., 2002). At least part of the Dutch specimens was introduced accidentally with oysters; another part was deliberately introduced (see below).

Area of origin.— Atlantic coast of North America from Nova Scotia to Yucatan (Eno et al., 1997).

Introduction into Atlantic Europe.— First imports in Baie d'Arcachon, France, in 1861 (Goulletquer et al., 2002). A live specimen was found in the Humber, England, in 1864; it is not present at that locality any longer (Eno et al., 1997).

Introduction into The Netherlands.— Kaas & Ten Broek (1942) and Van Benthem Jutting (1943) record that shells were observed a few times on the Dutch North Sea beaches, among others at Westkapelle (see Kaas, 1937). All finds date from after 1933. A live specimen was observed in the sluice dock of Ostend, Belgium, in the same period. This species had been imported earlier in France for human consumption. Since that time it is living along the French coast. Hence, the Flemish and Dutch specimens found before 1943 probably have been imported with French oysters. Wolff (unpublished) observed dead specimens *in situ* in a saltmarsh creek near De Piet in the Veerse Meer in 1961 after the closure of the Veerse Gat that year; these specimens were said to have been introduced deliberately by The Netherlands Institute for Fisheries Research for culture experiments. L.P.M.J. Wetsteyn (pers. comm., 2000) observed 5 live adult specimens at Hoge Kraayer in the Oosterschelde estuary in December 1995, and 1 adult specimen in the same estuary near Tholen in summer 2000. Aquasense (1998) records that it was 'introduced in the Dutch Oosterschelde estuary in the 1950s (pers. comm. L.P.M.J. Wetsteyn)'.

Present occurrence in The Netherlands.— Oosterschelde estuary.

Mya arenaria (Linnaeus, 1758)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2), permanently established.

Vector.— Perhaps introduced into Scandinavia in bilge water of a Viking vessel returning from North America (Petersen et al., 1992). It is unknown how it reached The Netherlands, but transport of larvae by marine currents is likely.

Area of origin.— Atlantic coast of North America and northernmost Pacific (Cohen & Carlton, 1995). Gollasch (2002) considers it to be a cryptogenic species, but this conclusion seems unwarranted (see below).

Introduction into Atlantic Europe.— *Mya* was thought to have been introduced from the American coast during the 16th or 17th century because the species is absent from earlier fossil material (Hessland, 1946). However, there is evidence that this species was introduced from America to Europe before 1245-1295 (Petersen et al., 1992). It has been suggested that the latter introduction was due to transfer by the Vikings (Petersen et al., 1992), but this poses a problem. Except for an occasional vessel driven by gales, there was no direct transport between North America and Europe in the Viking

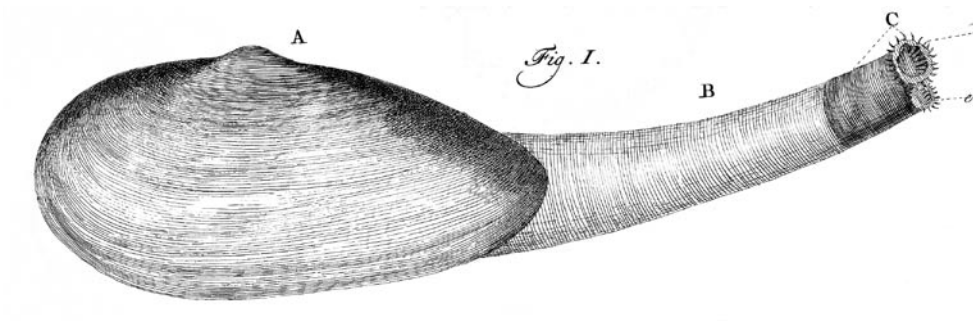

Fig. 29. Illustration of *Mya arenaria* by Baster (1765).

age (Marcus, 1980); Greenlanders visited North America more or less frequently and there were long-range voyages between Greenland and Norway, but not by the same vessels. So introduced *Mya* probably should have come from Greenland. However, we have no records of this species from Greenland (Ockelmann, 1958; Høpner Petersen, 1978, 1999).

Introduction into The Netherlands.— The oldest record is that by Baster (1765) from the creek Dijkwater near Zierikzee (fig. 29), but it probably was introduced earlier.

Present occurrence in The Netherlands.— Common species (Havinga, 1922; Kaas & Ten Broek, 1942; Van Benthem Jutting, 1943; Wolff, 1973; De Bruyne, 1994).

Mytilopsis leucophaeata Conrad, 1831
(Syn. Congeria cochleata (Kickx in Nyst, 1835))

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently established.

Vector.— Nyst (1835) observed barnacles on the specimens collected from the Scheldt estuary at Antwerp, Belgium, and assumed for that reason that the animals had been introduced as hull fouling by ocean-going ships. However, the barnacle *Balanus improvisus* Darwin, 1854, is known from the Scheldt estuary near Antwerp since the 17th century (see page 58), so the mere presence of barnacles does not prove transport on the hull of a ship. Gittenberger & Janssen (1998) suggest transport of larvae in ballast water. This, however, is unlikely since ballast water was not used before the 1870s (Carlton, 1985). Marelli & Gray (1983) suggest transport on "ballast rocks in somewhat less than watertight wooden vessels". This possibility cannot be excluded, but seems unlikely because one would expect anaerobic conditions in the hold of such a vessel. Given the tolerance of high salinities of all brackish-water species (Schlieper, 1958), I assume that *M. leucophaeata* has been introduced into Europe and into The Netherlands on ships' hulls.

Area of origin.— Atlantic coast of North America and Gulf of Mexico (Marelli & Gray, 1983; Gittenberger & Janssen, 1998).

Introduction into Atlantic Europe.— The first observation in Europe was made in the Scheldt estuary near Antwerp, Belgium, in 1835 (Marelli & Gray, 1983; Gittenberger & Janssen, 1998).

Introduction into The Netherlands.— Van Benthem Jutting (1943): 'Maitland made the first Dutch find in the Amstel near the Omval in 1895 (Maitland, 1897)'.

Present occurrence in The Netherlands.— Van Benthem Jutting (1936, 1943) records that *M. leucophaeata* (as *Congeria cochleata*) was abundant in the western margin of the Zuiderzee area; it occurred also in the coastal areas of the Wadden Sea, Friesland, Noord-Holland and Zuid-Holland. Due to large changes of the salinity of Dutch inland waters, *Mytilopsis* may be expected to have disappeared from the larger part of this area. Wolff (1969a) mentions it in the Dutch Delta area from near Maassluis and in the Kanaal door Voorne (as *Congeria cochleata*); he was not aware of recent records from these localities. Peeters (1988) found it abundant in the Noordzeekanaal. Gittenberger & Janssen (1998) give an overview of all Dutch records and mention recent observations from the Noordzeekanaal between IJmuiden and Amsterdam and from the River Waal near Nijmegen. Kelleher et al. (1999) record the species from the freshwater Biesbosch and suspect that vessels from the brackish Noordzeekanaal may have imported specimens into the River Waal. Kuijper (2000) records occurrence in Noordzeekanaal and Kanaal van Gent naar Terneuzen as well as earlier finds in a few other localities. Faasse & Van Moorsel (2003) record *M. leucophaeata* from the brackish eastern part of the Westerschelde estuary around 2000.

Pecten maximus (Linnaeus, 1758)

Status in The Netherlands.— NE Atlantic non-indigenous species, not established.

Vector.— Introduced with oysters (Kaas & Ten Broek, 1942).

Area of origin.— European Atlantic species.

Introduction into The Netherlands.— Kaas & Ten Broek (1942) state 'Fragments have been found regularly in Zeeland. Once a juvenile specimen was collected alive in an oyster pond at Kattendijke. Probably introduced.'

Present occurrence in The Netherlands.— Not present.

Petricola pholadiformis Lamarck, 1818

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4, 6, 7), permanently established.

Vector.— Probably introduced into Europe with oysters (Eno et al., 1997). It is unknown how it reached The Netherlands, although expansion of the larval stage with marine currents is likely.

Area of origin.— Atlantic coast of North-America from Gulf of St. Lawrence to Gulf of Mexico (Cohen & Carlton, 1995; Eno et al., 1997).

Introduction into Atlantic Europe.— It was probably introduced with North-American oysters, not later than 1890, and found in the River Crouch, Essex, England (Eno et al., 1997).

Introduction into The Netherlands.— Schlesch (1932: not seen) records *P. pholadiformis* from the Belgian-Dutch coast in 1899. Van Breemen (1907a) and Denker (1907) record this species from the Dutch coast in 1905; they consider this to be the first Dutch record. In 1906 the species was found near Noordwijk (Icke, 1907).

Present occurrence in The Netherlands.— Heinsius & Jaspers (1913) consider this

species to be common; Dorsman (1919) already records this species from the entire Dutch coast. Kaas & Ten Broek (1942) state that this species increases in abundance, and that along the entire coast it is locally very abundant. Van Benthem Jutting (1943) writes that *P. pholadiformis* is one of the most common species of the Dutch coast.

Psiloteredo megotara (Forbes & Hanley, 1848)

It is unclear if this species is an exotic non-indigenous species. If introduced, probably in wooden vessels. It was found in wooden fishing vessels from Scheveningen (Redeke, 1912). De Bruyne (1994) records it in wood (of wracks) along the entire Dutch coast.

Spisula solidissima (Dillwyn, 1817)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), not established.

Vector.— Unknown.

Area of origin.— Atlantic coast of North America from Nova Scotia to South Carolina (Doeksen, 1983).

Introduction into Atlantic Europe.— Unknown.

Introduction into The Netherlands.— A live adult specimen washed ashore at Terschelling (paal 17) on 25.xii.1982 (Doeksen, 1983; Stiva, 1983).

Present occurrence in The Netherlands.— Not present.

Teredo navalis Linnaeus, 1758

Status in The Netherlands.— Probably an exotic non-indigenous species (criterion 1(?), 6), permanently established. Its massive occurrence in 1730-32 (Vrolik et al., 1860; Van Benthem Jutting, 1943) is characteristic for a non-indigenous species, but this seems to be contradicted by older records which, however, cannot be verified.

Vector.— If introduced, most likely in wooden ships.

Area of origin.— Many classical authors such as Aristotle, Ovid, and Pliny (Vrolik et al., 1860) knew shipworms of unknown specific identity. This knowledge must refer to the Mediterranean. To prevent infestation by shipworms several forms of coating and sheathing were used by the Phoenicians and the Greeks (Gomoiu et al., 2002). A thousand years later, starting in 1516 several sources report on shipworms of unknown specific identity in the West Indies and Atlantic Europe (Moll, 1914). Vrolik et al. (1860) record fossil finds from NW Europe, but it is unclear whether these are of Holocene age and belong to this species. Moll (1914) lists fossil finds only belonging to other species. Van Benthem Jutting (1943) considers *T. navalis* to be a cosmopolitan species, probably originating from the North Sea area. Turner (1966) records *T. navalis* from the Atlantic coast of Europe, Australia, New Zealand, Pacific Islands, SE Asia, Indonesia, New Guinea, Japan, and West and East coasts of North America. Gollasch (1996) assumes a warm-temperate or tropical origin, in 2002 the same author considers it to be cryptogenic.

Introduction into Atlantic Europe.— 'Man findet in Abhandlungen aus neuerer Zeit häufig die Vermutung ausgedrückt, dasz sie in Europa erst etwa seit Anfang des 18.

Jahrhunderts, wo sie die holländischen Deiche stark angriff, aufgetreten sei, und dasz sie wahrscheinlich durch Schiffe aus Amerika oder Indien eingeschleppt worden sei. Wenn man aber die zahlreichen Stellen in der älteren Literatur ansieht, so nimmt es geradezu Wunder, wie ein so bekanntes Tier für fast ein Jahrtausend so vollständig aus dem Gesichtskreise der Ingenieure und Naturforscher verschwinden konnte, dasz seine Auffindung im Jahre 1700 geradezu als eine neue Entdeckung angesehen wurde' (Moll, 1914). However, Moll's old records all seem to refer to the Mediterranean. The oldest records in Atlantic Europe apparently come from The Netherlands. There seem to be no records of damage to Viking vessels in northern Europe (Hoppe, 2002).

Introduction into The Netherlands.— The description of *Teredo navalis* by Linnaeus in 1758 was based on material collected by Sellius in The Netherlands in 1730-32. Van Benthem Jutting (1943) states that before 1730 *T. navalis* occurred sporadically along the Dutch coast. She refers to P.C. Hooft (Ned. Historiën, 1580) who recorded damage to seawalls in Zeeland, however, without identifying the cause (Moll, 1914). Also Martinet (1778) records damage in the 16th century and in doing so probably based himself on Hooft. The Journal des Sçavans (1665, p. 273-275) publishes a letter from Amsterdam complaining about the damage caused by shipworms. Vrolik et al. (1860) cite the same 'Journal des Savants de l'an 1665' and cite that vessels in the IJ estuary were virtually destroyed by the shipworm (but this may concern another species, e.g. *Psiloteredo megotara* or *Teredo norvagica* (Spengler, 1792), and the ships may have contracted the 'worms' elsewhere). Also Martinet (1778) records heavy damage to herring fishing vessels in 1714 and 1727. So, any records before 1730 concern either unspecified damage or occurrence of shipworms in vessels. Hence, it seems that until the 18th century we have no clear indications that *T. navalis* occurred in benthic habitats in The Netherlands.

In 1730 massive damage to wooden constructions along seawalls is recorded from Zeeland and West-Friesland (van Benthem Jutting, 1943). Vrolik et al. (1860) record damage to seawalls in 1730, 1731 en 1732, 1770, 1827, 1858 and 1859. In the latter year damage was recorded all along the Dutch coast. They state that, although ships returning from the East Indies are held responsible for the introduction of these damaging animals (see, e.g., Martinet (1778)), finds of shipworms in fossil wood prove that it is an endemic species. However, there is no indication that these fossil finds refer to the same species; in fact, most, if not all, of these seem to be different (Moll, 1914). Vrolik et al. (1860) found a relationship between the outbreaks of *Teredo* and dry, warm summers with high salinities.

Den Hartog & Van der Velde (1987) consider *T. navalis* to be a non-indigenous species but do not explain why. Wolff (1992, 1996, 1999) and Wolff et al. (1994) consider *Teredo* a non-indigenous species in the Wadden Sea, Zuiderzee, and Delta, based on Den Hartog & Van der Velde (1987) and the information cited above.

Present occurrence in The Netherlands.— Kaas & Ten Broek (1942) describe *T. navalis* as 'Common in driftwood along the entire coast'. Van Benthem Jutting (1943) also considers it common. De Bruyne (1994) writes: 'Common, especially in the Oosterschelde estuary.' A. Vos (pers. comm.) found it recently abundant in shipwrecks in the western Wadden Sea.

17.16. Bryozoa

Bowerbankia imbricata (Adams, 1798)

Den Hartog & Van der Velde (1987) consider *Bowerbankia* div. sp. to be introduced exotic species, but do not explain why. Hence, *B. imbricata* is perhaps an exotic non-indigenous species. It is fairly common in the estuaries of the Delta area (Heerebout, 1969). It is permanently established. If introduced, it probably arrived on ships' hulls. Its area of origin is unknown. It occurs in the Eastern Atlantic from the Barents Sea to the Mediterranean Sea and also in the Black and Caspian Seas (although the latter two localities may concern a different species). In the Western Atlantic it ranges from the USA to Argentina (Hayward, 1985).

Bowerbankia gracilis (Leidy, 1855)

Den Hartog & Van der Velde (1987) consider *Bowerbankia* div. sp. to be exotic non-indigenous species, but do not explain why. Hence, *B. imbricata*is perhaps an exotic non-indigenous species. Wolff (1999) considers *B. gracilis* to be a cryptogenic species. It is common in the estuaries and non-tidal brackish waters of the Delta area (Heerebout, 1969). It is permanently established. If introduced, it probably arrived on ships' hulls. Its area of origin is unknown. In the eastern Atlantic the species occurs from the Arctic into the Mediterranean and the Black Sea, and in the western Atlantic from Greenland to Brazil. It is probably cosmopolitan (Hayward, 1985).

Bugula simplex Hincks, 1886

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 3, 4, 7), recently established.

Vector.— If a non-indigenous species, probably introduced into Europe as fouling on ships' hulls since it was described from the Adriatic Sea in 1886; its recent expansion to The Netherlands and Belgium is probably due to transfer by yachts (De Blauwe & Faasse, 2001).

Area of origin.— Known from NW Atlantic, NE Atlantic, Australia, and New Zealand (De Blauwe & Faasse, 2001).

Introduction into Atlantic Europe.— Described from the Adriatic Sea but known from European Atlantic waters since the 19th century. Almost all records are from harbours and ports (De Blauwe & Faasse, 2001).

Introduction into The Netherlands.— First observed in the marina at Goesse Sas along the Oosterschelde estuary in 2000 (De Blauwe & Faasse, 2001).

Present occurrence in The Netherlands.— Only known from Goesse Sas, Oosterschelde estuary (De Blauwe & Faasse, 2001).

Bugula stolonifera Ryland, 1960

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 1, 3, 4), permanently established.

Vector.— On ships' hulls? (D'Hondt & Cadée, 1994).

Area of origin.— NW Atlantic (Cohen & Carlton, 1995).

Introduction into Atlantic Europe.— Described from the British coast in 1960 (Ryland, 1960). The species expands its distribution range. Presently it is known from both sides of the Atlantic Ocean and from the Mediterranean; also found at Le Havre, France. Possibly this concerns introductions via fouling on ships' hulls; most new observations are from the vicinity of harbours (D'Hondt & Cadée, 1994).

Introduction into The Netherlands.— D'Hondt & Cadée (1994) found this species on a pontoon in the NIOZ harbour at Texel in October 1993.

Present occurrence in The Netherlands.— Texel (D'Hondt & Cadée, 1994); Middelburg, Kanaal door Walcheren, 1990, 1992; Havenkanaal Goes, 1997; harbour Burghsluis, 1998; harbour Scharendijke, 1998; Springersdiep, seaside Brouwerdam, 1998 (Faasse, 1998a).

Tricellaria inopinata d'Hondt & Occhipinti Ambrogi, 1985

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 4, 5, 7), recently established.

Vector.— Has reached Europe probably on ships' hulls; transport within Europe probably mainly on hulls of yachts (De Blauwe & Faasse, 2001).

Area of origin.— Probably Pacific coast of North America, also Japan, Taiwan, Australia, and New Zealand (Dyrynda et al., 2000).

Introduction into Atlantic Europe.— The species was described from the lagoon of Venice in 1985; it was found already in 1982. The first Atlantic occurrence was in Galicia, Spain, in 1996 (De Blauwe & Faasse, 2001).

Introduction into The Netherlands.— After records from southern England in 1998 (Dyrynda et al., 2000), the first observations in The Netherlands, Belgium, and France were made in 2000 (De Blauwe & Faasse, 2001). Earlier introduction, in 1999 or before, is likely, however, in view of the widespread occurrence in 2000.

Present occurrence in The Netherlands.— Known from the Oosterschelde estuary, the entrance of the Westerschelde estuary, Lake Grevelingen, and Goesse Meer, in almost all cases from marinas (De Blauwe & Faasse, 2001; De Blauwe, 2002).

Victorella pavida Kent, 1870

According to Den Hartog & Van der Velde (1987) this is an exotic non-indigenous species in The Netherlands. Wolff (1999) considers it to be a cryptogenic species. It is common in non-tidal brackish water of the Dutch Delta area (Heerebout, 1969). It is permanently established. Its area of origin is unknown; the species has a cosmopolitan distribution (Hayward, 1985). Cohen & Carlton (1995) argue that it may be a native of the Indian Ocean. If introduced, it most likely arrived on ships' hulls.

Walkeria uva (Linnaeus, 1758)

Unclear if this is a non-indigenous species. According to Wolff (1999) it is a cryptogenic species. If it is introduced, it probably arrived on ships' hulls. It occurs in the

West Atlantic as well as in the East Atlantic from the Barents Sea to the Mediterranean (Hayward, 1985). It is a common species in the estuaries of the Delta area (Heerebout, 1969). It is permanently established.

17.17. Chordata

17.17.1. Urochordata

Aplidium glabrum (Verrill, 1871)

This is perhaps a NE Atlantic non-indigenous species. It was collected in the Oosterschelde estuary at Yerseke for the first time in 1977 and 1979 (Buizer, 1983). In 1988 it was found at Lokkersnol and Boomkil, Oosterschelde estuary; in 1989 in oyster ponds at Yerseke Bank; entrance of the Oosterschelde estuary, and in the Grevelingen lake (Buizer, 1989). At present widely distributed in Lake Grevelingen, Oosterschelde estuary, and Havenkanaal Goes (M.A. Faasse, pers. comm.), suggesting that this is a case of a natural range extension.

Botrylloides violaceus Oka, 1927

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), recently established.

Vector.— Probably introduced in Europe as fouling on ships' hulls or with oysters (Faasse & De Blauwe, 2002). It reached The Netherlands perhaps by fouling of pleasure craft.

Area of origin.— Described from Japan, but later also found on the Pacific and Atlantic coasts of North America and in Italy (Faasse & De Blauwe, 2002).

Introduction into Atlantic Europe.— First found in Atlantic Europe in the Westerschelde estuary near Breskens, The Netherlands, in 2000 (Faasse & De Blauwe, 2002).

Introduction into and present occurrence in The Netherlands.— First found in the Westerschelde estuary near Breskens in 2000. In 2002 also in the Oosterschelde estuary at Yerseke and Wemeldinge (Faasse & De Blauwe, 2002).

Diplosoma listerianum (Milne Edwards, 1841)

This might be a NE Atlantic non-indigenous species since its area of origin is given as European waters (Millar, 1970) and cosmopolitan (Buizer, 1983), respectively. Although Bloklander et al. (1956) state that this species had been recorded from the Dutch coast, Buizer (1983) states that it was found for the first time in 1977. Faasse (1991a): 'Until 1988 *D. listerianum* was known only from the southern coast of the isle of Schouwen-Duiveland. On 20.ii.1988 B.G. Otten and W. Tinbergen found two colonies in the Oosterschelde estuary near the Goese Sas. In 1990 I found the species in the Kanaal door Walcheren near Vlissingen, Nieuw- en St.Joosland and Veere.' At present widely distributed in Lake Grevelingen, Oosterschelde estuary, and Havenkanaal Goes (M.A. Faasse, pers. comm.), suggesting that this is a case of a natural range extension.

Molgula manhattensis (De Kay, 1843)

Status in The Netherlands.— Probably an exotic non-indigenous species (criteria 2, 7), permanently established.

Vector.— If introduced, only hull fouling can have been the way of transport because the species occurred already in The Netherlands in the 18th century (see below).

Area of origin.— *Molgula manhattensis* has been recorded from Europe, Atlantic coast of North America, and Australia (Monniot, 1969; Millar, 1970; Buizer, 1983). Hayward & Ryland (1995), however, state that the European *Molgula tubifera* Oersted, 1844 is 'To be regarded as different from the American *M. manhattensis*.' In that case the European population should not be considered to be non-indigenous. I have followed Monniot (1969) who studied both American and European specimens and found no difference. According to Cohen & Carlton (1995) and Grosholz & Ruiz (1996) *M. manhattensis* originates from the NW Atlantic.

Introduction into Atlantic Europe.— Engel (1934) and Buizer (1983) state that the species recorded by Baster (1762) as 'Zak-pijp of Ascidium' growing on the doors of sluices and locks in the Dijkwater at the island of Schouwen, is *Molgula manhattensis* (fig. 30). This identification obviously is based on the resemblance of the primitive drawing to *Molgula*, the locality and habitat where the specimens were found, and the species known to occur in The Netherlands at present.

Introduction into The Netherlands.— See above. Den Hartog & Van der Velde (1987) consider *M. manhattensis* to be a non-indigenous species, but do not give an argumentation. Wolff (1992, 1996) and Wolff et al. (1994) follow Den Hartog & Van der Velde (1987).

Present occurrence in The Netherlands.— Common species; used to be abundant in the former Zuiderzee (Bloklander et al., 1956; Buizer, 1983).

Styela clava Herdman, 1882

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 4), permanently established.

Vector.— Introduced as fouling on ships' hulls, some populations perhaps with oysters (Lützen, 1999). Unknown how it reached The Netherlands.

Area of origin.— According to Lützen (1999) it is indigenous to the Sea of Okhotsh, Sea of Japan and the coasts of Japan, Korea and northern China as far south as Shanghai.

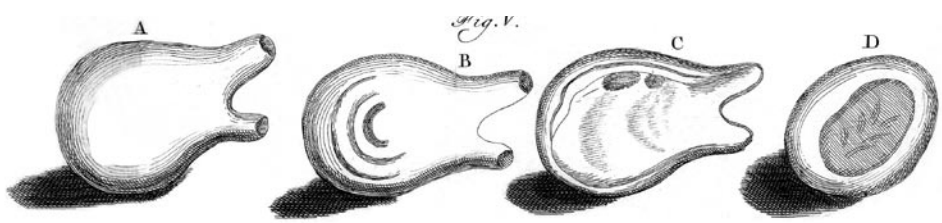

Fig. 30. Illustration of *Molgula manhattensis* by Baster (1762). A: habitus; B: habitus with light from the back; C: longitudinal section; D: cross section

Introduction into Atlantic Europe.— Probably introduced into Europe in 1952 as it was found in Plymouth, UK, in 1953 (Buizer, 1980a, 1983; Eno et al., 1997; Lützen, 1999). Lützen (1999) presents a map with the distribution in Europe from 1952 to 1997. Lützen (1999) writes 'Circumstantial evidence suggests that *S. clava* was first introduced into Europe by vessels returning in 1952 to Devonport (at Plymouth) and Portsmouth from the Korean war (Coughlan, 1969). ... Probably ... many of the French and some Dutch populations originated with spat of the Pacific oyster introduced from Japan ... or with oysters transferred within the Channel region.'

Introduction into The Netherlands.— First observed in The Netherlands in the harbour of Den Helder in 1974 and a few months later also in the ferry harbour at Texel (Huwae, 1974; Huwae & Lavaleye, 1975). Again a few months later also in the Oosterschelde estuary (Westerwil, 1975).

Present occurrence in The Netherlands.— Common species: Terschelling, Texel, Den Helder, Grevelingen, Oosterschelde estuary, Kanaal door Zuid-Beveland, Kanaal door Walcheren (Buizer, 1980a, 1983; Faasse, 1991a). Also in Calandkanaal, Beerkanaal and adjacent harbour basins near Rotterdam (Paalvast, 1998).

17.17.2. Pisces

Atherina boyeri (Risso, 1810)
(Syn. Atherina mochon Valenciennes, 1835)

Status in The Netherlands.— NE Atlantic non-indigenous species, permanently established.

Vector.— Transport of eggs by ships? (Van der Velde & Polderman, 1972, 1976).

Area of origin.— Mediterranean species (Van der Velde & Polderman, 1972). Atlantic coast of southern Europe, southern North Sea (Nijssen & De Groot, 1987).

Introduction into The Netherlands.— Schrieken & Swennen (1969) state that since 1964 this species (as *A. mochon*) was caught in increasing numbers in the fish monitoring program of Vaas (1970) in Lake Veerse Meer. Vaas (1975) believed that the appearance of this species was the result of improved taxonomic knowledge. However, Van der Velde & Polderman (1972, 1976) conclude that this species could be introduced thanks to the heated cooling water discharged into the inner harbour of Vlissingen and the connected Kanaal van Walcheren (which in turn is connected to Lake Veerse Meer). They believe that the eggs of the species were introduced on ships' hulls.

Present occurrence in The Netherlands.— Known from the connected non-tidal, brackish systems of inner harbour of Vlissingen, Kanaal door Walcheren, and Lake Veerse Meer at least until 1990 (Vaas, 1970; Van der Velde & Polderman, 1972, 1976; Nijssen & De Groot, 1987; Faasse, 1991a). Dumoulin (1984) found the species in the brackish creek Braakman, Zeeuws-Vlaanderen, in 1982. Kloosterman & Schrieken (2003) record *A. boyeri* from Den Helder.

Gobius niger Linnaeus, 1758

Although Den Hartog & Van der Velde (1987) list *Gobius niger* as a non-indigenous species, it is better to consider its appearance in The Netherlands as a natural range

extension (see also Nijssen & de Groot (1987)). Perhaps this was made possible by human-induced environmental changes in the SW Netherlands. It is known from the Mediterranean, NE-Atlantic Ocean, North Sea, Norwegian coast, Skagerrak, Kattegat, and Baltic (Vaas, 1964; Nijssen & De Groot, 1987). Vaas (1964) caught the first specimen in the Veerse Meer near Kamperland in autumn 1964. Vaas et al. (1975) knew the species from the Veerse Meer (1st specimen in 1964, another 3 specimens in May 1966, in December 1969 1 specimen, present in all trawl catches from autumn 1970 onwards), Kanaal door Walcheren (since 1972), and the southern shore of the Oosterschelde estuary (since 1972). It occurs now also in Lake Grevelingen.

Lebistes reticulatus (Peters, 1859)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), permanently established.

Vector.— Released aquarium specimens? (Nijssen & De Groot, 1987).

Area of origin.— Northern part of South-America (Nijssen & De Groot, 1987), but exact area not known (De Nie, 1996).

Introduction into Atlantic Europe.— Unknown.

Introduction into The Netherlands.— Since many years guppies have been observed in heated inland waters, among others the brackish Noordzeekanaal near the Hoogovens at IJmuiden (De Groot, 1985; Nijssen & De Groot, 1987). De Nie (1996) knows only this locality in brackish waters.

Present occurrence in The Netherlands.— De Nie (1996) records one locality in brackish water, viz. the Noordzeekanaal.

Oncorhynchus mykiss (Waldbaum, 1792)
(Syn. Salmo gairdneri Richardson, 1836)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), not established.

Vector.— Deliberately introduced for angling purposes (De Groot, 1985).

Area of origin.— Pacific coast of Asia South to Kamchatka and Amur River (http://www.fishbase.org); Pacific coast of North America from Alaska to Mexico (Vooren, 1972).

Introduction into Atlantic Europe.— First deliberate introduction into France in 1882 (Nijssen & De Groot, 1987).

Introduction into The Netherlands.— From 1898 onwards fish cultivated in Germany have been released frequently into Dutch waters. From the middle of the 1960s (Vooren (1972): 1968, 1969) also released in the brackish lake Veerse Meer and later also the brackish lake Grevelingen (De Groot, 1985; Nijssen & De Groot, 1987). Steinmetz (1978) records that since the first introductions until 1978 300,000 rainbow trout have been released into the Veerse Meer.

Present occurrence in The Netherlands.— Introduced into Lake Veerse Meer, Lake Grevelingen and Lake Oostvoornse Meer (Nijssen & de Groot, 1987; De Nie, 1996). Caught in these lakes as well as in the Oosterschelde estuary and near the Haringvliet sluices, but not reproducing in these waters.

Oncorhynchus kisutch Waldbaum, 1792

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3, 7), not established.

Vector.— Deliberately introduced into northern France; Dutch specimens probably are stray individuals (De Groot, 1985).

Area of origin.— North Pacific: Anadyr River, Russia, South to Hokkaido, Alaska, South to Baja California, Mexico. North America (De Groot, 1985).

Introduction into Atlantic Europe.— First release by a private party in the Somme estuary in Picardy, France, in 1981 and 1982 (De Groot, 1985).

Introduction into The Netherlands.— De Groot (1985): 'a specimen of the coho salmon was first caught in The Netherlands on 16 December 1982 in brackish water of the Calandkanaal, Europoort, Rotterdam, by an angler. Another specimen was caught a few days later. On 6 January 1984 another female coho was caught, this time near IJmuiden. These are probably related to releases by a private party in the Somme estuary in Picardy, France in 1981 and 1982.'

Present occurrence in The Netherlands.— Unknown, probably absent.

Trinectes maculatus (Bloch & Schneider, 1801)
(Syn. Achirus fasciatus Hubbs, 1932)

Status in The Netherlands.— Exotic non-indigenous species (criteria 1, 2, 3), temporarily established.

Vector.— Unknown.

Fig. 31. Specimen of *Trinectes maculatus* caught in the Wadden Sea in 1984. Photograph courtesy Dr. H.W. van der Veer.

Area of origin.— Atlantic coast of North America.

Introduction into Atlantic Europe.— No information.

Introduction into The Netherlands.— One specimen of 13.1 cm length (fig. 31) was caught alive at the Javaruggen in the Dutch Wadden Sea on 14 November 1984; it lived in an aquarium at The Netherlands Institute for Sea Research (NIOZ) for several years (M. Fonds and H.IJ. Witte, pers. comm.). Aquasense (1998): 'In the original OSPAR list (...) the fish *Achirus fasciatus* is mentioned as introduced by ballast water in Dutch coastal waters. However, as far as is known, this species is not yet established in the coastal waters.'

Present occurrence in The Netherlands.— Not present.

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