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The Importance of Ship Hull Fouling as a Vector of Species Introductions into the North Sea

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Ships have long been recognized as a major vector for the introduction of non-native and harmful organisms. From 1992 to 1996 a shipping study was undertaken in Germany, focusing on the fauna transported by ships, to assess the importance of species introductions by international shipping traffic. Ballast water, tank sediment or hull fouling of 186 vessels was sampled. A total of 257 species were identified, ranging from Foraminifera to Teleostei, and 57% of the species sampled were considered to be non-native to the North Sea region, originating from elsewhere in the world including the north eastern Atlantic (west of the English Channel). Non-native species were recorded in 38% of all ballast water samples, 57% of all sediment samples and 96% of all hull samples, indicating that hull fouling is an important vector of introduction. Four species (1.6%) of unknown origin (cryptogenic species) were identified. The potential for establishment in the North Sea region of all non-native species found was classified into three categories based on the degree of similarity of climatic conditions in the North Sea and the donor region. Based on this criterion 19 of the species found in the fouling communities on ships' hulls were deemed to have a high potential for establishment in the North Sea.

Keywords: ship; hull; fouling; ballast water; introductions; North Sea

INTRODUCTION

Unintentional introductions of non-native aquatic organisms have resulted in the establishment of many species beyond their native ranges. Such introductions have the potential to alter environments and cause the loss of earnings through displacement of indigenous species or habitat

modification (Carlton, 1985; 1987; Cohen & Carlton, 1995). It is generally assumed that the main means of introduction of introduced species into aquatic ecosystems are aquaculture practices and transport by ships (Bonnot, 1935; Elton, 1958; Tambs-Lyche, 1964; Farnham, 1980; Carlton, 1985; 1987; Sindermann, 1991; Baldwin, 1992; Eno, 1995; Eno *et al.*, 1997; Reise *et al.*, 1999).

The North Sea is subject to extensive shipping traffic, as well as aquaculture, and to date about 80 species have been reported as introduced into the North Sea, and currently occur as self-sustaining populations. This number is lower than in some other enclosed seas or bays, *e.g.* the Chesapeake Bay (116 introduced species) and San Francisco Bay with 253 introduced species (Nichols & Pamatmat, 1988; Cohen & Carlton, 1995; Carlton, personal communication). The majority of North Sea introductions are invertebrates, primarily crustaceans, molluscs, polychaetes and hydroids, while introduced algae are mostly red and brown macroalgae followed by phytoplankton (Hayward & Ryland, 1990; Eno *et al.*, 1997; Maggs & Stegenga, 1999; Nehring & Leuchs, 1999; Reise *et al.*, 1999; Wallentinus, 1999). On open coasts in the North Sea approximately 6% of the macrobenthic species are exotics, while in estuaries this proportion can reach 20% (Reise *et al.*, 1999). About 25% of the established non-native species are widespread and form locally high abundances, dominating some coastal habitats (Reise *et al.*, 1999). Although the percentage and abundance of introduced species in the North Sea can thus be substantial in some habitats, the overall effect on the ecosystem seems to be restricted to the addition of new species without subsequent replacement of

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TABLE I Number of samples taken over the sampling period

	1992			1993			1994			1995		
	B	S	H	B	S	H	B	S	H	B	S	H
January							5	1	5			
February				6	2	1		1	3			
March	2			9	5	6	4		4		2	2
April	1	1	1	16	11	9						1
May		2	1	4	7	9	1		2	2		
June				8	4	13	5		2			
July	1			13	5	11	1	1	1			1
August	2			4	1	7	2	3	2			1
September	4	2		10	3	8	1					
October	2	1		9	9	20		2	1			
November	8			2	4	8		1	2			
December	5	1	2	5	2	8						
Total	25	7	4	86	53	100	19	9	22	2	2	5

B = ballast water samples; S = tank sediment samples; H = hull samples

indigenous fauna. This suggests that the North Sea has some capacity to accommodate invaders (Reise *et al.*, 1999).

This study focused on vectors of species introductions into the North Sea. Specifically, the objectives of this study were to i) assess the importance of ballast water, tank sediment and hull fouling as transport vectors for fauna into the North Sea, ii) determine if hull fouling is a significant means of species introduction and iii) assess if species are more likely to become established in the North Sea if they originate from similar climatic regions.

MATERIALS AND METHODS

This shipping study, carried out in 1992–1996 and jointly involving the University of Hamburg and the Institut for Marine Sciences in Kiel, Germany, was the first study sampling ballast tanks in Europe. Initially the focus was on ballast water and ballast tank sediments as potential vectors for species introductions into the North Sea. Ballast tanks were sampled for phytoplankton, zooplankton and zoobenthos (Lenz *et al.*, 2000). Shortly after the sampling of the first ships it was realised that a high number of species were transported in the fouling communities of ships' hulls, and frequent sampling of the fauna in the fouling community began. As sampling methods differed for the different parts of the ship, the comparison of hull fouling as a vector for introductions relative to ballast water and tank sediment was done on a qualitative basis only.

Ship Sampling

In total 132 ballast water samples, 131 hull samples and 71 sediment samples were taken from 186 ships visiting German ports between March 1992 and August 1995 (Table I). Ships for sampling were

chosen according to the type of vessel and the shipping route. The main focus was on container vessels, the prevailing type of shipping traffic in the North Sea region, but samples were also taken from other ship types, including bulk and oil carrier vessels, research vessels and cruiseliners. Ships travelling on the main shipping routes to the North Sea region (from Asia and North America) were emphasised. The shipping route of sampled vessels was documented according to the ships' log books. Ships travelling solely within the North Sea region were not sampled. The size of the sampled ships varied from 1,000 deadweight tonnage (dwt) to 45,330 dwt. Samples were taken according to the accessibility of sampling onboard and all individuals classified to species (below).

Most ballast water samples were taken by lowering a hose through the sounding pipe of the ballast tank, enabling ballast water to be pumped up (using a hand-pump) from a maximum depth of 7 m. A volume of 30–100 l was pumped up and sieved through a zooplankton net of 55 μm mesh size. A second method employed to sample ballast water consisted of lowering a cone-shaped zooplankton net (mesh size 55 μm , cone diameter 9.7 cm, net diameter 25 cm) through opened tank hatches (manholes) and pulling the net vertically through the water column. The sampling depth using this second technique varied from 2 m to 15 m according to the construction of the ballast tanks. However, support frames used to stabilise the tanks in many cases prevented the lowering of the plankton net to the bottoms of the tanks. Due to these and other difficulties, such as unremovable cargo on top of manholes, this second method was employed less than ten times.

Sediment samples were taken by climbing down to the bottom of emptied ballast tanks and pulling 11 jars with an opening of 6 cm through the sediment surface. The thickness of the sediment layer inside ballast tanks was measured in each tank at various

TABLE II Probability of colonization of non-native species according to matching climate (temperature) in donor and recipient regions (after Gollasch, 1996)

RECIPIENT region	DONOR region			
	Arctic & Antarctic	Cold-temperate	Warm-temperate	Tropics
Arctic & Antarctic	High	Medium	Low	Low
Cold-temperate	Medium	High	Medium	Low
Warm-temperate	Low	Medium	High	Medium
Tropics	Low	Low	Medium	High

locations. The maximum thickness of sediment in any tank was 50 cm, but in most tanks was <5 cm. Wherever possible at least 1 l (to a maximum of 3 l) of sediment was collected from each tank.

To sample organisms from the hull fouling community three heavily fouled areas (mostly in the stern section of the vessels) were chosen arbitrarily and sampled as replicates by scraping the fouling from 100 cm² of the ship's surface. Access to ships' hulls was only permitted in dry docks, when vessels had entered the dock to renew their antifouling paints as part of their regular interdocking period.

Organisms from all samples were preserved in ethanol (70%). For species identification stereomicroscopes and microscopes were used. For confirmation of identification, individuals were sent to recognized taxonomists (see Acknowledgements). Algae found in hull samples of ships were not considered in detail in this report as all algae found could only be identified to generic level or above, and determination of whether an organism is native or not is more difficult for taxonomic levels above that of species. Results for the phytoplankton and zooplankton community collected within the ballast water and sediment sampling are published elsewhere (Gollasch *et al.*, 2000; Lenz *et al.*, 2000).

Classification of Species

Four categories of species were defined from the samples, *viz.* native to the North Sea, established non-native (= established), non-established non-native (= non-native) and cryptogenic (the later are species whose status as introduced or native is unknown; Carlton, 1996). Established (non-native) species were defined as species originating from outside the North Sea, but which have been previously introduced and now form apparently self-sustaining populations in the North Sea. This contrasts with non-native species which are not known to occur as self-sustaining populations in the region (*i.e.* non-established). The status of species and the references used to determine the status of each species, are given in Appendix 1.

These categories of species were based on boundaries of the North Sea defined by the British Channel in the south, the Skagerrak and Kattegat in

the east and the Shetland Islands in the North, following definitions used by the North Sea Task Force (1993). The distribution of many species is confined to the Atlantic seaboard (Crisp & Southward, 1958; Southward, 1995), suggesting that there are environmental parameters distinguishing the North Sea. For example, the western part of the British Channel on average has warmer water temperatures and less severe winters. Many warm water species are common in the western part of the Channel, but fail to penetrate into the eastern part. The eastern part of the Channel is colder in winter, and is likely to be a distributional barrier for some warm water species (Crisp & Southward, 1958).

Risk Assessment of Species Introduction and Establishment

For all non-native species sampled from the ballast water, tank sediments and ships' hulls a qualitative assessment of the probability of establishment in the North Sea region was carried out (Table II). This used a previously developed scheme (Gollasch, 1996) which takes into account the climatic conditions (temperature) in the area of origin (donor area) and the recipient area. Based on the temperature regime in the area of origin *vs* the North Sea all non-native species were sorted into three categories, *viz.* establishment in the North Sea region improbable (Category 1), establishment of medium probability (Category 2) and establishment highly probable (Category 3).

RESULTS

The total species richness of all samples from the ballast water, tank sediment and hull fouling is given in Table III. Data on hull fouling are given in more detail in Appendix 1A. The most common fouling taxa were Crustacea (59 species, 53.6%) and Mollusca (30 species, 27.3%). Within the Crustacea, barnacles were most common (36 species), and in the Mollusca the Bivalvia prevailed with 28 species. The most common species was *Balanus improvisus* (Cirripedia), which was recorded from 87 ships. Fouling was heavy on some hulls, reaching 30 cm in thickness on

TABLE III Number of native, non-native and cryptogenic species found in all samples according to type of sample

Taxa in samples	Number					
	All species	Native species	All non-native and non-established species	Previously established species	Cryptogenic species	
Taxa in ballast samples	98	56	38	2	2	
Total						
Taxa in sediment samples	110	53	50	5	2	
Total						
Taxa in hull samples	110	26	75	6	3	
Total						
Foraminifera	1		1			
Cnidaria	6	4	1	1		
Hydrozoa	3	1	1	1		
Anthozoa	9	3	6			
Bryozoa	1				1	
Turbellaria	1					
Nematoda	1	1				
Mollusca						
Gastropoda	1		1			
Nudibranchia	1	1				
Bivalvia	28	6	19	2	1	
Crustacea						
Copepoda, Calanoida	1	1				
Cirripedia, Balanomorpha	36	3	30	2	1	
Cirripedia, Lepadomorpha	5		5			
Decapoda	7	3	4			
Isopoda	1		1			
Amphipoda	9	3	6			

The total number species was 257 (the "All species" categories sum to 318 species due to the occurrence of some species in both ballast tanks and hull fouling). Species from hull samples are classified to higher taxa below, with details on each species given in Appendix 1A

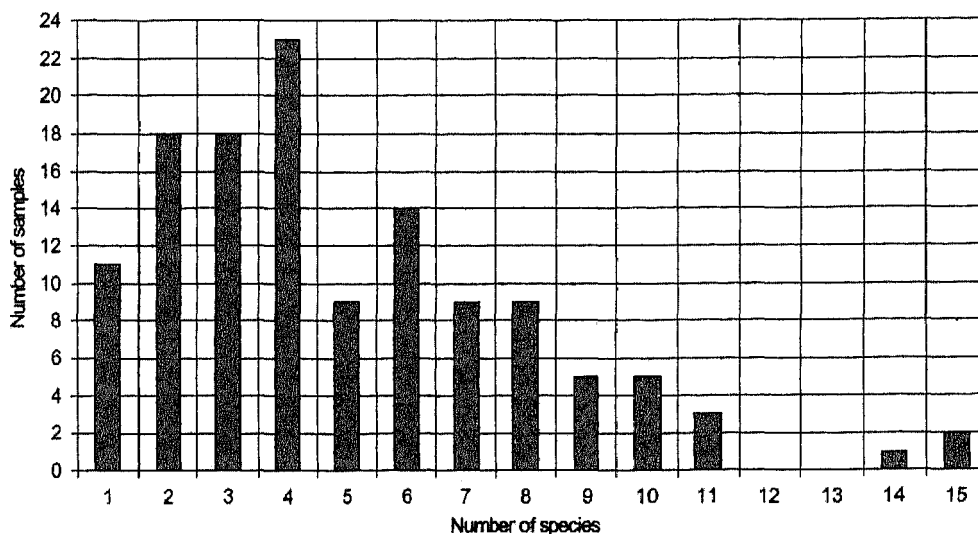


FIGURE 1 Frequency histogram of the number of species found per ship's hull.

some areas on one vessel. While most species of fouling organisms were sessile, 21% (23 species) of all species found on the ships' hulls were mobile. Mobile organisms from the fouling community consisted predominantly of Amphipoda, Isopoda and Decapoda and other crustaceans (Table III).

In total, 146 (57%) of the 257 species collected in all samples were classified as non-native to the North Sea region. Ten non-native species, predominantly identified from hull samples, were previously introduced into the North Sea region and had established self-sustaining populations (Appendix 1A). Nearly all (96.2%) samples from ships' hulls contained at least one non-native species. Fifteen species (of which 12 were identified as non-native) were found in samples from the hull of a single ship (Figure 1), with the average number per ship being 6.2 (range 0–15, SD = 3.8). The mean number of non-native species found per ship was 4.3 (range 0–11, SD = 1.9). Many of the non-native barnacles found occurred at high frequencies. *Balanus amphitrite* was found in hull samples from 64 ships, and *B. eburneus* in 43 samples.

The lowest number of non-native species (established and non-established) was found in ballast water samples (40 species, 41% of all species identified in ballast water samples). In sediment samples 55 non-native species (50% of all species identified in sediment samples) were collected. Hull samples contained 81 non-native species (74% of all species identified in hull samples), more than twice as many non-native species as in ballast water samples (Table III).

Four cryptogenic species were found, viz. *Cryptostylochus hullensis* (Turbellaria), *Mya arenaria* (Bivalvia), *Teredo navalis* (Bivalvia) and *Balanus improvisus* (Cirripedia). Most cryptogenic species were identified from hull samples. The only cryptogenic species

found in ballast water samples was (larval) *T. navalis*. No cryptogenic species were found in sediment samples (Appendix 1A). The turbellarian *Cryptostylochus hullensis* (Faubel & Gollasch, 1996) is a new species and was first found in a ship hull sample during this study.

Risk Assessment

The origin of the 146 non-native species in the samples was predominantly from warmer climatic regions than the North Sea (warm-temperate regions 60%, 88 species and the tropics 18%, 26 species; as per references in Appendix 1B). For these species an establishment along North Sea shores was assessed as unlikely. Thirty two of all the 146 non-native species (22%) originated from cold-temperate regions and regions near cold-temperate climatic zones outside Europe. The climatic conditions of these regions, in regard to extreme temperatures and daily and seasonal variation in temperatures is comparable to North Sea conditions. Therefore, these species are more likely to become introduced than species originating in warmer climate zones and were assigned to risk assessment Category 3 (establishment highly probable). The origin of these species was North America, predominantly from the east coast, the upwelling area off western Africa, the northern part of Japan, and cold-temperate climatic regions from the southern hemisphere. In this category, the prevailing taxa were Crustacea and Mollusca. According to the transport vector, the majority (19 of the 32 species or 59%) of the species with a high potential to become introduced was found in ships' hull samples (Table IV). In ballast water samples 25% (8 of all 32 species assigned to this category) and in sediment samples 16% (5 of all

TABLE IV Non-native species from ships' hull fouling with a high potential to become introduced to the North Sea

Species	Origin	Comment	References
<i>Bugula neritina</i>	Warm-temperate regions of New Zealand and Australia	Introduced to Hongkong, Wales and English Channel	Crisp & Southward, 1953; Walford & Wicklund, 1973; Morton, 1987
Bryozoa			
<i>Savignyiella</i>	Warm-temperate regions, Mediterranean Sea	Frequently found on ships' hulls	Osburn, 1914; Redfield <i>et al.</i> , 1952; Relini <i>et al.</i> , 1976; Pisano & Balduzzi, 1985
<i>Nassarius costellifera</i> Gastro-poda	Warm- to cold-temperate regions Atlantic Ocean		Grasse, 1968; Willmann, 1989
<i>Crassostrea virginica</i> Bivalvia	Cold-temperate to tropical regions of North American east coast	Frequently introduced as target species for aquaculture	Galtsoff, 1964; Hanna, 1966; Morris, 1973; Walford & Wicklund, 1973; Arakawa, 1990; Krantz, 1991
<i>Ostrea lurida</i> Bivalvia	Cold-temperate to tropical regions of North American west coast (Alaska to Baja California)	Frequently introduced as target species for aquaculture	Chew, 1979; Meinke, 1981; Lipton <i>et al.</i> , 1992; Santos <i>et al.</i> , 1993
<i>Erodium macroides</i> Bivalvia	Cold-temperate to tropical regions of South American east coast	Also recorded from brackish waters	Morris, 1973
<i>Macrura discors</i> Bivalvia	Warm-temperate regions of Pacific Ocean, New Zealand		Allan, 1962
<i>Musculus senhousii</i> Bivalvia	Cold-temperate to tropical regions of Far East (Russia to Singapore)	Introduced to San Francisco Bay, New Zealand, Australia and Mediterranean Sea	Carlton, 1969; Kuroda <i>et al.</i> , 1971; Willan, 1987; Zibrowius, 1991; Kimura & Sekiguchi, 1994
<i>Semita senilis</i> Bivalvia	Warm- to cold-temperate regions, north east Atlantic (west coast of Africa; Ghana, Senegal)	Also recorded from brackish waters	Yoloye, 1976; Lindner, 1990; Waller, 1980
<i>Xenostrobus securis</i> Bivalvia	Warm-temperate regions of Pacific Ocean (western Australia, New Zealand)	Another <i>Xenostrobus</i> species was introduced into the Mediterranean Sea	Straughan, 1973; Powell, 1979; Sabelli & Speranza, 1994
<i>Balanus amphitrite</i> Cirripedia	Warm-temperate regions of Japan and Korea	Wide spread throughout tropical and warm-temperate regions of all oceans. Records from southern Great Britain	Bishop, 1950; Allen, 1953; Rainbow, 1984
<i>Balanus campbelli</i> Cirripedia	Warm-temperate regions of New Zealand		Foster, 1978
<i>Balanus perforatus</i> Cirripedia	Warm- to cold-temperate regions, north east Atlantic (south-west coast of Great Britain to Africa, Mediterranean Sea)	Frequently found on ship hulls	Hentschel, 1923; Crisp & Southward, 1953; Bassindale, 1964; Southward, 1995
<i>Balanus variegatus</i> Cirripedia	Cold-temperate to tropical regions of Far East (Vladivostok to Sumatra), Australia, India	Frequently found on ships hulls	Nilsson-Cantell, 1994; Henry & McLaughlin 1975; Jones <i>et al.</i> , 1990; Anderson & Underwood, 1994; Dhandapani & Fernando, 1994
<i>Elminius kingii</i> Cirripedia	Cold-temperate regions of South America (up to Terra del Fuego)	Introduced to the east coast of Canada	Weltner 1898; Kühl, 1963; Graefe, 1968; Bourget, 1977; Stotz, 1988
<i>Elminius simplex</i> Cirripedia	Cold-temperate to tropical regions. Indian Ocean, Australia, South America	Introduced to the east coast of Canada	Weltner, 1898; Nilsson-Cantell, 1938; Pope, 1945; Bourget, 1977
<i>Hemigrapsus penicillatus</i> Decapoda	Warm-temperate regions of Far East (Japan, China, Korea)	Introduced to French Atlantic coast	Noel <i>et al.</i> , 1997; Gollasch, 1999, Türkay, personal communication
<i>Dynamene bilentata</i> Isopoda	Warm- to cold-temperate regions, north east Atlantic (Mediterranean Sea, Spain, English Channel)		Naylor, 1972; Silva & Fernandez, 1988; Arrontes & Anadon, 1990; Gruner <i>et al.</i> , 1993
<i>Paracamprella tenuis</i> Amphipoda	Arctic to cold-temperate regions of the west coast of North America and Gulf of Mexico		Barnard, 1958; Laubitz, 1972

32 species assigned to this category) were assigned to Category 3 (not shown).

DISCUSSION

All non-native species are potentially harmful unless it is shown that the risks involved are low or that the introduction of the species is beneficial. This uncertainty emphasises the need for a precautionary approach in order to minimize unintentional transport of species. For example, species which have no negative impact in the native area may cause unwanted economic effects or ecological changes elsewhere. Impacts could include competition with native species or the introduction of parasites and may result in changes in the abundance of native species (Rosenthal, 1980; Williams & Sindermann, 1991; Kern, 1994; Grosholz & Ruiz, 1995; Holmes & Minchin, 1995; Ribera & Boudouresque, 1995). Significant changes to the structure of food webs may result from the introduction of even a single non-native species. Recent invasions which have caused ecological and economical damages in various parts of the world are described by Carlton and Geller (1993), Hedgpeth (1993) and Gollasch and Mecke (1996).

The majority of previously introduced species in the North Sea are invertebrates, predominantly crustaceans, polychaetes and molluscs (Millar, 1960; Farnham, 1980; Reise, 1990; 1991; Utting & Spencer, 1992; Gollasch, 1996; Farnham & Critchley, 1997; Nehring & Leuchs, 1999). Most of these species have been introduced by ships (47 introductions) or through aquaculture activities (36 introductions). Nearly two thirds of the ship-mediated introductions were transported on ships' hulls (Reise *et al.*, 1999). British and Australian investigations have also suggested that hull fouling may have been the most important vector for species introductions in the past (Eno *et al.*, 1997, Hewitt, personal communication).

Many of the 81 non-native species found in the hull samples are distributed over a wide geographical range, possibly due to earlier shipping activities (Gollasch, 1996; Lenz *et al.*, 2000). It should be noted that 23% of the species classified as non-native are either native or previously introduced to coasts along the north east Atlantic ocean, including the west coast of the British Isles, but have not been recorded from the North Sea. These species might invade the North Sea region by means of natural range expansion or secondary introduction, although the British Channel seems to be a migration barrier for warm water species (Crisp & Southward, 1958; Southward, 1995). However, for these reasons possible future occurrences of these invaders in the

North Sea cannot be attributed to the transport *via* ships' hull fouling alone.

In this investigation 110 species were identified from hull fouling samples. Past shipping studies of docked vessels revealed 22 to 107 different species (Visscher, 1927; Bertelsen & Ussing, 1936; Skerman, 1960; Southward & Crisp, 1963; Hardy, 1981). The most frequently encountered species were members of the Cirripedia and Bivalvia (Hentschel, 1923; Zvyagintsev & Mikhailov, 1978). As reported in this study, Pyefinch (1950) also collected Cirripedia from 92% of the ships investigated. The second most frequent organisms were tube worms (Pyefinch, 1950) followed by members of the Cnidaria, Bryozoa, Mollusca and Cirripedia (Neu, 1932a; 1932b). The maximum number of organisms on a ship's hull (107 *B. improvisus* and 64 *M. edulis* 100 cm⁻²) was comparable to data from Hentschel (1923) who collected a maximum of 147 Balanidae 100 cm⁻².

The fouling community on ships is comprised not only of sessile organisms, but also mobile organisms (Chilton, 1911; Carlton, 1979). Neu (1932a) assumed that mobile organisms in the fouling community would be removed from hulls during voyages due to the strong water currents induced by the ships movement. Ships are now faster than in Neu's time, with many reaching a cruising speed >10 ms⁻¹. However, mobile organisms, such as *Hemigrapsus penicillatus* (Decapoda, Reptantia), recently introduced to Europe and native to Asia (Noel *et al.*, 1997), were found during this study in empty barnacle shells in the hull fouling (Gollasch, 1999). More generally, mobile organisms can be transported for weeks or months amongst the fouling assemblage in, for example, empty shells of barnacles, or by sheltering in densely fouled areas of the hull.

The potential of all non-native species identified to become successfully introduced was estimated according to matching temperatures in the area of origin and the North Sea region. Species in Category one are unlikely to become introduced (non-matching climates). Most of the non-native species recorded were determined as belonging to Category two, in which establishment shows medium probability. These species might become introduced if the water temperature increases due to global warming or on a smaller scale from (*e.g.*) the heated effluents of power plants. After adaptation to local conditions, species might be able to spread, as documented for the introduced polychaete *Mercierella enigmatica* in the 1970s (Kühl, 1977). The species was first recorded near a power plant and spread into a wide range of habitats after several years of a locally limited distribution (Kühl, 1977).

Thirty two species (22% of all non-native species found) were classified as having the potential for successful introduction (matching climate of donor and recipient region). Most (19 species, Table IV) of

the species in this category were sampled from ships' hulls. Among others, the decapod *Hemigrapsus penicillatis*, native to the cold-temperate areas of Japan, was listed in this category before first records from European coasts were published (Noel *et al.*, 1997). The introduction of *H. penicillatus* indicates that the proposed species classification gives a useful first estimate of the probability of establishment and indicates the importance of matching climate in donor and recipient areas for the successful colonisation of new habitats.

Accurate conclusions based on the results of shipping studies are only valid if the sampling techniques used were adequate. Given that sampling of ships is different from sampling natural communities in the field, and the constraints imposed by ships' operations, the best methods available were used. For example, during an intercalibration experiment different sampling methods previously used during ballast water studies in Australia, Canada, China Germany, Israel, Lithuania, Norway, the United Kingdom and the USA were compared. After a plankton tower was spiked with a known density of *Artemia salina* and oyster larvae all methods were used consecutively. As a result, the efficiency of all methods employed in this intercalibration experiment was ranked. The methods used in this shipping study were highly ranked as being efficient in the recovery of species from ballast tanks (Gollasch *et al.*, personal observations).

More generally, although hull fouling samples contained a higher number of non-native species than ballast water and tank sediments, sampling methods differed substantially between ships' hulls, sediments and ballast water. Thus comparisons can only be made on a qualitative basis. For example, comparisons between the three different transport vectors (ballast water, tank sediment and hull fouling) may be biased because organisms can more easily hide in ballast tanks than in hull fouling. Additionally the ships sampled entered dockyards after the usual interdocking period when the hulls are heavily fouled and heavily fouled hull areas were arbitrarily chosen for sampling. Furthermore, three replicates were taken from the hull fouling compared to one sample of ballast water and tank sediments. Therefore, the importance of hull fouling as a transport vector may have been overemphasised. However, the results clearly show that hull fouling is an important vector and possibly the most important vector of species introductions into the North Sea region.

CONCLUSIONS

The overall impact of introduced species in the North Sea to date may be "additive", as

replacements of native species have not yet been reported. Thus the North Sea may be capable of accommodating some invaders, but each species invasion still has the potential to severely alter the environment. Thus a precautionary approach to prevent or minimize future introductions should be given high priority (Reise *et al.*, 1999), since the eradication of an introduced species once established will be either very expensive or even impossible (Peters *et al.*, 1936; Critchley *et al.*, 1986; Riberia & Boudouresque, 1995; Schaffelke *et al.*, 2000). These measures should not focus on species transported in ballast tanks alone, but should take into account introductions as a result of the transport of organisms in the fouling of ships' hulls, since hull fouling was clearly an important vector for species introductions.

The importance of hull fouling as vector of species introductions may not be generally appreciated. Each vessel calling at North Sea ports is a potential carrier of non-native organisms capable of establishing a founder population. Most vessels carried native and non-native species of different origins, highlighting the fact that the North Sea region is not only a receiving area, but a donor area for species transported to other regions. Public awareness campaigns could create a more realistic focus on the essential environmental concerns related to hull fouling while highlighting the potential impacts caused by species introductions.

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APPENDIX 1A

List of all species recorded, according to stage (l = larvae, j = juvenile, a = adult, r = resting stages), sample (B = ballast water, S = sediment, H = hull, (H) = mobile species in hull samples) and status (native, non-native, cryptogenic and established in the North Sea region). Climate of source region of non-native species: AT = arctic region, CT = cold-temperate region, WT = warm-temperate region, TR = tropical region. Species are listed in alphabetical order within each taxonomic group. Reference numbers refer to references in Appendix 1B

TABLE AI

Species	Taxon	Stage	Sample	Status/climatic source	Reference
<i>Ammonia beccarii</i>	Foraminifera	a	S	native	34
<i>Brizalina variabilis</i>	Foraminifera	a	S	native	34
<i>Elphidium articulatum</i>	Foraminifera	a	S	native	34
<i>Elphidium crispum</i>	Foraminifera	a	S	non-native, WT	132
<i>Elphidium cf. excavatum</i>	Foraminifera	a	S	native	34
<i>Globorotalia tumida</i>	Foraminifera	a	S	non-native, WT-TR	132
<i>Planorbulina mediterraneensis</i>	Foraminifera	a	S (H)	non-native, WT	78
<i>Rosalina bradyi</i>	Foraminifera	a	S	non-native, WT-TR	78
<i>Spiroculina communis</i>	Foraminifera	a	S	non-native, WT-TR	132
<i>Clytia hemisphaerica</i>	Hydrozoa	a	H	native	117
<i>Cordylophora caspia</i>	Hydrozoa	a	H	established, WT-CT	6,103
<i>Laomedea angulata</i>	Hydrozoa	a	H	native	20
<i>Obelia cf. bidentata</i>	Hydrozoa	a	H	native	15,45,60
<i>Obelia dichotoma</i>	Hydrozoa	a	H	native	15,45,60
<i>Obelia longissima</i>	Hydrozoa	a	H	native	15,45,60
<i>Diadumene cf. cincta</i>	Actinaria	a	H	established, WT	45,103
<i>Haliplanella luciae</i>	Actinaria	a	H	non-native, WT	95,103
<i>Sagartiogeton undatus</i>	Actinaria	a	H	native	14,51,95
<i>Bugula neritina</i>	Bryozoa	a	H	non-native, WT	103,78
<i>Conopeum reticulatum</i>	Bryozoa	a	S H	native	51,136
<i>Cryptosula pallasiana</i>	Bryozoa	a	H	native	51,136
<i>Membranipora tenuis</i>	Bryozoa	a	H	non-native, WT-TR	101
<i>Membranipora tuberculata</i>	Bryozoa	a	S H	non-native, WT-TR	101
<i>Savignyella lafontii</i>	Bryozoa	a	H	non-native, WT	105
<i>Schizoporella errata</i>	Bryozoa	a	H	native	51
<i>Thalamoporella rozieri</i>	Bryozoa	a	H	non-native, WT-TR	101
<i>Watersipora arcuata</i>	Bryozoa	a	S H	non-native, WT-TR	7
<i>Cryptostylochus hullensis</i>	Turbellaria	a	(H)	cryptogenic, CT	27
<i>Anuraeopsis fissa</i>	Rotatoria	a	B	native	59
<i>Brachionus budapestensis</i>	Rotatoria	a	B	native	59,130
<i>Brachionus calyciflorus anuraeiformis</i>	Rotatoria	a	B S	native	59,130
<i>Brachionus diversicornis</i>	Rotatoria	a	B	native	59,130
<i>Brachionus quadridentatus rhenanus</i>	Rotatoria	a	B	native	59,130,124
<i>Brachionus urceolaris</i>	Rotatoria	a	B S	native	59,130,124
<i>Keratella cochlearis cochlearis</i>	Rotatoria	a	B	native	59,106,124
<i>Keratella cochlearis tecta</i>	Rotatoria	a	B	native	59,106
<i>Keratella irregularis</i>	Rotatoria	a	B	native	59,106
<i>Keratella quadrata reticulata</i>	Rotatoria	a	B S	native	59,106,124
<i>Oncholaimus oxyuris</i>	Nematoda	j a	B S (H)	native	112,113
<i>Tripoloides marinus</i>	Nematoda	j a	S	native	112

TABLE AI - continued

Species	Taxon	Stage	Sample	Status/climatic source	Reference			
<i>Atlanta cf. oligogyra</i>	Gastropoda	a	S	non-native, TR	131			
<i>Cavolinia inflexa imitans</i>	Gastropoda	a	S	non-native, TR	54			
<i>Cavolinia longirostris limbata</i>	Gastropoda	a	S	non-native, TR	54			
<i>Clio pyramidata lanceolata</i>	Gastropoda	a	S	non-native, TR	65			
<i>Crepidula cf. fornicata</i>	Gastropoda	a	S	established, CT	104,103,148			
<i>Facelina cf. auriculata</i>	Gastropoda	a	(H)	native	16,45,51			
<i>Limacina cf. helicina helicina</i>	Gastropoda	l	S	established, CT	145			
<i>Limacina cf. inflata</i>	Gastropoda	l	S	non-native, TR	22,125			
<i>Limacina cf. lesueuri</i>	Gastropoda	l	S	non-native, WT	108			
<i>Limacina cf. trochiformis</i>	Gastropoda	l	B	non-native, TR	125			
<i>Nassarius costellifera</i>	Gastropoda	a	(H)	non-native, CT-WT	42			
<i>Anadara cf. scapha</i>	Bivalvia	j	H	non-native, TR	2			
<i>Anadara cf. subcrenata</i>	Bivalvia	l	H	non-native, TR	41			
<i>Anomia cf. ephippium</i>	Bivalvia	a	S	native	51,91,147			
<i>Anomia simplex</i>	Bivalvia	a	S	H	non-native, WT-TR	120		
<i>Argopecten irradians</i>	Bivalvia	a	S	non-native, CT-WT	77			
<i>Astarte borealis</i>	Bivalvia	a	S	native	91,92,147			
<i>Cerastoderma edule</i>	Bivalvia	a	S	native	50,52,113			
<i>Cerastoderma lamarcki</i>	Bivalvia	a	S	native	50,91,147			
<i>Chama macerophylla</i>	Bivalvia	a	H	non-native, WT-TR	77			
<i>Chione cancellata</i>	Bivalvia	a	H	non-native, WT-TR	77			
<i>Corbula barrattiana</i>	Bivalvia	a	S	non-native, WT-TR	1			
<i>Corbula gibba</i>	Bivalvia	a	S	native	91,92,147			
<i>Crassostrea gigas</i>	Bivalvia	l	j	B	H	established, CT-WT	82,103	
<i>Crassostrea Virginica</i>	Bivalvia	a	S	H	non-native, CT-TR	77,137		
<i>Cryptomya californica</i>	Bivalvia	a	S	S	non-native, WT-TR	1		
<i>Dreissera bugensis</i>	Bivalvia	a	S	H	non-native, CT-WT	72		
<i>Dreissera polymorpha</i>	Bivalvia	a	S	H	established, CT-WT	6		
<i>Erodona mactroides</i>	Bivalvia	a	S	H	non-native, CT-TR	77		
<i>Lyrodus pedicellatus</i>	Bivalvia	l	B	B	non-native, WT-TR	13		
<i>Macoma balthica</i>	Bivalvia	a	S	S	native	17,104,113		
<i>Macra corallina</i>	Bivalvia	l	B	S	native	91,147		
<i>Macra discors</i>	Bivalvia	a	H	H	non-native, WT	2		
<i>Macra glauca</i>	Bivalvia	a	S	S	non-native, CT-WT	91,129		
<i>Macra nitida</i>	Bivalvia	a	H	H	non-native, WT-TR	2		
<i>Macra turgida</i>	Bivalvia	a	H	H	non-native, TR	2		
<i>Modiolus barbatus</i>	Bivalvia	l	B	S	non-native, CT-WT	91,92		
<i>Modiolus cf. demissus</i>	Bivalvia	l	B	S	non-native, CT	121		
<i>Modiolus modiolus</i>	Bivalvia	l	a	S	H	native	91,102,147	
<i>Mulinia portoricensis</i>	Bivalvia	a	H	H	non-native, TR	1,77		
<i>Musculus discors</i>	Bivalvia	a	H	H	native	91,147		
<i>Musculus niger</i>	Bivalvia	a	H	H	native	147		
<i>Musculus senhousei</i>	Bivalvia	a	H	H	non-native, CT-TR	115,141		
<i>Mya arenaria</i>	Bivalvia	a	S	H	cryptogenic, CT	55,91,147		
<i>Mytilus edulis</i>	Bivalvia	l	a	B	S	H	Native	4,50,53,144
<i>Mytilus cf. galloprovincialis</i>	Bivalvia	l	S	S	non-native, WT	91,142		
<i>Ostrea cucullata</i>	Bivalvia	a	H	H	non-native, WT-TR	44		
<i>Ostrea edulis</i>	Bivalvia	l	a	S	H	native	15	
<i>Ostrea lurida</i>	Bivalvia	a	S	H	non-native, CT-WT	18		
<i>Parvicardium ovale</i>	Bivalvia	a	S	S	native	91,147		
<i>Placamen tiara</i>	Bivalvia	a	S	S	non-native, TR	139		
<i>Senilia senilis</i>	Bivalvia	a	H	H	non-native, CT-WT	143		
<i>Spisula elliptica</i>	Bivalvia	a	H	H	non-native, CT-WT	92		
<i>Spisula solida</i>	Bivalvia	a	H	H	native	91,147		
<i>Telemacra abbreviata</i>	Bivalvia	a	H	H	non-native, TR	139		
<i>Tellina fabula</i>	Bivalvia	a	S	S	native	91,147		
<i>Teredo navalis</i>	Bivalvia	l	B	S	cryptogenic, TR	51,113		
<i>Venus fasciata</i>	Bivalvia	a	S	S	native	91,147		
<i>Xenostrobus cf. securis</i>	Bivalvia	a	H	H	non-native, WT	123		
<i>Capitella capitata</i>	Polychaeta	a	S	S	native	37,104		
<i>Marcierella enigmatica</i>	Polychaeta	a	S	S	established, WT-TR	63,145,146		
<i>Hydroides elegans</i>	Polychaeta	a	S	S	non-native, WT-TR	6,37,103		
<i>Nereis pelagica</i>	Polychaeta	a	S	S	native	16,37		
<i>Nereis succinea</i>	Polychaeta	a	S	S	native	37		
<i>Alona rectangular</i>	Cladocera	a	B	B	native	6,73		
<i>Bosmina coregoni martima</i>	Cladocera	j	a	B	S	native	6,73	
<i>Bosmina longirostris</i>	Cladocera	j	a	B	S	native	6,73,113	
<i>Chydorus cf. sphaericus</i>	Cladocera	a	B	S	native	100		
<i>Daphnia cucullata incerta</i>	Cladocera	a	B	S	native	6,73,124		
<i>Daphnia galeata</i>	Cladocera	j	a	r	B	S	native	6,73,113
<i>Ilyocryptus sordidus</i>	Cladocera	j	a	r	B	S	native	73
<i>Leydigia acanthoceroides</i>	Cladocera	a	r	B	S	native	73	

TABLE AI - continued

Species	Taxon	Stage	Sample	Status/climatic source	Reference
<i>Moina micrura</i>	Cladocera	r	S	non-native, WT-TR	47
<i>Simocephalus expinosus</i>	Cladocera	a	B	native	73,113
<i>Cyprideis salebrosa</i>	Ostracoda	a	S	non-native, WT-TR	122
<i>Acartia bifilosa inermis</i>	Calanoida	a	B	native	74,96,111
<i>Acartia clausi</i>	Calanoida	j	B	native	74,96,111
<i>Acartia discaudata</i>	Calanoida	a	B	native	74,96
<i>Acartia grani</i>	Calanoida	a	B	non-native, CT	119
<i>Acartia hudsonica</i>	Calanoida	a	B	non-native, CT	10
<i>Acartia latisetosa</i>	Calanoida	a	B	non-native, WT	119
<i>Acartia lilljeborgi</i>	Calanoida	a	S	non-native, WT-TR	39
<i>Acartia tonsa</i>	Calanoida	j	B	established, CT-WT	58,103
<i>Calanus finmarchicus</i>	Calanoida	a	B	native	74,96,111
<i>Calanus helgolandicus</i>	Calanoida	a	(H)	native	74,96
<i>Centropages furcatus</i>	Calanoida	a	B	non-native, WT-TR	39
<i>Centropages hamatus</i>	Calanoida	a	B	native	74,96,111
<i>Centropages typicus</i>	Calanoida	a	B	native	74,96,111
<i>Centropages velificatus</i>	Calanoida	a	B	non-native, TR	29
<i>Eurytemora affinis</i>	Calanoida	a	B	native	74,96,138
<i>Eurytemora hirundo</i>	Calanoida	a	B	native	74,96
<i>Eurytemora hirundoides</i>	Calanoida	a	B	native	74,96
<i>Metridia brevicauda</i>	Calanoida	a	B	non-native, WT	128
<i>Paracalanus cf. denudatus</i>	Calanoida	a	B	non-native, WT-TR	135
<i>Paracalanus cf. parvus</i>	Calanoida	a	B	native	74,75,96
<i>Pseudocalanus elongatus</i>	Calanoida	a	B	native	32,75,96
<i>Pseudocyclops crassiremis</i>	Calanoida	a	B	non-native, CT	107
<i>Temora longicornis</i>	Calanoida	a	B	native	74,96,111
<i>Temora stylifera</i>	Calanoida	a	B	non-native, TR	29,39,135
<i>Acanthocyclops robustus</i>	Cyclopoida	a	B	native	96
<i>Oithona amazonica</i>	Cyclopoida	a	B	non-native, TR	70
<i>Oithona brevicornis</i>	Cyclopoida	a	B	non-native, WT-TR	107
<i>Oithona hebes</i>	Cyclopoida	a	B	non-native, WT-TR	39,107
<i>Oithona helgolandica</i>	Cyclopoida	a	B	native	96
<i>Oithona nana</i>	Cyclopoida	a	B	non-native, WT-TR	33,107
<i>Ectinosoma cf. minor</i>	Harpacticoida	a	S	native	23,76,90
<i>Enhydrosoma propinquum</i>	Harpacticoida	a	S	native	23,97
<i>Euterpina acutifrons</i>	Harpacticoida	a	B	native	23,76,90
<i>Longipedia rosea</i>	Harpacticoida	a	B	native	23,76,90
<i>Macrosetella gracilis</i>	Harpacticoida	a	B	non-native, WT-TR	93
<i>Microarthridion littorale</i>	Harpacticoida	a	B	native	23,97
<i>Microsetella norvegica</i>	Harpacticoida	a	B	native	23,76,90
<i>Microsetella rosea</i>	Harpacticoida	a	B	non-native, TR	93
<i>Pseudonychocamptus koreni</i>	Harpacticoida	a	B	non-native, WT	67
<i>Tachidius discipulus</i>	Harpacticoida	a	B	native	23,97
<i>Tisbe elegantula</i>	Harpacticoida	j	B	non-native, CT-WT	66
<i>Tisbe furcata</i>	Harpacticoida	a	B	native	76,90,99
<i>Tisbe graciloides</i>	Harpacticoida	a	B	non-native, WT	66
<i>Tisbe gurneyi</i>	Harpacticoida	a	B	non-native, CT	66
<i>Tisbe inflata</i>	Harpacticoida	a	B	non-native, CT	66
<i>Tisbe longicornis</i>	Harpacticoida	a	B	native	76,90,99
<i>Tisbe wilsoni</i>	Harpacticoida	a	B	non-native, CT	66
<i>Corycaeus anglicus</i>	Poecilostomatoida	a	B	native	40
<i>Corycaeus brehmi</i>	Poecilostomatoida	a	B	non-native, WT	107
<i>Corycaeus latus</i>	Poecilostomatoida	a	B	non-native, TR	26
<i>Lubbockia aculeate</i>	Poecilostomatoida	a	B	non-native, CT	36
<i>Oncaea dentipes</i>	Poecilostomatoida	a	B	non-native, WT-TR	26
<i>Oncaea mediterranea</i>	Poecilostomatoida	a	B	non-native, WT-TR	26
<i>Oncaea subtilis</i>	Poecilostomatoida	a	B	native	133
<i>Oncaea venusta</i>	Poecilostomatoida	a	B	non-native, WT-TR	26
<i>Saphirella cf. tropica</i>	Poecilostomatoida	a	B	non-native, TR	84
<i>Acasta nitida</i>	Cirripedia	a	H	non-native, WT-TR	140
<i>Balanus amaryllis</i>	Cirripedia	a	S	non-native, WT-TR	85
<i>Balanus amphitrite amphitrite</i>	Cirripedia	a	S	non-native, WT	3,103
<i>Balanus amphitrite cirratus</i>	Cirripedia	a	S	non-native, TR	85
<i>Balanus amphitrite cochinchinensis</i>	Cirripedia	a	H	non-native, TR	89
<i>Balanus amphitrite communis</i>	Cirripedia	a	S	non-native, WT-TR	85,89
<i>Balanus amphitrite kruegeri</i>	Cirripedia	a	H	non-native, TR	86
<i>Balanus balanoides</i>	Cirripedia	a	S	native	11,51,62,71
<i>Balanus balanus</i>	Cirripedia	l	B	native	51,62,71
<i>Balanus campbelli</i>	Cirripedia	a	S	non-native, WT	31
<i>Balanus citerosum</i>	Cirripedia	a	H	non-native, WT-TR	49
<i>Balanus concavus</i>	Cirripedia	a	H	non-native, WT-TR	49,86
<i>Balanus crenatus</i>	Cirripedia	a	S	native	5,11,62,71

TABLE AI - continued

Species	Taxon	Stage	Sample	Status/climatic source	Reference
<i>Balanus denticaricus</i>	Cirripedia	a	H	non-native, TR	49
<i>Balanus eburneus</i>	Cirripedia	a	H	established, TR	103,116
<i>Balanus improvisus</i>	Cirripedia	l	B S	cryptogenic, TR	4,6,30,61
<i>Balanus kondakovi</i>	Cirripedia	a	H	non-native, WT-TR	49
<i>Balanus perforatus</i>	Cirripedia	a	S	non-native, CT-WT	21
<i>Balanus reticulatus</i>	Cirripedia	a	S	non-native, WT-TR	49
<i>Balanus subalbidus</i>	Cirripedia	a	H	non-native, WT-TR	49
<i>Balanus trigonus</i>	Cirripedia	a	S	non-native, WT-TR	3,89
<i>Balanus uliginosis</i>	Cirripedia	a	S	non-native, WT-TR	134
<i>Balanus variegatus</i>	Cirripedia	a	S	non-native, CT-TR	49
<i>Conchoderma auritum</i>	Cirripedia	a	H	non-native, WT-TR	140
<i>Conchoderma virgatum</i>	Cirripedia	a	H	non-native, WT-TR	140
<i>Elminius kingii</i>	Cirripedia	a	H	non-native, CT	140
<i>Elminius modestus</i>	Cirripedia	a	H	established, TR	103,116
<i>Elminius simplex</i>	Cirripedia	a	S	non-native, CT-TR	89,140
<i>Lepas anatifera</i>	Cirripedia	a	H	non-native, WT-TR	85
<i>Lepas anserifera</i>	Cirripedia	a	H	non-native, WT-TR	85
<i>Lepas hillii</i>	Cirripedia	a	H	non-native, WT-TR	85
<i>Megabalanus decorus</i>	Cirripedia	a	H	non-native, WT-TR	31
<i>Megabalanus spinosus</i>	Cirripedia	a	H	non-native, WT	83
<i>Megabalanus tintinnabulum linzei</i>	Cirripedia	a	H	non-native, WT	31
<i>Megabalanus tintinnabulum rosa</i>	Cirripedia	a	H	non-native, WT-TR	85
<i>Megabalanus tintinnabulum tintinnabulum</i>	Cirripedia	a	S	non-native, WT-TR	89
<i>Megabalanus tintinnabulum volcano</i>	Cirripedia	a	H	non-native, WT-TR	89
<i>Octomeris angulosa</i>	Cirripedia	a	H	non-native, WT-TR	85
<i>Tesseropora wireni</i>	Cirripedia	a	H	non-native, TR	87
<i>Tetraclita aoranga</i>	Cirripedia	a	s	non-native, WT-TR	85,88
<i>Tetraclita purpurascens</i>	Cirripedia	a	H	non-native, WT-TR	85,86,89
<i>Tetraclita squamosa squamosa</i>	Cirripedia	a	H	non-native, WT-TR	85
<i>Mesopodopsis slabberi</i>	Mysidacea	j	B	native	6,64,136
<i>Neomysis integer</i>	Mysidacea	a	B	native	6,64,113
<i>Paramysis kervillei</i>	Mysidacea	a	B	native	6,64,113
<i>Cymodoce truncata</i>	Isopoda	a	B	non-native, CT	81
<i>Dynamene bidentata</i>	Isopoda	a	(H)	non-native, CT-WT	81
<i>Sphaeroma rugicauda</i>	Isopoda	a	S	native	43,113
<i>Corophium acherusicum</i>	Amphipoda	a	B S	(H) non-native, WT-TR	8
<i>Corophium acutum</i>	Amphipoda	a	(H)	non-native, WT-TR	69
<i>Corophium lacustre</i>	Amphipoda	a	S	(H) native	38,57,110
<i>Corophium uenoi</i>	Amphipoda	a	(H)	non-native, WT	9
<i>Erichthonius brasiliensis</i>	Amphipoda	a	B	(H) non-native, WT-TR	9
<i>Gammarus salinus</i>	Amphipoda	a	S	native	56,110,114
<i>Gammarus zaddachi</i>	Amphipoda	a	B S	native	56,110,114
<i>Jassa cf. falcata</i>	Amphipoda	a	(H)	native	5,51,57
<i>Jassa cf. marmorata</i>	Amphipoda	a	S	non-native, WT	9
<i>Leptocheirus pilosus</i>	Amphipoda	a	(H)	native	57
<i>Microdeutopus gryllotalpa</i>	Amphipoda	A	S	native	57
<i>Paracaprella cf. tenuis</i>	Amphipoda	a	B	(H) non-native, AT-CT	8
<i>Stenothoe tergestina</i>	Amphipoda	a	(H)	non-native, WT	68
<i>Alpheus bourvieri</i>	Decapoda	a	(H)	non-native, WT	19
<i>Ashtoret lunaris</i>	Decapoda	a	S	non-native, WT-TR	35
<i>Brachynotus sexdentatus</i>	Decapoda	a	(H)	non-native, WT	80
<i>Callinectes sapidus</i>	Decapoda	a	S	non-native, WT-TR	127,103
<i>Cancer pagurus</i>	Decapoda	j	(H)	native	16,45,109
<i>Carcinus maenas</i>	Decapoda	a	S	native	4,5,113,118
<i>Charybdis cf. feriatus</i>	Decapoda	j	S	non-native, WT-TR	12,94
<i>Crangon crangon</i>	Decapoda	j	B S	native	46,109,136
<i>Eriocheir sinensis</i>	Decapoda	a	S	established, WT-TR	98,103
<i>Hemigrapsus penicillatus</i>	Decapoda	a	(H)	non-native, WT	100
<i>Pachygrapsus gracilis</i>	Decapoda	j	(H)	non-native, TR	24
<i>Palaemon longirostris</i>	Decapoda	a	(H)	native	109
<i>Pirimela denticulate</i>	Decapoda	l	B	(H) native	109
<i>Portunus pelagicus</i>	Decapoda	j	S	non-native, TR	12
<i>Portunus cf. sanguinolentus</i>	Decapoda	a	S	non-native, WT-TR	126
<i>Petromyzon marinus</i>	Agnatha	a	S	native	79
<i>Allosmerus cf. elongatus</i>	Pisces	l	B	non-native, CT-WT	25
<i>Ammodytes lobianus</i>	Pisces	a	S	native	79
<i>Anguilla anguilla</i>	Pisces	a	S	native	48,79
<i>Clupea harengus</i>	Pisces	a	B	native	28,48,79
<i>Gasterosteus aculeatus</i>	Pisces	a	B S	native	48,79
<i>Osmerus eperlanus</i>	Pisces	a	B S	native	48,79,106
<i>Pomatoschistus minutus</i>	Pisces	a	B S	native	48,79
<i>Sprattus sprattus</i>	Pisces	a	B S	native	48,79
<i>Syngnathus rostellatus</i>	Pisces	a	B	native	28,79

APPENDIX 1B

References used to classify species as native, non-native or established (see Appendix 1A).

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