National checklist for aquatic alien species in Germany

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Abstract

More than 140 aquatic alien species (AAS) have been reported from coastlines of the North Sea and the Baltic Sea and from inland waters within the national borders of Germany. The majority of these species has established self-sustaining populations. The most important vectors of introduction are shipping, species imports for aquaculture purposes and species imports as part of the ornamental trade. Several AAS have reached German waters via shipping canals. Many species show a locally limited distribution, but almost half of all AAS have spread successfully across larger areas. Several introduced species are abundant and approximately 20% of all AAS in Germany can be considered as invasive. Prime source regions are the north-western Atlantic, the Indo-Pacific, and the Ponto-Caspian region. For all source regions considered, the invasion rate has been increasing since the end of the last century.

Key words: Germany, North Sea, Baltic Sea, inland waters, aquatic species introductions, shipping, aquaculture, population status, invasive

Introduction

Invasive alien species may threaten native species, alter habitats, and even affect ecosystem function (e.g. Eno et al. 1997, Nehring and Leuchs 1999, Wolff 2005), and thus represent a significant risk to the receiving environments. Following direct habitat destruction, invasive alien species are considered as the second most important cause of global biodiversity change (CBD 2000).

One of the first summaries of aquatic invaders in German coastal waters was prepared by Gollasch (1996). In 1997 Eno et al. published a summary of coastal aquatic alien species in the United Kingdom. Nehring and Leuchs (1999), Nehring (2000a), and Tittizer et al. (2000) published overviews on “neozoans” of the German macroinvertebrate fauna. In 1999, Reise et al. published a summary of invasive species in the North Sea and several regional updates were published thereafter: e.g. Weidema (2000) for Nordic countries, Nehring (2005) and AeT umweltplanung (2006) for Germany, Jensen and Knudsen (2005) for Denmark and Wolff (2005) for The Netherlands. In 2006 Gollasch published an overview on introduced aquatic species known from European coasts. Here we update the earlier summaries of alien species in German inland and coastal waters. Another data set of aquatic invaders, which contains more comprehensive information for each species listed, is prepared by the authors for the currently ongoing EU-Programme Delivering Alien Invasive Species Inventories for Europe (DAISIE, see http://www.daisie.se for details).
Aquatic alien species (AAS) in Germany

A total of 141 non-native taxa were reported from the waters considered in this overview, i.e. the coasts of the North Sea and the Baltic Sea and the inland waters within the national borders of Germany (Annex). The vast majority of these species were introduced by ship traffic and, intentionally, by stocking or for aquaculture. Species which reached the region on their own i.e. via drift with currents, swimming, or other ways of natural range expansion, were excluded from this overview. Most AAS have been reported from inland waters, followed by the coastal waters of the North Sea and the Baltic Sea.

More than two thirds of the known introduced species have established self-sustaining populations (Table 1). Some species were only recorded over a certain time period (e.g. the Hydrozoa Bougainvillia macloviana Lesson, 1830 the Anthozoa Haliplanella luciae (Verrill, 1898) and the Bivalvia Crassostrea virginica (Gmelin, 1791) and have since become extinct (Annex).

| Region        | All species | Established species |
|---------------|-------------|---------------------|
| Baltic Sea    | 34          | 28                  |
| North Sea     | 62          | 49                  |
| Inland waters | 86          | 82                  |

Intentional fish introductions were predominantly motivated by a perceived improvement to the inland fisheries. About 70 “alien” fish species have been recorded in German waters (Geiter et al. 2002). A two century history of fish stocking and translocation makes it impossible to reconstruct the native range of most alien commercial fish species and their phylogeographic structure might also have been obscured. Consequently, some of these 70 species are considered as cryptogenic (see below). At present, ten fish species have been recognized as aliens and are established in self-sustaining populations with locally restricted distribution.

The invasion rate has been increasing in all waters since the end of the last century, with the highest rate of increase found in inland waters (Figure 1). It is anticipated that more species were found in recent years as new findings are usually published with a time-lag. Many of the alien species are at least locally abundant (Table 2) and nearly half of all AAS have spread successfully across a larger area. A few alien species have developed large populations and mass developments have been observed as, for example, for the Chinese mitten crab Eriocheir sinensis Milne-Edwards, 1854 in German inland waters (Figure 2).

Figure 1. Number of aquatic species introductions into German waters for 20 year intervals between 1850 and 2006.

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Major natural hydrographical and topographical differences exist between the three aquatic ecosystems considered (i.e., inland waters, North Sea and Baltic Sea coasts). These differences are also reflected in a distinct occurrence of alien species.

Some species where only found in single or a few records, i.e. the decapod Callinectes sapidus Rathbun, 1896, the anthozoan Cercocephum pedunculatus (Pennant, 1777), the hydroid Gonionemus vertens Agassiz, 1862, the horseshoe crab Limulus polyphemus Linnaeus, 1758 and the fish Neogobius kessleri (Günther, 1861) (Annex).

Table 2. Population status of aquatic alien species known from German waters

| Population Status | Baltic Sea | North Sea | Inland Waters |
|-------------------|------------|-----------|--------------|
| Unknown           | 1          | 1         |              |
| Extinct           | 1          | 4         | 1            |
| Single record(s)  | 1          | 4         | 1            |
| Rare              | 6          | 16        | 33           |
| Local             | 11         | 16        | 29           |
| Common            | 1          | 5         | 10           |
| Abundant          | 13         | 16        | 14           |
| Total             | 33         | 62        | 86           |

The relationship between salinity and species diversity is well known. In contrast to freshwater and pure seawater, brackish waters are characterized by the lowest number of indigenous species (“Artenminimum” sensu Remane 1934) and seem to provide opportunities for alien species invasions. It has recently been shown for German waters that the brackish areas of estuaries have been invaded more frequently by alien macroinvertebrate species than rocky or sandy sea shores or inland waters (Nehring 2006a). The author also stated that a low indigenous species richness in aquatic communities facilitates invasions of "new" species, but the frequency and intensity (or size) of the inoculation are critical components in determining colonization success. Brackish waters seem to have many open ecological niches and are often exposed to intensive international ship traffic. Thus, these habitats have the highest potential for species introductions. In addition, estuaries are subjected to a two-sided invasion pressure by alien species via the ocean (e.g., due to shipping) and via inland waters (e.g., canal constructions).

Since the 1980s, polychaetes of the genus Marenzelleria have appeared in the North Sea and Baltic Sea. The taxonomic identification of the species, which were introduced with ballast water discharge of ocean going ships, was rather difficult and led to confusions and misidentifications. Sikorski and Bick (2004) showed that at least two Marenzelleria species occur in German waters: Marenzelleria neglecta Sikorski et Bick, 2004 and M. viridis (Verrill, 1873) (former taxonomic determinations and synonyms for M. neglecta are: M. viridis, M. cf. viridis and M. Type II, and for M. viridis: M. wireni Augener, 1913, M. cf. wireni and M. Type I). After the first appearance of M. viridis in 1979 in a Scottish estuary, the species arrived at the German North Sea coast in 1983 (Essink and Kleef 1986). First individuals of M. viridis were found in the German Baltic Sea by 2004 (Bastrop and Blank 2006). Since 1985 M. neglecta occurs along the German Baltic Sea coast (Bick and Burckhardt 1989). In 1996 the polychaete was detected in the Kiel Canal (connecting the North Sea with the Baltic Sea) as well as in the Elbe estuary (North Sea) and by 1997 M. neglecta had arrived in the Weser estuary (Nehring and Leuchs 2000). Both Marenzelleria species spread rapidly and became the predominant polychaete worms in German coastal waters. In the estuaries of the German North Sea coast both Marenzelleria species show distinct occurrences due to the salinity gradient (Nehring and Leuchs 2001). M. viridis prevails in the mesohaline zone, while M. neglecta colonizes mainly the oligohaline zone. In the area between the two zones, both species occur sympatrically.

While many alien species seem to remain insignificant additions to the native biota of Germany, approximately 20 % of the introduced species show invasive behaviour (sensu CBD 2000). The following provides a simple classification, modified after Jansson (1994) and Hopkins (2000), to document the different impacts of introduced alien species in the recipient ecosystem, viz:

- Disruption of existing interactions between species or food web links (e.g., predators, prey, grazers, and competition) - e.g. Crassostrea gigas (Thunberg, 1793) (Bivalvia), Dikerogammarus villosus (Sovinsky, 1894) (Amphipoda), Dreissena polymorpha (Pallas, 1771) (Bivalvia);
- Hybridisation with native and other alien species, resulting in changes of biological and
genetic diversity. Potential candidates in German waters: *Acipenser* spp. (Pisces), *Crassostrea gigas* (Bivalvia), *Lepomis* spp. (Pisces), *Spartina anglica* Hubbard, 1968 (Poacea);
- Introduction of parasites and disease agents. The introduced species may function as a host for pathogens or parasites which affect indigenous species - e.g., *Anguillicola crassus* (Kuwahara, Niimi et Hagaki, 1974) (Nematoda), *Orconectes limosus* (Rafinesque, 1817) (Decapoda);
- Habitat modification - e.g., *Chelicorophium curvispinum* (Sars, 1895) (Amphipoda), *Crassostrea gigas* (Bivalvia), *Hypania invalida* (Grube, 1860) (Polychaeta), *Sargassum muticum* (Yendo) Fensholt, 1955 (Phaeophyceae);
- Impact on species used in fisheries and aquaculture, resulting in decrease of output - e.g., *Anguillicola crassus* (Nematoda), *Eriocheir sinensis* (Decapoda), *Crassostrea gigas* (Bivalvia);
- Impact on resource users may result in harmful consequences on human health and well-being, recreation, and socio-economics - e.g., *Crassostrea gigas* (Bivalvia), *Elodea canadensis* Michaux, 1803 (Hydrocharitaceae), *Spartina anglica* (Poacea).

![Figure 2](image)

**Figure 2.** Mass upstream migration of juvenile Chinese mitten crabs, *Eriocheir sinensis*, in the Elbe River near Hamburg in 1998. Photo Stephan Gollasch

Although we have some information about some of the direct impacts of AAS, the longer-term ecological consequences for native plant and animal communities and the scale on which biodiversity is modified by invasive species is still poorly understood. Analyses of the economic effects of AAS are also needed.

![Figure 3](image)

**Figure 3.** Introduction vectors of aquatic alien species in German waters

The most important vectors for species introductions in the Baltic Sea and the North Sea are shipping and species imports for aquaculture. In inland waters most AAS invasions are attributed to canal constructions facilitating species migrations, to the release of species that have been imported with the ornamental trade, stocking and ship traffic (Figure 3).

Prime source regions for AAS that have invaded German waters are the Ponto-Caspian area, the north-western Atlantic and the Indo-Pacific for the Baltic Sea, the northern Pacific, the Indo-Pacific, the north-western Atlantic for the North Sea, and north America and the Ponto-Caspian area for inland waters (Figure 4).

**Cryptogenic species**

The native range of some of the species which have been considered as alien is controversial. These species are referred to as cryptogenic.
species, i.e., species that are neither native or introduced (Carlton 1996). Those species include the polychaetes *Aphelochaeta marioni* (Saint-Joseph, 1894), *Microphthalmus similes* Bobretzky, 1870, *Nereis virens* Sars, 1835, *Polydora ligerica* (Ferronière, 1898) and the Dinophyceae *Prorocentrum redfieldii* Bursa, 1959 (Annex). As those species may be introduced, they were included in the Annex for reasons of comparison.

**Figure 4.** Source regions of aquatic alien species in German waters

Another interesting case is a turbellarian sampled from a ship hull in a German port. After careful taxonomic consideration it was found that this species is new to science and it was described as *Cryptostylochus hullensis* Faubel et Gollasch, 1996 (Polycladida, Acotylea, Plathelminthes). Because this flatworm is only known from this single sample, the native range remains unclear (Faubel and Gollasch 1996). The species was never found again in German waters and is therefore not included in the species list attached.

**Species introductions and climate change**

We excluded species that reached German waters from their known distribution range by natural means such as range expansion from e.g., the north-east Atlantic or the Mediterranean Sea. It has been hypothesized that temporary or permanent climate change facilitates natural range expansion (Nehring 1998a, Stachowicz et al. 2002). Franke et al. (1999) and Franke and Gutow (2004) reported several nonindigenous species from the North Sea near Helgoland which are known to occur west of the British Channel and/or in the Mediterranean Sea. Examples include the decapods *Palaemon longirostris* Milne Edwards, 1837, *Portumnus latipes* (Pennant, 1777), the Polychaeta *Sabellaria alveolata* (Linnaeus, 1767) and the Bacillariophyceae *Thalassiosira hendeyi* Hasle et Fryxell, 1977.

The cord-grass *Spartina anglica*, a fertile hybrid of the European species *S. maritima* (Curtis) Fernald, 1916 and the North-American species *S. alterniflora* Loiseleur-Deslongchamps, 1807, was introduced into the Wadden Sea in the 1920s to promote sediment accumulation. However, the intended stabilization of mudflats was not always achieved. Recently this alien species has spread naturally into the tidal zone, where it displaces the native glass-word *Salicornia stricta* Dumort, 1868 (Figure 5). This range extension may have been promoted by higher spring temperatures. *S. anglica* may further benefit from climate change and may become more abundant in the near future, resulting in unforeseeable consequences for coastal protection (Nehring 2003, Nehring and Adsersen 2006).

**Warm water effluents as hot spots of species invasions**

Alien species, native to warmer climate regimes, may also have colonised the North Sea in localities with unusual high water temperatures, e.g. near cooling water outlets of power plants. One example is the Pacific polychaete *Ficopomatus enigmaticus* (Fauvel, 1923). This brackish water species was first recorded in the London Docks, United Kingdom in 1922 (Eno et al. 1997), in the port of Vlissingen, The Netherlands in 1967 near a power plant (Wolff 2005) and also in the German Port of Emden in
close vicinity of a power plant (Kühl 1977a). Today, *F. enigmaticus* is widespread in coastal areas of all North Sea countries.

Another species which "benefited" from locally heated waters is the freshwater Asiatic clam *Corbicula fluminea* (O.F. Müller 1756) which was first found in Europe in 1989 near the port of Rotterdam, The Netherlands (Wolff 2005). In 1990 it was collected from the German section of the Rhine River (Figure 6), in 1997 from the Danube, and in 1998 from the Elbe (Tittizer et al. 2000). It has been suggested that the successful dispersal of the Asiatic clam in European waters is correlated with winter water temperature minima of 2 °C (Schöll 2000). In Germany, temperatures of inland waters frequently drop below 2 °C in winter and consequently *C. fluminea* should have limited opportunities for establishment. However, industrial and residential discharges of warm water into many German rivers have raised winter temperature almost permanently above 2°C, thereby promoting the establishment of *C. fluminea* in high abundances (Galil et al. 2007).

**Species findings attributed to drift**

Newly recorded species may also have reached German coastal regions by drift with exceptional water inflow due to rare hydrodynamic situations or storms. In some cases, such as for the Bacillariophyceae *Corethron criophilum* Castracane, 1886 and *Rhizosolenia indica* Peragallo, 1892, the Cirripedia *Lepas anatifera* Linnaeus, 1758 and *Lepas fascicularis* Ellis et Solander, 1786, the Decapoda *Pachygrapsus marmoratus* (Fabricius, 1787) and the clupeid fish *Sardina pilchardus* Walbaum, 1792 this has resulted in a temporary occurrence outside of their native range (Luther 1987, Nehring 1998b, Ehrich and Stransky 2001, G. Meurs (Nationalpark-Zentrum Multimar Wattforum, Tönning, Germany) pers. comm.). These species have not been included in the Annex.

In October 2006 the Ctenophore *Mnemiopsis leidyi* Agassiz, 1865 has been found for the first time along the German part of the Baltic Sea coast (U. Sommer and J. Javidpour (Leibniz-Institut für Meereswissenschaften, Kiel, Germany) pers. comm.). Recently it was also found in Dutch estuaries (Faasse and Bayha 2006, this issue), in the Skagerrak and Kattegatt (Hansson 2006, this issue) and in southern Norway (A. Jelmert (Floedevigen Research Station, His, Norway) pers. comm.), but not yet along the German North Sea coast. This western Atlantic species was possibly transported into the Baltic by easterly directed water currents or introduced by human activities, however, its current alien status is unkown.

**Canals as invasion corridors**

The natural barriers between river and sea basins that have existed since the end of the Pleistocene have been largely eliminated by canals built during the last centuries. The occurrence of 26 alien species in German waters can be attributed to canal construction. The following examples highlight the importance of shipping canals as invasion corridors.

The opening of the Bug-Pripyat Canal in 1784, which connects the Dnieper-Pripyat...
system to the rivers Bug and Vistula, was of crucial importance for the early and frequent occurrence of Ponto-Caspian species in northern Europe (e.g., the invasive zebra mussel *Dreissena polymorpha*). After the opening of the Main-Danube Canal in Germany in 1992, which connects the Rhine River and the Danube River, this southern corridor is today the most important link between the Ponto-Caspian area and western Europe. Recently, several Ponto-Caspian species have been found in increasing abundances in the German rivers Main and Rhine (e.g. the isopod *Jaera istri* [Schleuter and Schleuter 1995]). In contrast Bernauer and Jansen (2006) reported that the polychaete *Hypania invalida* decreased in numbers in the upper Rhine River between 2003 and 2004.

In 1995 the Ponto-Caspian amphipod *Dikerogammarus villosus* arrived in the Rhine basin via the Main-Danube-Canal (Tittizer et al. 2000). Since then this new invader has dispersed over large distances in a short period of time and in 2000 the first organisms were observed in the German/Polish river Odra (Müller et al. 2001). This dynamic geographic expansion of *D. villosus* in Germany was facilitated by several man-made canals in northern Germany which created connections to all large river systems (Rhine, Weser, Elbe, Odra). Due to the rapidly increasing population density of this invasive amphipod it became a major component of the macrobenthic fauna in German freshwater systems, eliminating both native and other alien amphipod species (Tittizer et al. 2000, Haas et al. 2002, Nehring 2005).

More Ponto-Caspian species, mainly invertebrates and fishes, are expected to migrate into the North Sea basin via the Main-Danube-Canal. Especially those species which already occur in the upper and middle Danube will likely arrive in the North Sea basin soon.

The Chinese mitten crab (*Eriocheir sinensis*), introduced with ships and first recorded in the Aller River in 1912 (Schnakenbeck 1924, Marquard 1926), was reported from the North Sea coast in 1915 (Schnakenbeck 1924), and from the Baltic Sea in 1932 (Boettger 1933a, Peters 1933). *E. sinensis* was also found in the Kiel Canal in the 1920s (Neubaur 1936), and it was subsequently recorded from the Wadden Sea (Cole 1982, Kühl 1977b, Adema 1991, Nehring 2000b, Van der Velde et al. 2000).
species in transit. It should be noted that the zebra mussel was first recorded in the North American Great Lakes in the 1980s, but ships from its donor region arrived in the lakes since many decades before the species was introduced, i.e. it took quite some time and probably multiple discharge events until all factors triggering the invasion were right.

"Why do we need to go active right now?"

The number of invaders was increasing towards the end of the last century. Several investigations have shown that since 1950s the number of new records of invaders have clearly increased (Figure 1). Further new free trade agreements and ship improvements (see above) may have increased the invasion rate even further, thereby indicating the need for immediate action with the aim to reduce the number of new alien species arrivals.

"Biological invasions are a natural phenomenon and happen anyway. The only thing we do is to speed up the process"

This is simply not true as there is no natural means to transport a species from e.g. North America to Australia. Biogeographical textbooks describe the Pacific Ocean as a migration barrier as the duration of the zooplankton larval phase is too short to enable a distribution across the Pacific with natural means. Human mediated vectors, such as ballast water or hull fouling transports, are essential for a species to become dispersed across the Pacific. Also, freshwater species cannot reach new habitats separated by marine waters. However, ballast water releases from e.g. the freshwater port of St. Petersburg (Russia) in the port of Hamburg (Germany) may introduce species which could not reach the area by natural means due to the higher salinity in the western Baltic and North Sea.

"Humans should not interfere with species distributions"

Invasion biologists know that biological components and their interaction in an environment are not a stable process. It was also agreed that initiatives should not be undertaken to hinder natural migration activities of species. However, human mediated species introductions should be kept to a minimum as a precautionary approach. Case histories have shown severe, unwanted impacts of invaders which were introduced unintentionally with e.g. ballast water or associated with aquaculture imports. Natural migrations and human mediated species introductions should clearly be treated separately.

“Only 10% of the invaders show a significant impact”

This statement refers to the "10s-rule". The rule was originally postulated based on invasion histories in terrestrial habitats. The figure was revised frequently. No matter how detailed these revisions were it has to be noted that each invasion has its impact on the recipient region. In some cases the impact is quite clear, in other instances the impact is not as obvious. Further, in many cases an impact is only noted when the invader forms a mass development which may occur long time after the initial introduction. In invasion biology it is not the quantity which matters, but the quality, i.e. just one introduced species may severely impact the receiving environment.

“Phytoplankton species are not matter of discussion as these species are distributed world-wide anyway”

It was documented that the number of phytoplankton blooms increased during the last two decades world-wide and it was suggested that this was supported not only by eutrophication but also by biological invasions. The recent occurrence of potentially toxin producing phytoplankton species in the North Sea is a good indication that we should be prepared for additional invaders of this kind.

“Keep the ballast water onboard as long as possible and the species will die over time”

Although many species die during the first days in ballast tanks, scientific studies have shown that after more than 4 months living zooplankton can be found in ballast tanks and under certain circumstances zooplankton species even reproduce in ballast tanks (Gollasch et al. 2000a,b, Gollasch et al. 2002). Further, some plankton species are enabled to form resting stages that survive unfavourable conditions for years or decades. Therefore, keeping ballast water onboard for longer periods of time is not a measure to significantly reduce the risk of species invasions.
The exchange of ballast water in high seas is an appropriate means to reduce the number of invaders. The exchange of ballast water in mid-ocean can reduce the abundance and diversity of taxa in ballast water. It is further unlikely that coastal organisms taken up in ports survive open ocean conditions where ballast water is exchanged – and plankton from high seas is unlikely to survive in coastal areas. In contrast to this assumption scientists showed that the exchange of ballast water could increase the species diversity in ballast tanks, especially in many domestic shipping routes, where no deep water exchange zones occur. Also the number of individuals in ballast tanks may increase when ballast water exchange is undertaken in zones with e.g. phytoplankton blooms. Ballast water exchange is therefore recommended as a very first management option, but effective treatment measures are urgently needed to avoid ballast water mediated species invasions in the future.

The future of alien species introductions into German waters and their potential impacts

The publication of recently introduced species in scientific journals is sometimes a time consuming process, and it is likely that by the time this checklist is published new alien species have already invaded German waters. These may include the Rapana venosa (Valenciennes, 1846) (Gastropda), which was observed for the first time in the south-western North Sea in 2005 (Kerckhof et al. 2006), but outside German national waters. This species was already known from European waters and the new findings in the North Sea likely represent a secondary introduction. However, the occurrence of this species in various locations in Europe may also be a result of multiple introductions from its native range. Noting its potential to spread, it is anticipated that this species may be found in German waters soon.

The recent spread of C. gigas is likely triggered by (a) recent warm summers which support its recruitment and by (b) the absence of cold winters which promote recruitment of M. edulis. In northern Europe the Pacific oyster may benefit from global warming and may become more abundant than mussel beds have ever been (Diederich et al. 2005, Nehring 2006b).

Because the impact of introduced species is potentially enormous, and very unpredictable, we should be aware of new species introductions. One known source of alien species is ship’s ballast water which can contain millions of organisms and that is discharged in our coastal waters every day. Other vectors of introductions include species that are transported in the hull fouling of ships (Gollasch et al. 2000a, b, Nehring 2001, Gollasch 2002, Gollasch et al. 2002) and canal migrations. The latter have increased in magnitude and frequency over the past decade(s) (Harka and Biro 2004, Nehring 2005, Galil et al. 2007).

Similar to a worldwide trend, the rate of invasion of AAS has also increased in German waters since the 1950s, and will probably continue to rise due to the effects of climate change. The introduction of C. gigas and other species, is likely to increase in the future.
change and further improvements in ship design. It is hoped that measures, such as ballast water treatment to reduce the organism load or the installation of migration barriers such as deterrent electrical systems, salt or freshwater water locks, and air bubble curtains to reduce the uncontrolled range expansion of alien species via canals are taken soon to protect our waters from new species invasions and their potentially detrimental effects.

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Annex

Aquatic alien species reported from coastal areas of the North Sea and Baltic Sea and from inland waters within the national borders of Germany. Species which arrived by drift or other means of natural range expansion were not considered. IAS = an invasive alien species which threatens ecosystems, habitats or native species (sensu CBD 2000)

| Species | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References |
|---------|------------------------------------------|---------------------|--------|---------|------------------------------------------|------------|
| **PHYTOPLANKTON** | | | | | | |
| Dinophyceae | | | | | | |
| *Karenia (= Gymnodinium mikimotoi* (Miyake et Kominami ex Oda) Hansen et Moestrup, 2000) | 1966 | Pacific | unintentional | ships | bloom forming | Hickel et al. 1971 |
| *Prorocentrum redfieldii* Bursa, 1959 | <1999 | unclear | unintentional | ships? | bloom forming | Nehring 1998b, Elbrächter 1999 |
| *Chattonella antiqua* (Hada) Ono, 1980 | 1991 | Pacific? | unintentional | Ships | potentially toxic | Elbrächter 1994, Vriezing et al. 1995, Lu and Göbel 2000 |
| *Chattonella marina* (Subrahmanyan) Hara et Chihara, 1982 | 1991 | Pacific? | unintentional | Ships | potentially toxic | Elbrächter 1994 |
| *Fibrocapsa japonica* Toriumi et Takano, 1973 | 1991 | Pacific? | unintentional | Ships | toxic / IAS | Elbrächter 1994 |
| **Bacillariophyceae** | | | | | | |
| *Coscinodiscus wailesii* Gran et Angst, 1931 | 1977 | Indo-Pacific | unintentional | aquaculture | competition, bloom forming / IAS competition | Hasle 1990, Laing 1999, Wiltshire & Dürselen 2004 |
| *Odontella sinensis* (Greville) Grunow, 1884 | 1904 | Indo-Pacific | unintentional | Ships | toxic / IAS | Ostenfeld 1908 |
| *Thalassiosira punctigera* (Castracane) Hasle, 1983 | <1983 | Indo-Pacific | unintentional | aquaculture | unknown | Hasle 1983, 1990 |
| **MACROPHYTES** | | | | | | |
| Pteridophyta | | | | | | |
| *Azolla filiculoides* Lamarck, 1783 | 1980s | S America | intentional | ornamental trade | unknown | Hussner 2005 |
| *Spermatophyta* | | | | | | |
| Apiaceae | | | | | | |
| *Hydrocotyle ranunculoides* Linnaeus, 1781 | 2004 | N America | intentional | ornamental trade | competition, habitat modification/ IAS | Hussner 2005 |
| **Crassulaceae** | | | | | | |
| *Crassula helmitii* (Kirk) Cockayne, 1907 | 1980s | Australia | intentional | ornamental trade | competition, habitat modification / IAS | Kowarik 2003, Hussner 2005 |
| **Hydrocharitaceae** | | | | | | |
| *Egeria densa* Planchnon, 1849 | 1980s | S America | intentional | ornamental trade | unknown | Kowarik 2003, Hussner 2005 |
| *Elodea canadensis* Michaux, 1803 | 1859 | N America | intentional | ornamental trade | competition, habitat modification / IAS | Kowarik 2003, Hussner 2005, Arndt 1931, Kowarik 2003, Hussner 2005, Wallentinus submitted |
| *Elodea nuttallii* (Planchon) St. John, 1920 | 1953 | N America | intentional | ornamental trade | competition, habitat modification / IAS | Kowarik 2003, Hussner 2005, Wallentinus submitted |
| Species | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References |
|---------|------------------------------------------|---------------------|--------|---------|----------------------------------------|------------|
| Vallisneria spiralis Linnaeus, 1753 | 1966 | N America | intentional | ornamental trade | unknown | Kowarik 2003, Hussner 2005 |
| Lemna minuta Kunth, 1816 | 1983 | N America | intentional | ornamental trade | unknown | Kowarik 2003 |
| Lemna turionifera Landolt, 1975 Haloragaceae | 1965 | N America | intentional | ornamental trade | unknown | Kowarik 2003 |
| Myriophyllum aquaticum (Velloso) Verdouc, 1973 | 1980s | S America | intentional | ornamental trade | unknown | Hussner 2005 |
| Myriophyllum heterophyllum Michaux, 1803 | 1962 | N America | intentional | ornamental trade | unknown | Kowarik 2003 |
| Spartina anglica Hubbard, 1968 | 1927 | W Atlantic | intentional | planting | competition, habitat modification, hybridisation? / IAS | Kolumbe 1931, Dijkema 1983, Wallentinus submitted |
| Phaeophyceae | | | | | | |
| Ascophyllum nodosum (Linnaeus) Le Jolis, 1863 | 1990s | unclear | unknown | unknown | unknown | Bartsch and Kuhlenkamp 2000, Wallentinus submitted |
| Colpomenia peregrina (Sauvageau) Hamel, 1937 Agardh, 1820 | 1905 | Pacific | unintentional | aquaculture | unknown | Fletcher and Farrell 1999 Wallentinus 1999, Hopkins 2001 |
| Fucus evanesens Agardh, 1820 | 1989 | N Pacific | unintentional | ships | competition, habitat modification, hybridization | Wallentinus 1992, Bartsch and Kuhlenkamp 2000, Wallentinus submitted |
| Sargassum muticum (Yendo) Fensholt, 1955 | 1988 | N Pacific | unintentional | aquaculture | fouling, habitat modification / IAS | Wallentinus 1992, Bartsch and Kuhlenkamp 2000, Wallentinus submitted |
| Rhodophyceae | | | | | | |
| Bonnemaisonia hamifera Hariot, 1891 | <1959 | N Pacific | unintentional | aquaculture | competition | Kylin 1930, Bartsch and Kuhlenkamp 2000 Wallentinus pers. comm., Schories and Selig 2006 Nehls 2004, Schories and Selig 2006 Wallentinus 1999, Maggs and Stegenga 1999 |
| Dasys baillouiviana (Gmelin) Montagne, 1841 | 2002 | W Atlantic | unintentional | aquaculture | unknown | Wallentinus pers. comm., Schories and Selig 2006 Nehls 2004, Schories and Selig 2006 Wallentinus 1999, Maggs and Stegenga 1999 |
| Gracilaria vermiculophylla (Ohmi) Papenfuss, 1967 | 2005 | 2002 | Pacific | unintentional | aquaculture | unknown | |
| Polysiphonia harveyi Bailey, 1848 | 1960s | N Pacific | unintentional | aquaculture | unknown | |
| Chlorophyceae | | | | | | |
| Codium fragile ssp. tomentosoides (van Goor) Silva, 1955 | 1930s | N Pacific | unintentional | aquaculture | competition, fouling, habitat modification | Bartsch and Kuhlenkamp 2000, Wallentinus submitted |
| ZOOPLANKTON | | | | | | |
| Mnemiopsis leidyi Agassiz, 1865 | 2006 | unclear | unknown | unknown | unknown | Javidpour and Sommer pers. comm. |
| Species                        | Year of first record and recipient region | Origin / donor area | Vector     | Pathway                | Impact or potential impact / invasiveness | References                                                                 |
|-------------------------------|------------------------------------------|---------------------|------------|------------------------|-------------------------------------------|----------------------------------------------------------------------------|
| **Crustacea**                 |                                          |                     |            |                        |                                           |                                                                            |
| Acartia tonsa Dana,1848       | <1981 1931                               | Baltic Sea          | North Sea  | Inland waters          |                                           |                                                                            |
|                               |                                          |                     |            |                        |                                           |                                                                            |
| Ameira diversans              | 1970s                                    | Baltic Sea          | North Sea  | Inland waters          | competition                              | Klie 1933, Arndt and Schnese 1986                                         |
| Nicholls, 1939                |                                          |                     |            |                        |                                           | Scheibel 1974                                                              |
| Cercopagis pengoi (Ostroousov, 1891) | 2004                                    | Baltic Sea          | North Sea  | Inland waters          | competition, predation                    | Gruzka pers. com. in WGITMO 2005                                          |
| **MACROZOOBENTHOS**           |                                          |                     |            |                        |                                           |                                                                            |
| *Porifera*                    |                                          |                     |            |                        |                                           |                                                                            |
| Eunapius carteri              | 1993                                     | Baltic Sea          | North Sea  | Inland waters          | ornamental trade                         | Gugel 1995, Nehring 2002                                                   |
| Bimeria francisciana          | <1952                                    | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Schütz 1963a,b, Cohen and Carlton 1995                                    |
| Torrey, 1902                  |                                          |                     |            |                        |                                           |                                                                            |
| Bougainvillea macloviana      | 1895                                     | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Hartlaub 1897, Broch 1924                                                   |
| Lesson, 1830                  |                                          |                     |            |                        |                                           | Kirchenpauer 1862, Hinkelmann 1899, Schulze 1899, Gruzka 1999               |
| Cordylophora caspia           | 1870                                     | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Hartlaub 1897, Broch 1924                                                   |
| (Pallas, 1771)                |                                          |                     |            |                        |                                           | Kirchenpauer 1862, Hinkelmann 1899, Schulze 1899, Gruzka 1999               |
| **Cruspedacusta sowerbyi**    | 1923                                     | Baltic Sea          | North Sea  | Inland waters          | ornamental trade                         | Tittizer 1996, Tittizer et al. 2000                                        |
| Lancaster, 1880               |                                          |                     |            |                        |                                           | Werner 1950, Tams-Lyche 1964                                                 |
| Goninomenus vertens           | 1947                                     | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Hartlaub 1911, Kühl 1962                                                   |
| Agassiz, 1862                 |                                          |                     |            |                        |                                           |                                                                            |
| Nemopsis bachei               | 1942                                     | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Hartlaub 1911, Kühl 1962                                                   |
| Agassiz, 1849                 |                                          |                     |            |                        |                                           |                                                                            |
| Anthozoa                      |                                          |                     |            |                        |                                           |                                                                            |
| Cereus pedunculatus           | 1921                                     | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Müllenger 1921, Pax 1936                                                    |
| (Pennaunt, 1777)              |                                          |                     |            |                        |                                           | Pax 1936, Kluijver 1991                                                     |
| Diadumene cincta              | 1928                                     | Baltic Sea          | North Sea  | Inland waters          | aquaculture competition                   | Pax 1920, Gollasch and Riemann-Zünneck 1996                                |
| (Stephenson, 1925)            |                                          |                     |            |                        |                                           |                                                                            |
| Haliplanaella luciae (= lineata) (Verrill, 1898) | 1920                                    | Baltic Sea          | North Sea  | Inland waters          | ships                                     | Pax 1920, Gollasch and Riemann-Zünneck 1996                                |
| **Bivalvia**                  |                                          |                     |            |                        |                                           |                                                                            |
| Congeria leucophaeta           | <1996 <1994                              | Baltic Sea          | North Sea  | Inland waters          | competition, fouling                      | Boettger 1933b, Post and Landmann 1994, Jungbluth 1996, Kinzelbach 1991, Meister 1997, Nehring 2002, Meyer-Waarden 1964, Utting and Spencer 1992, Reise 1998a,b |
| (Conrad, 1831)                |                                          |                     |            |                        |                                           |                                                                            |
| Corbicula fluminalis (O.F. Müller, 1774) | 1984                                    | Baltic Sea          | North Sea  | Inland waters          | competition, IAS                        |                                                                            |
| Corbicula fluminea (O.F. Müller, 1756) | 1997                                    | Baltic Sea          | North Sea  | Inland waters          | competition, IAS                        |                                                                            |
| Crassostrea angulata (Lamarck, 1819) | 1911                                    | Baltic Sea          | North Sea  | Inland waters          | competition, IAS                        |                                                                            |
| Crassostrea gigas (Thunberg, 1793) | 1991                                    | Baltic Sea          | North Sea  | Inland waters          | competition, IAS                        |                                                                            |
| Crassostrea virginica (Gmelin, 1791) | <1887 <1911                             | Baltic Sea          | North Sea  | Inland waters          | competition, IAS                        |                                                                            |
| Species | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References |
|---------|------------------------------------------|---------------------|--------|---------|------------------------------------------|------------|
| *Dreissena polymorpha* (Pallas, 1771) | 1828 | 1835 | 1824 | Ponto-Caspian | unintentional canal competition, fouling, habitat modification, parasite carrier / IAS | Dahl 1891, Bentheim-Juttling 1922, Arndt 1931, Thiemenmann 1950 |
| *Ensis americanus* (Binney, 1870) | 1993 | 1979 | NW Atlantic | unintentional ships | competition, habitat modification / IAS | Von Cosel et al. 1982, Essink 1985, van Urk 1987, Gürs et al. 1993 Arndt 1931, Petersen et al. 1992, Reise 1998, Nehring 2000a |
| *Mya arenaria* (Linnaeus, 1758) | <1200 | <1200 | <1931 | NW Atlantic | unintentional ships competition? | Arndt 1931, Petersen et al. 1992, Reise 1998, Nehring 2000a |
| *Petricola pholadiformis* Lamarck, 1818 | 1927 | 1896 | NW Atlantic | unintentional aquaculture | competition, habitat modification | Schlesch 1932, Kuckuck 1957, Knudsen 1988, Jensen & Knudsen 2005 |
| *Teredo navalis* Linnaeus, 1758 | <1993 | <1808 | Indo-Pacific? | unintentional ships | habitat modification / IAS | Hahn 1956, Schütz 1961, Sordyl et al. 1998 |
| *Unio mancus* Lamarck, 1819 | <1922 | | | S Europe | unintentional canal | Tittizer et al. 2000 |
| *Crepidula fornicata* (Linnaeus, 1758) | 1934 | | | W Atlantic | unintentional aquaculture | competition, habitat modification, parasite carrier unknown | Havinga 1929, Ankel 1935, Kuckuck 1957, Minchin et al 1995 Geiter et al. 2002 |
| *Gyraulus parvus* (Say, 1817) | 1981 | | | N America | intentional ornamental trade | canal parasite carrier | Thienemann 1950, Junghuhn 1996, Nehring 2002 Geiter et al. 2002 |
| *Lithogyphus naticoides* (Pfeiffer, 1828) | 1883 | | | E Europe | unintentional ornamental trade | canal parasite carrier | Thienemann 1950, Junghuhn 1996, Nehring 2002 Geiter et al. 2002 |
| *Menetus dilatatus* (Gould, 1841) | 1980 | | | N America | intentional ornamental trade | unknown | Geiter et al. 2002 |
| *Physella acuta* (Draparnaud, 1805) | 1895 | | | SW Europe | intentional ornamental trade | unknown | Sukopp & Brande 1984, Junghuhn 1996, Nehring 2002 Junguhn 1996, Nehring 2002 Geiter et al. 2002 |
| *Physella heterostropha* (Say, 1817) | <1927 | | | N America | intentional ornamental trade | unknown | Thienemann 1950, Cole 1982 |
| *Planorbiella duryi* (Weatherby, 1879) | 1980s | | | N America | intentional ornamental trade | unknown | Geiter et al. 2002 |
| *Potamopyrgus antipodarum* (Gray, 1843) | 1900 | | | New Zealand | unintentional ships | competition, parasite carrier | Thienemann 1950, Cole 1982 |
| *Platyhelminthes* | | | | | | |
| *Dendrocoelum romanum-danubiale* (Codreanu, 1949) | 1992 | | | Ponto-Caspian | unintentional canal | unknown | Tittizer et al. 2000, Nehring 2002 Hauer 1950, Tittizer 1996, Nehring 2002 |
| *Dugesia tigrina* (Girard, 1850) | 1931 | | | N America | unintentional ornamental trade | unknown | Tittizer et al. 2000, Nehring 2002 |
| Kamptozoa | | | | | | |
| *Urnatella gracilis* Leidy, 1851 | 1960 | | | N America | unintentional ships | unknown | Franz 1992, Vranovsky and Sporka 1998, Geiter et al. 2002 |
| Species | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References |
|---------|------------------------------------------|---------------------|--------|---------|------------------------------------------|------------|
| Oligochaeta | | | | | | |
| Branchiura sowerbyi (Beddard, 1892) | 1959 | W Pacific | unintentional | ornamental trade | habitat modification | Tobias 1972, Tittizer 1996, Gruszka 1999, Nehring 2002 |
| Polychaeta | | | | | | |
| Aphelochaeta marioni (Saint-Joseph, 1894) | 1938 | unclear | unknown | unknown | unknown | Caspers 1950 |
| Ficopomatus enigmaticus (Fauvel, 1923) | 1975 | S Pacific | unintentional | ships | fouling | Kühl 1977a, Cole 1982, Zibrowius 1991 |
| Hypania invalida (Grube, 1860) | 1995 | Ponto-Caspian | unintentional | canal | habitat modification | Kothe 1968, Tittizer 1996, Nehring 2002 |
| Marenzelleria neglecta (= cf. viridis) Sikorski et Bick, 2004 | 1985 | NW Atlantic | unintentional | ships | competition, habitat modification, predation / IAS | Bick and Burchhardt 1989, Bick and Zettler 1997, Bastrop et al. 1997, Sikorski and Bick 2004, Essink and Kleef 1986, Bick and Burchhardt 1989, Bick and Zettler 1997, Sikorski and Bick 2004 |
| Marenzelleria viridis (= cf. wireni) (Verrill, 1873) | 2004 | NW Atlantic | unintentional | ships | competition, habitat modification, predation / IAS | Essink and Kleef 1986, Bick and Burchhardt 1989, Bick and Zettler 1997, Sikorski and Bick 2004 |
| Microphthalmus similis Bobretzky, 1870 | 1962 | unclear | unknown | unknown | unknown | Hartmann-Schröder and Stripp 1968 |
| Nereis virens Sars, 1835 | 1920s | unclear | unintentional? | ships? | predation | Reibisch 1926, Hagmeier and Kändler 1927, Hartmann-Schröder 1996, Augener 1940, Jaeckel 1962, Hartmann-Schröder 1996, Hauser 1973, Hartmann-Schröder 1996 |
| Polydora ligerica (Ferronière, 1898) | <1932 | unclear | unknown | unknown | unknown | Augener 1940, Jaeckel 1962, Hartmann-Schröder 1996 |
| Tharyx killariensis (Southern, 1914) | 1972 | unclear | unintentional? | aquaculture? | unknown | Hauser 1973, Hartmann-Schröder 1996 |
| Crustacea | | | | | | |
| Astacus leptodactylus Eschscholtz, 1823 | 1910s | Ponto-Caspian | intentional | stocking | unknown | Geiter et al. 2002, Souty-Grosset et al. 2006 |
| Atyaeophyra desmarestii (Millet, 1831) | 1932 | Mediterranea | unintentional | canal | unknown | De Lattin 1967, Tittizer 1996, Tittizer et al. 2000, Nehring 2002 |
| Balanus improvisus Darwin, 1854 | 1867 | 1858 | <1899 | W Atlantic | unintentional | ships | fouling, habitat modification | Kirchenpauer 1862, Hoek 1875, Dechow 1920, Broch 1924, Bäthe 1995 |
| Callinectes sapidus Rathbun, 1896 | 1964 | NW Atlantic | unintentional | ships | predation | Gruner 1962, Kühl 1965 |
| Caprellida mutica Schurin, 1935 | 2004 | Pacific | unintentional | ships | clogging of gear? | Schrey and Buschbaum 2006 |
| Species                                      | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References                                                                 |
|----------------------------------------------|------------------------------------------|---------------------|--------|---------|------------------------------------------|---------------------------------------------------------------------------|
| Chelicorophium curvispinum (Sars, 1895)      | 1932                                     | Baltic Sea 1920s    | 1912   | unintentional canal                       | competition, habitat modification / IAS                                    | Wundsch 1912, Schlienz 1922, Neuhaus 1933, Tittizer 1996, Bernauer et al. 1996, Gruszka 1999, Nehring 2002 |
| Chelicorophium robustum (Sars, 1895)         | 2004                                     | Ponto-Caspian       | unknown| canal                             | unknown                                                              | Eggers and Martens 2004                                                  |
| Corophium sextonae Crawford, 1937           | 1997                                     | S Pacific           | 1997   | unintentional ships                      | competition                                                           | Nehring and Leucha 1999                                                |
| Crangonyx pseudogracilis Bousfield, 1958     | 1992                                     | N America           | 1992   | unintentional stocking?                  | unknown                                                              | Bernauer et al. 1996                                                   |
| Dikerogammarus haemobaphes (Eichwald, 1841) | 1993                                     | Ponto-Caspian       | 1993   | unintentional canal                       | competition                                                           | Tittizer 1996, Nehring 2002, Wawrzyniak-Wydrowska and Gruszka 2005       |
| Dikerogammarus villosus (Sovinsky, 1894)     | 1995                                     | Ponto-Caspian       | 1995   | unintentional canal                       | competition, predation / IAS                                           | Tittizer 1996, Nehring 2002                                             |
| Echinogammarus berrilloni (Catta, 1878)      | 1924                                     | Mediterranean       | 1924   | unintentional canal                       | unknown                                                              | Tittizer 1996, Nehring 2002                                             |
| Echinogammarus ischnus (Stebbing, 1899)      | 1977                                     | Ponto-Caspian       | 1977   | unintentional canal                       | unknown                                                              | Tittizer 1996, Nehring 2002                                             |
| Echinogammarus trichiatus (Martynov, 1932)   | 2000                                     | Ponto-Caspian       | 2000   | unintentional canal                       | unknown                                                              | Podraza et al. 2001, Nehring 2002                                       |
| Elminius modestus Darwin, 1854               | 1953                                     | S Pacific           | 1953   | unintentional ships                      | competition?, fouling                                                | Bishop 1947, Käh 1954                                                   |
| Eriocheir sinensis Milne-Edwards, 1854       | 1932                                     | NW Pacific          | 1932   | unintentional ships                      | competition, habitat modification, parasite carrier, predation / IAS | Schnakenbeck 1924, Marquard 1926, Boettger 1933, Peters 1933, Peters and Hoppe 1938, Panning 1938, Bousfield 1958, Schmitz 1960, Klein 1969, Bulnheim 1976, Nehring 2002, Wawrzyniak-Wydrowska and Gruszka 2005 |
| Gammarus tigrinus Sexton, 1939               | 1975                                     | NW Atlantic         | 1975   | intentional stocking                     | competition, parasite carrier, predation                               | Boettger 1933, Peters and Hoppe 1938, Panning 1938, Bousfield 1958, Schmitz 1960, Klein 1969, Bulnheim 1976, Nehring 2002, Wawrzyniak-Wydrowska and Gruszka 2005 |
| Hemimysis anomala Sars, 1907                 | 1997                                     | Ponto-Caspian       | 1997   | unintentional canal                       | competition, predation                                               | Faasse 1998, Ketelaars et al. 1999, Nehring 2002                         |
| Jaera stii Vieuille, 1979                    | 1995                                     | Ponto-Caspian       | 1995   | unintentional canal                       | unknown                                                              | Kothe 1968, Tittizer 1996, Nehring 2002                                 |
| Limnornysis benedeni Czerniavsky, 1882       | 1997                                     | Ponto-Caspian       | 1997   | unintentional canal                       | unknown                                                              | Tittizer et al 2000, Nehring 2002                                       |
| Obesogammarus crassus (Sars, 1894)           | 2004                                     | Ponto-Caspian       | 2004   | unintentional canal                       | unknown                                                              | Eggers and Anlauf 2005                                                   |
| Obesogammarus obesus (Sars, 1894)            | 2004                                     | Ponto-Caspian       | 2004   | unintentional canal                       | unknown                                                              | Nehring 2006c                                                           |
| Orchestia cavimana Heller, 1865              | 1920                                     | Ponto-Caspian       | 1920   | unintentional ships                      | unknown                                                              | Schlienz 1922, Tittizer 1996                                            |
## Checklist for aquatic alien species in Germany

| Species | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References |
|---------|------------------------------------------|---------------------|--------|---------|------------------------------------------|------------|
| *Orconectes immutis* (Hagen, 1870) | 1997 | N America | intentional | ornamental trade | parasite carrier, habitat modification / IAS | Geiter 1998, Souty-Grosset et al. 2006 |
| *Orconectes limosus* (Rafinesque, 1817) | 1890 | NE America | intentional | stocking | parasite carrier, competition, predation / IAS | Schellenberg 1928, Boettger 1934, Sukopp and Brande 1984 |
| *Pacifastacus leniusculus* (Dana, 1852) | 1980s | N America | intentional | stocking | parasite carrier, competition, predation, habitat modification / IAS | Huber and Schubart 2005, Souty-Grosset et al. 2006 |
| *Palaemon macrodactylus* Rathbun, 1902 | 2004 | SE Asia | unintentional | ships | unknown | González-Ortega et al. 2006 |
| *Pontogammarus robustoides* (Sars, 1894) | 1994 | Ponto-Caspian | unintentional | canal | competition, hybridization, predation | Rudolph 1997, Nehring 2002, Wawrzyniak-Wydrowska and Grużka 2005 |
| *Proasellus canalis* (Dollfus, 1892) | <1987 | Mediterranean | unintentional | canal | unknown | Gruner 1965, Post and Landmann 1994, Tittizer 1996, Nehring 2002 |
| *Proasellus meridianus* (Racovitza, 1919) | 1930s | W Europa | unintentional | canal | unknown | Thienemann 1950, Gruner 1965, Tittizer 1996, Nehring 2002, Souty-Grosset et al. 2006 |
| *Procambarus clarkii* (Girard, 1852) | 1990s | N America | intentional | ornamental trade | parasite carrier, competition, predation, habitat modification / IAS | Geiter et al. 2002, Souty-Grosset et al. 2006 |
| *Rhithropanopeus harrisi* (Gould, 1841) | 1936 | NW Atlantic | unintentional | ships | competition, predation | Neubauer 1936, Buitendijk and Holthuis 1949, Christiansen 1969, Van der Velde et al. 2000, Kühn 1977b, Cole 1982, Adema 1991, Tittizer 1996, Nehring 2000b |
| Chelicerata | | | | | | |
| *Caspihalacarus hyrcanus* Vietz, 1928 | <2006 | Ponto-Caspian | unintentional | canal | unknown | Martens et al. 2006 |
| *Limulus polyphemus* Linnaeus, 1758 | 1866 | NW Atlantic | intentional | ornamental trade | unknown | Lloyd 1874, Holthuis 1950, Wolff 1977 |
| Bryozoa | | | | | | |
| *Pectinatella magnifica* (Leidy, 1851) | 1883 | N America | unintentional | ships | unknown | Tittizer et al. 2000, Nehring 2002, Kneplein 1887, Ax 1952 |
| *Victorella pavida* Saville Kent, 1870 | 1911 | Indo-Pacific? | unintentional | ships | competition, predation, habitat change | |
| Ascidiaea | | | | | | |
| *Styela clava* Herdman, 1882 | 1997 | N Pacific | unintentional | ships | competition, fouling | Millar 1960, Reise 1998a,b |

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| Species | Year of first record and recipient region | Origin / donor area | Vector | Pathway | Impact or potential impact / invasiveness | References |
|---------|------------------------------------------|---------------------|--------|---------|------------------------------------------|------------|
| Acipenser baerii Brandt, 1869 | 1980s | 1980s | Russia | intentional stocking | hybridisation | Spratte and Hartmann 1997, Gessner et al. 1999 |
| Acipenser gueldenstaedti Brandt et Ratzeberg, 1833 | <1990s | | unclear | intentional stocking | hybridisation | Gerstmeier and Romig 1998 |
| Acipenser ruthenus Linnaeus, 1758 | <1992 | | unclear | intentional stocking | hybridisation | Gerstmeier and Romig 1998, Gessner et al. 1999 |
| Acipenser transmontanus Richardson, 1836 | <1990s | | N America | intentional stocking | hybridisation | WGITMO 2006 |
| Ameiurus (= Ictalurus) melas (Rafinesque, 1820) | 1990s | | N America | intentional stocking | competition, predation | Welcomme 1988, Spratte and Hartmann 1997 |
| Ameiurus (= Ictalurus) nebulosus (Lexueur, 1819) | 1885 | | N America | intentional stocking | competition | Spratte and Hartmann 1997 |
| Carassius auratus (Linnaeus, 1758) | <1560 | | Asia | intentional stocking | hybridization | Arnold 1990 |
| Coregonus peled (Gmelin, 1789) | 1965 | | Asia | intentional stocking | hybridization, predation | Geiter et al. 2002 |
| Lepomis cyanellus Rafinesque, 1819 | 1965 | | N America | intentional stocking | hybridization | Arnold 1990 |
| Lepomis gibbosus (Linnaeus, 1758) | 1880 | | N America | intentional stocking | competition, predation, hybridisation, competition, predation | Welcomme 1988, Spratte and Hartmann 1997 |
| Neogobius kessleri (Günther, 1861) | <2004 | | unclear | unknown | unknown | Harka & Biro 2004 |
| Neogobius melanostomus (Pallas, 1811) | 1999 | | Ponto-Caspian | intentional canal | competition, predation, hybridisation, competition, predation, competition, predation, competition, predation | Winkler et al. 2000, Szaniawksa and Dobryzcka-Krehel 2004 |
| Oncorhyncus mykiss (Walbaum, 1792) | 1882 | | N America | intentional stocking | unknown | Welcomme 1988, Spratte and Hartmann 1997, Winkler et al. 2000 |
| Proterorhinus marmoratus (Pallas, 1811) | 1999 | | Ponto-Caspian | intentional canal | unknown | Schad 2000, Harka and Biro 2004 |
| Pseudorasbora parva (Temminck et Schlelegel, 1846) | 1984 | | E Asia | intentional stocking | competition | Spratte and Hartmann 1997 |
| Salvelinus fontinalis (Mitchill, 1814) | 1890 | | NW Atlantic | intentional stocking | competition, hybridisation, predation | Muus and Dahlström 1968 |
| Umbra krameri Wallbaum, 1792 | <1997 | | unclear | intentional ornamental trade | unknown | Spratte and Hartmann 1997, Duncker 1939, Spratte and Hartmann 1997 |
| Umbra pygmaea (De Kay, 1842) | 1924 | | 1910s | N America | intentional | ornamental trade | competition |
| AMPHIBIAN | | | | | | |
| Anura | | | | | | |
| Rana catesbeiana Shaw, 1802 | 1990s | | N America | intentional | ornamental trade | predation / IAS |
| PARASITES | | | | | | |
| Oomycota | | | | | | |
| Aphanomyces astaci Schikora, 1906 | 1878 | | N America | unintentional | stocking | crayfish parasite / IAS | Dehus 1990 |
| Species                                      | Year of first record and recipient region | Origin / donor area | Vector | Pathway      | Impact or potential impact / invasiveness | References |
|----------------------------------------------|------------------------------------------|---------------------|--------|--------------|-----------------------------------------|------------|
| Acanthocephala                              |                                          |                     |        |              |                                         |            |
| *Parateniasentis ambiguus* (van Cleave, 1921) | 1987                                    | N America           | stocking | eel parasite | Taraschewski et al. 1987                  |            |
| Platyhelminthes                              |                                          |                     |        |              |                                         |            |
| *Pseudodactylogyrus anguillae*               | 1980s                                   | E Asia              | stocking | eel parasite | Buchmann et al. 1987, Sures and Streit 2001 |            |
| *Pseudodactylogyrus bini* (Kikuchi, 1929)    | 1980s                                   | E Asia              | stocking | eel parasite | Buchmann et al. 1987, Sures and Streit 2001 |            |
| Nematoda                                    |                                          |                     |        |              |                                         |            |
| *Anguillicola crassus* (Kuwahara, Niimi et Hagaki, 1974) | 1980s, 1980s                        | E Asia              | stocking | eel parasite / IAS | Taraschewski et al. 1987, Minchin and Rosenthal 2002 |            |
| *Barbronia weberi* (Blanchard, 1897)         | 1994                                    | S Asia              | ornamental trade | predation | Potel et al. 1998                        |            |
| *Caspiodella fadejewi* (Epshtein, 1961)      | 1999s                                   | Ponton-Caspian      | canal   | fish leech   | Geissen and Schöll 1998                   |            |
| *Piscicola haranti* Jarry, 1960              | 1999s                                   | Ponton-Caspian      | canal   | fish leech   | Schimmer 1995, Tittizer et al. 2000       |            |
| *Xironogiton victoriensis* Gelder et Hall, 1990 | 2003                                    | N America           | stocking | crayfish parasite | Martens et al. in press                   |            |