6. Introduced Species

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Pacific (Japanese) oyster (*Crassostrea gigas*) (Photo: N. Dankers)

6.1 Introduction

A major component of global change in the biosphere is the introduction of species across natural barriers. If this process continues at present rate, the result will be a complete mix of biota from all climatically similar biogeographical provinces around the world. The young, relatively species-poor Wadden Sea will have to accommodate more and more species, particularly from shores with higher biodiversity such as the Pacific regions. Once introduced marine species have become established, there is no way to eliminate or to control their populations without harming other components of the ecosystem. The only way to stem the advancing tide of non-native immigrants is to prevent further introductions. Does the current status provide sufficient evidence that swift action is required? To answer this question it is necessary to evaluate the effects of introduced species on native biota and human affairs.

At the North Sea coast, introduced algae and invertebrates arrived via shipping or via aquaculture. They most often became established within estuaries and on hard substrates, with more than 80 known species of which about 52 also occur within the Wadden Sea (Table 6.1; Reise *et al.*, 2002). While many seem to remain insignificant additions to the native biota, the focus of this status report is on the few species that have the potential to attain high abundance, to alter the habitat, and to displace residents. In addition, some introduced phytoplankton species occasionally form conspicuous blooms in the coastal waters. Such species include the toxic flagellates *Gymnodinium mikimotoi* (syn. *Gyrodinium aureolum*) and *Fibrocapsa japonica*, and the non-toxic diatoms *Odontella sinensis, Thalassiosira punctigera* and *Coscinodiscus wailesii.* This chapter provides an update of the 1999 QSR (de Jong *et al.*, 1999) that contained information on introduced species scattered over different sections. For the introduced species *Rosa rugosa* and the moss *Campylopus introflexus* see chapter 9.2 'Dunes'.

6.2 Introduced species – a selection

6.2.1 *Spartina anglica* (Cord-grass)

The cord-grass *Spartina anglica*, a fertile hybrid of *S. maritima* and *S. alterniflora*, was introduced into the Wadden Sea in the 1920s to promote sediment accretion. It grows as a pioneer plant in the upper tidal zone, where it has colonized most sheltered shorelines, occurs in coherent swards at the seaward front of salt marshes and in patches on the tidal flats between the spring and neap high tide line. Often, a conspicuous, almost monotypic, belt of *S. anglica* is formed. Sediment retention may finally give an advantage to other salt marsh plants. A dynamic mosaic often develops in the lower salt marsh zone where *S. anglica* patches

Table 6.1: Number of introduced species which became established in the Wadden Sea, and their origin and mode of transport. Where two alternatives are assumed to be equally alike, a species is counted twice, if unknown no entry is made (from data in Reise et al. 2002, and unpubl. data)

Major group	Number of species	Origin		Brought in by	
		Atlantic	Pacific	ship	aquaculture
Phytoplankton	9	1	8	5	3
Macroalgae	12	1	11	3	10
Poaceae	1	1	0	1	0
Cnidaria	4	2	2	4	0
Nematoda	1	0	1	0	1
Mollusca	9	6	3	4	3
Annelida	4	2	2	4	0
Crustacea	11	5	6	11	0
Ascidiacea	1	0	1	1	0

may alternate with those of *Halimione portulacoides, Puccinellia maritima* or *Artemisia maritima* and others. On upper tidal flats the cord-grass displaces the glass-wort *Salicornia stricta*, seagrass *Zostera noltii*, the lugworm *Arenicola marina* and associated species.

Recently *S. anglica* seem to have spread again in the northern Wadden Sea. Locally, this may be due to reduced domestic grazing pressure on salt marshes but more generally this introduced plant may take advantage of higher spring temperatures over the last two decades (Loebl *et al.*, in prep.). The genus *Spartina* belongs to plants with a C_4 pathway with physiological thresholds of 4 °C for germination and 7 °C for photosynthesis. These threshold temperatures have often been exceeded in April since 1986 but rarely were in the years before. Warmer spring seasons thus could have promoted this neophyte to undergo a recently accelerated spread which might continue with global warming.

6.2.2 *Sargassum muticum* (Japanese seaweed)

This large Pacific alga was unintentionally introduced with oysters to Europe and spread rapidly. The first records are from the English Channel coast in 1973, from the Wadden Sea near Texel in 1980 and near Sylt in 1993. In the Wadden Sea, the Japanese seaweed occurs mainly epizootically attached to mussels and oysters, particularly when these are overgrown with barnacles. It is found in a zone close to low tide line, often slightly below patches of the native bladder wrack *Fucus vesiculosus* (Schories and Albrecht, 1995; Buschbaum, 2005). The alga is perennial with longest thalli occurring in July, up to 2.5 m long but usually less than 1.5 m. Then reproductive branches easily break off and float with their viable gametes and germlings still attached, enabling wide and rapid dispersal in the tidal waters.

It is rather unlikely that in the Wadden Sea *S. muticum* will displace resident macroalgae as it has been reported for rocky shores. Instead, the large thalli with their multitude of fine branches offer a highly complex phytal habitat for epigrowth and motile fauna (Buschbaum *et al.*, in prep.). Near Sylt 24 algal and 56 invertebrate taxa have been recorded to be associated with *S. muticum*. On the smaller *F. vesiculosus* with its foliose thallus, less than half of that number could be found. This is a case where an introduced species may significantly enrich habitat complexity and species richness around spring low water level in the Wadden Sea.

6.2.3 *Marenzelleria* cf. *wireni*

This North American estuarine polychaete worm was first recorded for the Wadden Sea in the Ems estuary in 1983, where a large population developed with densities of 2,000-3,000 m^2, giving rise to a macrozoobenthic assemblage entirely dominated by polychaetes (Essink *et al.*, 1998; Essink, 1999). The worm dwells in vertical burrows and feeds with two palps at the sediment-water interface, has a high tolerance for salinity fluctuations, and reproduces in early spring with pelagic larvae for wide dispersal. The young reach high densities in mud of the upper intertidal, while adults are often more numerous in sand of the lower tidal zone.

Following a lag-phase in the initial population in the Ems estuary, it increased exponentially, then leveled off and eventually declined (Essink and Dekker, 2002). Apparently there were otherwise not fully utilized food sources which could be exploited by this immigrant. The decline remains unexplained. From the Ems, other estuaries in the

Japanese seaweed *(Sargassum muticum)* (Photo: C. Buschbaum)

Wadden Sea were invaded within a few years. Colonization of tidal flats beyond the inner estuaries still seems to be in progress. The Balgzand near Texel was reached in 1989. The more marine tidal flats near Sylt were not reached before 2003. At Balgzand and subtidal areas in the western Dutch Wadden Sea *Marenzelleria* strongly decreased during 2003 (Dekker and Waasdorp, 2004). Although there are several other polychaetes of similar size and feeding type in the Wadden Sea, no clear evidence for competitive interactions between the invader and the natives have been found so far. A predecessor, which immigrated in the late 1960s, is the small worm *Tharyx* cf. *killariensis* of unknown origin and uncertain taxonomic status. It is still common in the Wadden Sea.

6.2.4 *Ensis americanus* (American razor clam)

No razor clams occurred in the Wadden Sea before the arrival of *Ensis americanus* (syn. *E. directus*) in ballast water near Helgoland in 1978. By larval and postlarval drifting this species rapidly extended its distribution, approximately 75 km per year in westward direction and 125 km to the north (Armonies, 2001; Essink, 1985). We may learn from this rate of spread that for benthic species with similar dispersal capabilities, studies on local effects require knowledge of population dynamics on a scale of at least 200 km (*i.e.*, half of the coastal length of the Wadden Sea) to differentiate the local phenomena from general trends.

Successful recruitment is rather irregular in the Wadden Sea (Armonies and Reise, 1999; Beukema and Dekker, 1995). Near Sylt, only six strong year-classes were recorded within two decades. Although present in the lower tidal zone, maximum densities occur in shallow subtidal sand including the coastal region offshore of the barrier islands, with a biomass similar to that of dense beds of the native cockles and mussels. Very high larval abundances in plankton samples suggest that adult densities are still underestimated due to insufficient sampling gear (M. Strasser, pers. comm.). Significant interactions with native suspension feeders have not been noted so far, although *E. americanus* may now be the most abundant large bivalve in the shallow subtidal. It has become a significant food item for eider ducks and common scoters (T. Jensen, pers. comm.; Leopold *et al.*, in prep.; Wolf and Meiniger, 2004). Contrary to the belief that introduced molluscs may be free of parasites, *E. americanus* contained many of the larval trematodes known from native cockles, however, the intensity of infestation was much lower (Krakau *et al.*, in prep.). Thus, razor clams may constitute a healthier food for final trematode hosts, such as eiders, than native bivalves, although they may be harder to swallow.

6.2.5 *Crepidula fornicata* (American slipper limpet)

Unintentionally introduced with oysters to Europe in the 1870s, the American slipper limpet *Crepidula fornicata* (L.) is now found from the Mediterranean to Norway. At southern European coasts, especially in France, this epizootic suspension feeder became superabundant, forming thick carpets of individual snails adhering to each other and covering shallow subtidal soft bottoms with up to 9,000 limpets m^{-2} (Blanchard, 1997). Also in the saline lake Grevelingen in the Dutch Delta region such high abundances do occur. In the Wadden Sea abundances are still an order of magnitude lower. However, since the first records 70 years ago, slipper limpets have increased, shifted

American slipper limpet (*Crepidula fornicata*) (Photo: C. Buschbaum)

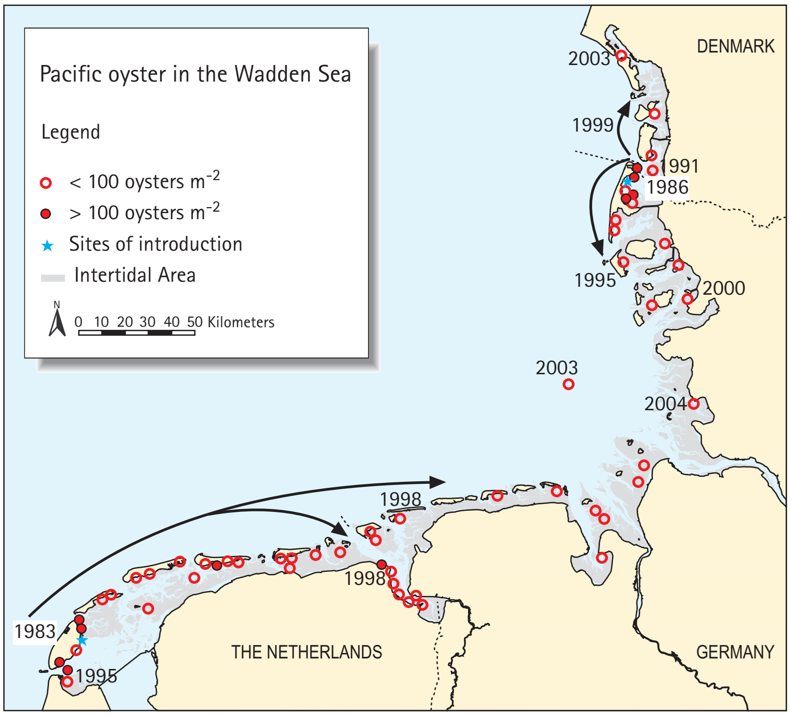

Figure 6.1: The Pacific oyster *Crassostrea gigas* in the Wadden Sea. Asterisks indicate sites and years (boxed) of introduction (Texel, Sylt). Other years indicate first records of settlement by larval dispersal for selected sites. Circles show mean abundance in 2003.

their habitat from oyster to mussel beds and locally form monospecific epibenthic assemblages with limpets attached to each other (Thieltges *et al.*, 2003). In the Dutch Wadden Sea the species was considered rare, but has increased considerably in the last two years on subtidal mussel beds.

While predation pressure on *Crepidula* is low and parasites absent, and reproduction and growth being similar to that reported from elsewhere, the main limiting factor for population increase in the Wadden Sea is apparently winter mortality (Thieltges *et al.*, 2004). Milder winters as a corollary of global warming in the years to come may allow this limpet to attain abundances similar to those reported from further south. This introduced species has the potential to displace other epibenthic suspension feeders. In experiments, limpets increased mortality and decreased growth of mussels to which they attach (Thieltges, 2005).

6.2.6 *Crassostrea gigas* (Pacific oyster)

In the Wadden Sea, attempts to restock the depleted oyster beds of the native *Ostrea edulis* failed with imported spat from outside, with American *Crassostrea virginica* or with *C. angulata* from Portugal and France – now considered to be a southern strain or sibling from the Pacific *C. gigas*. Since 1964, the Japanese *C. gigas* has been imported to several places in Europe, including the Wadden Sea. Attempts in the 1970s and 1980s in Niedersachsen were short-lived (Wehrmann *et al.*, 2000) but at Sylt a thriving culture became established in 1986, primarily with spat taken from British hatcheries (Reise, 1998). *C. gigas* was found in 1983 at Texel, probably brought there deliberately from the Dutch Delta region (Dankers *et al.*, 2004). Natural spread by larvae, and may be also by transport with attached young oysters on ships' hull or on relayed mussels, occurred during the 1990s from Texel and Sylt. In 2003 the records imply that *C. gigas* has achieved a continuous distribution throughout the entire Wadden Sea (Figure 6.1). Because of a good spatfall in 2003 many oyster beds are now rapidly developing into solid reefs at several sites in the region.

While no viable population of the native *O. edulis* is left in the Wadden Sea, the Pacific *C. gigas* is now firmly established. Is this exchange of oyster species neutral to the ecosystem or is it bound to conspicuous change? Although treated as similar at the market, ecologically these oysters are very different. *O. edulis* occurred subtidally and has a narrower tolerance range for temperature and salinity than *C. gigas* which lives primarily in the intertidal. Due to partial brooding, *O. edulis* produces less larvae which remain in the plankton for only a few days with limited dispersal, which is in contrast to the more numerous and widely broadcasted eggs and larvae of *C. gigas*.

Near Texel and Sylt development has locally advanced from solitary oysters to coherent reefs where subsequent generations attach to each other. This development may take 5 to 10 years (Dankers *et al.*, 2004). In contrast to most native bivalves with spawning in spring and early summer, *C. gigas* spawns in July and August. Successful recruitment did not occur every year. Near Sylt, years with high recruitment were those with highest temperatures in July and August (Diederich *et al.*, 2005). Thus, *C. gigas* in the northern Wadden Sea may benefit from global warming. Spat is difficult to find in the field and recruitment success is best assessed after one year when oysters have attained a shell diameter of 20 to 50 mm or more. In 2003, oyster sizes over 180 mm were common, and the largest specimen found in the Wadden Sea was of the gigantic size of 310 mm (Dankers *et al.*, 2004). This indicates that *C. gigas* may survive to old age in this region.

Solid calcareous reefs are a completely new biogenic structure for the Wadden Sea and may give rise to a biocoenosis very different from the one described by Karl Moebius (1877) for the native oyster beds. Once abundant, these reefs may considerably alter patterns of sediment erosion and deposition in the Wadden Sea. Although attaching to any kind of hard substrate, sites with living mussel beds or plenty of dead mussel shells, are the most frequent localities where *C. gigas* abounds and reef formation is commencing. This overgrowth and pre-emption of space, and possibly also competition for phytoplankton and filtering of larvae, may eventually diminish the still dominant cockles and mussels in the Wadden Sea. In the Eastern Scheldt almost 5% of tidal and subtidal sediments are covered by *C. gigas*, and in this semi-enclosed embayment such effects are already assumed to take place (Geurts van Kessel *et al.*, 2003).

Preliminary experiments and observations suggest that predation pressure by starfish, crabs and birds on *C. gigas* is lower than on native bivalves. The trematode parasite *Renicola roscovita* which takes periwinkles as first, cockles and mussels as second intermediate host and gulls and eider ducks as final host, is also infesting *C. gigas* but at lower intensity (M. Krakau, pers. comm.). Thus, provided no efficient predators on these oysters nor viral diseases become introduced, *C. gigas* is expected to take over in the Wadden Sea, both as an ecosystem engineer generating solid reefs and as a competitive suspension feeder.

No control is feasible which would not also harm other components of the Wadden Sea ecosystem. Harvesting wild *C. gigas* is unlikely to be effective and oysters cemented to each other in the reefs and larger in size than a human hand cannot be sold on the market.

6.3 Conclusions

We have singled out from some 52 introduced species six which already do have or which are about to have strong effects on habitat properties and native biota in the Wadden Sea. None of these cause any immediate harm to human health and economy nor do they offer a great benefit except for Pacific oysters in culture. These targeted species differ in their effects, some of which may be 'good' (*i.e.*, sediment retention by *Spartina*, habitat provision by *Sargassum*, more food for birds by *Ensis*) and others 'bad' (*i.e.*, displaced seagrass by *Spartina*, overtaking mussels by *Crassostrea*). The suspension feeder compartment in the coastal ecosystem will become strengthened and crowded by *Ensis, Crepidula* and *Crassostrea*, probably resulting in a major trophic regime shift. Global warming may benefit *Spartina, Crepidula* and *Crassostrea* in the coming years, resulting in further changes in dominance. Some introductions have become extremely numerous locally, such as *Marenzelleria*, and still we lack sufficient knowledge to even guess what the community effects will be. In any case, species introductions have considerably speeded up the rate of ecological change, calling into question the long-term utility of quality standards derived from present species assemblages.

Are these six introduced species threatening 'A healthy environment which maintains the diversity of habitats and species, its ecological integrity and resilience as a global responsibility', this written as a shared vision in the Trilateral Wadden Sea Plan (1997). There is no evidence that introduced species have caused the extinction of natives in the Wadden Sea (Wolff, 2000). 'Ecological integrity' is a vague term and may either imply in analogy to the territorial integrity of nations that the areal extent should not be reduced, or in analogy to personal integrity that the character should remain clear, uncorrupted and intact. The targeted six species are changing habitats, functions and species compositions in the ecosystem to some extent, and even to the untrained observer the tidal seascape will never turn again to be the same. 'Resilience' is defined as the ability to return to a previous state after a disturbance. To what extent this ability with and without introduced species is different may be determined only with a set of controlled experiments. However, results would strongly depend on the choice of disturbances, and a clear answer cannot be expected. From the fact alone that these introduced species are so successful in their recipient environment, one may infer that resilience is rather high, unless the introduced species itself is considered to be the disturbance. There is no indication that established non-native immigrants will ever leave the Wadden Sea again.

As species introductions are irreversible and accumulating over time, this issue may be considered to be more important than reversible effects of overfishing, eutrophication and contaminants. For the Wadden Sea the net effect of unhampered introductions would be a regional increase in species richness and a growing biotic similarity with other coasts. The unique character of the Wadden Sea would still be manifest in the physical environment but not any more in its living component.

6.4 Recommendations

Introduced species as such do not constitute a threat. Some deliberate introductions are at least economically beneficial, and most others have remained minor components in the Wadden Sea ecosystem. Unfortunately, attempts to predict which species among the immense spectrum of potential introductions are likely to become problematic have had a low success. The 'innocent until proven guilty' philosophy is inadequate in this case and should be replaced by 'guilty until proven innocent' (Simberloff, 2003). This requires comprehensive assessments of proposed introductions. This was not done with the oysters introduced into the Wadden Sea. Most introductions, however, were not intended. To reduce the rate of such introductions, effective precautionary measures are in need (Nehring and Klingenstein, 2005). Because of the high potential for natural dispersal in introduced species, and many human vectors for secondary dispersal along European coasts, adequate precautionary measures are beyond a trilateral management plan. For example, a decision not to introduce Pacific oysters for culturing would have merely postponed the invasion unless at European coasts outside the Wadden Sea the same decision would have been made. To protect the 'ecological integrity' of the Wadden Sea, European-wide solutions need to be supported. To provide sufficient reasons for these, thorough analyses of the impacts caused by the already introduced species are a necessary prerequisite. Compared to other regions, the Wadden Sea may have had good luck with the immigrants so far with the possible exceptions of toxic flagellates in the phytoplankton and of the Pacific oyster. One single introduced species may be able to cause severe ecological change, economic damage or a threat to human health, and this might be the next species about to arrive or one which is already there but its full impact has not yet been realized.

The TMAP should be able to discover new immigrant species. Adaptations of the TMAP may be necessary in order to provide the data for evaluating the possible impact on resident biological communities. Furthermore, it might be useful to consider the development of a trilateral policy on how to deal with invasive introduced species (Nehring and Klingenstein, 2005).

References

Armonies, W., 2001. What an introduced species can tell us about the spatial extension of benthic populations. Mar. Ecol. Prog. Ser. 209, 289-294.

Armonies, W. and Reise, K., 1999. On the population development of the introduced razor clam *Ensis americanus* near the island of Sylt (North Sea). Helgoländer Meeresunters. 52, 291-300.

Beukema, J.J. and Dekker, R., 1995. Dynamics and growth of a recent invader into European coastal waters: the American razor clam, *Ensis directus*. J. Mar. Biol. Ass. UK 75, 351-362.

Blanchard, M., 1997. Spread of the slipper limpet *Crepidula fornicata* (L. 1758) in Europe: current state and consequences. Sci. Mar. 61, 109-118.

Buschbaum, C., 2005. Pest oder Bereicherung? Der eingeschleppte Japanische Beerentang *Sargassum muticum* an der deutschen Nordseeküste. Natur und Museum (in press).

Dankers, N.M.J.A., Dijkman, E.M., Jong, M.L. de, Kort, G. de, and Meijboom, A., 2004. De verspreiding en uitbreiding van de Japanse Oester in de Nederlandse Waddenzee. Wageningen, Alterra, Alterra-rapport 909, pp. 51.

Dekker, R. and Waasdorp, D., 2004. Het Macrobenthos in de Waddenzee in 2003. NIOZ report 2004-3, pp. 55.

Diederich, S., Nehls, G., Beusekom, J.E.E. van, and Reise, K., 2005. Introduced Pacific oysters (*Crassostrea gigas*) in the northern Wadden Sea: Invasion accelerated by warm summers? Helgol. Mar. Res. 58 (in press).

Essink, K., 1985. On the occurrence of the American jackknife clam *Ensis directus* (Conrad, 1843) (Bivalvia, Cultellidae) in the Dutch Wadden Sea. Basteria 49, 73-80.

Essink, K., 1999. Dispersal and development of *Marenzelleria* spp. (Polychaeta, Spionidae) populations in NW Europe and The Netherlands. Helgoländer Meeresunters. 52, 367-372.

Essink, K. and Dekker, R., 2002. General patterns in invasion ecology tested in the Dutch Wadden Sea: The case of a brackish-marine polychaetous worm. Biological Invasions 4, 359-368.

Essink, K., Eppinga, J. and Dekker, R., 1998. Long-term changes (1977-1994) in intertidal macrozoobenthos of the Dollard (Ems Estuary) and effects of introduction of the North American spionid polychaete *Marenzelleria* cf. *wireni*. Senckenbergiana marit. 28: 21-25.

Geurts van Kessel, A.J.M., Kater, B.J. and Prins, T.C., 2003. Veranderende draagkracht van de Oosterschelde voor kokkels. Rapport RIKZ/2003.043, Rijkswaterstaat Rijksinstituut voor Kust en Zee, Middelburg.

Jong, F. de, Bakker, J.F., van Berkel, C.J.M., Dankers, N.M.J.A., Dahl, K., Gätje, C., Marencic, H. and Potel, P., 1999. Wadden Sea Quality Status Report. Wadden Sea Ecosystem No. 9. Common Wadden Sea Secretariat and Trilateral Monitoring and Assessment Group, Wilhelmshaven, Germany.

Möbius, K., 1877. Die Auster und die Austernwirthschaft. Wiegandt, Hempel Parey, Berlin, 1-126.

Nehring, S. and Klingenstein, F., 2005. Alien species in the Wadden Sea - A challenge to act. Wadden Sea Newsletter 2005, (in press).

Reise, K., 1998. Pacific oysters invade mussel beds in the European Wadden Sea. Senckenbergiana marit. 28, 167-175.

Reise, K., Gollasch, S. and Wolff, W.J., 2002. Introduced marine species of the North Sea coasts. In: Leppäkoski, E., Gollasch, S., Olenin, S. (Eds), Invasive aquatic species of Europe. Distribution, impacts and management. Kluwer Academic Publ, Dordrecht, 260-266.

Schories, D. and Albrecht, A. 1995. *Sargassum muticum* der japanische Beerentang im deutschen Wattenmeer. Natur und Museum, Frankfurt 125, 92-98.

Simberloff, D., 2003. Confronting introduced species: a form of xenophobia? Biological Invasions 5, 179-192.

Thieltges, D.W., 2005. Impact of an invader: Epizootic American slipper limpet *Crepidula fornicata* reduces survival and growth in European mussels. Mar. Ecol. Prog. Ser. 286, 13-19.

Thieltges, D.W., Strasser, M., Beusekom, J.E.E van, and Reise, K., 2004. Too cold to prosper – winter mortality prevents population increase of the introduced American slipper limpet *Crepidula fornicata* in northern Europe. J. Exp. Mar. Biol. Ecol. 311, 375-391.

Thieltges, D.W., Strasser, M. and Reise, K., 2003. The American slipper limpet *Crepidula fornicata* (L.) in the northern Wadden Sea 70 years after its introduction. Helgol. Mar. Res. 57, 27-33.

Trilateral Wadden Sea Plan, 1997. In: Ministerial Declaration of the Eighth Trilateral Governmental Conference on the Protection of the Wadden Sea, Stade, 1997, Annex 1. Common Wadden Sea Secretariat, Wilhelmshaven, pp. 13-83.

Wehrmann, A., Herlyn, M., Bungenstock, F., Hertweck, G. and Millat, G., 2000. The distribution gap is closed – first record of naturally settled Pacific oysters *Crassostrea gigas* in the East Frisian Wadden Sea. Senckenbergiana marit. 30, 153-160.

Wolf, P. and Meininger, P.L., 2004. Zeeën van zee-eenden bij de Brouwersdam. Nieuwsbrief Nederlands Zeevogelgroep 5(2), 1-2.

Wolff, W.J., 2000. Causes of extirpations in the Wadden Sea, an estuarine area in The Netherlands. Conservation Biology 14, 876-885.

Wolff, W.J. and Reise, K., 2002. Oyster imports as a vector for the introduction of alien species into northern and western European coastal waters. In: Leppäkoski, E., Gollasch, S., Olenin, S. (Eds.). Invasive aquatic species of Europe. Kluwer Academic Publ., Dordrecht, 193-205.