NOBANIS – Invasive Alien Species Fact Sheet

Crassostrea gigas

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Species description

Scientific names: *Crassostrea gigas* (Thunberg 1793), Ostreidae, Bivalvia
Synonyms: *Gryphaea angulata* Lamarck 1819; *Ostrea gigas* Thunberg 1793; *Ostrea laperousii* Schrenk 1861; *Ostrea talienwhanen*sis Crosse 1862.
Note: The Portuguese oyster *Crassostrea angulata* is a name often used for this species. According to genetic studies it was shown that *Crassostrea angulata* is likely a strain of *Crassostrea gigas* originating from Taiwan (Huvet *et al.* 2002). However, the identity of *C. gigas* and *C. angulata* remains unsettled. Molecular data indicate higher similarity than usual for distinct species, but still show distinct differences (Huvet *et al.* 2002, Boudry *et al.* 2003, Lam 2003, Cross *et al.* 2005).
Common names: giant oyster, Japanese oyster, Pacific oyster, Portuguese oyster (GB), Stillehavsøsters, japansk østers (DK), Felsenauster, Pazifische Auster, Portugiesische Auster (DE), Suur hiidauster (EE), risaostra (IS), Austre (LT), lielâ austere (LV), ostryga pacyficzna (PL), Japanskt jätteostron (SE)

Fig. 1 and 2. *Crassostrea gigas*, right and left value respectively, Danish Wadden Sea near the island of Rømø, February 2005, photo by Kathe R. Jensen.

Fig. 3. *Ostrea edulis* and *Crassostrea gigas*, left values, (Oe) Danish Wadden Sea near the island of Rømø, December 2003, (Cg) German Wadden Sea near the island of Sylt; January 2005, photo by Kathe R. Jensen.


Fig. 4. Farming of *Crassostrea gigas* near the German island of Sylt, April 2003, photo by Stefan Nehring. **Fig. 5.** Oyster reef *Crassostrea gigas* in the German Wadden Sea near the island of Sylt, January 2005, photo by Stefan Nehring.

Species identification

The Pacific oyster shell is extremely variable and irregular in shape. Its shape depends on the type of bottom on which it is grown, as well as the degree of crowding. It will have a rounded shape with extensive fluting on hard substrates, an ovate and smooth shell on soft substrates, and a solid shape with irregular margins on mini-reefs. The two valves are solid, but unequal in size and shape. The left valve is slightly convex and the right valve is quite deep and moderately cup shaped. One valve is usually entirely cemented to the substrate. The shells are sculpted with large, irregular, rounded, radial folds with overlapping, concentric lamellae in mature specimens. Colour usually whitish with many purple streaks and spots radiating away from the umbo. The interior of the shell is white, with a single muscle scar that is sometimes dark, but never purple or black. Normally the length of shells is 80-200 mm, exceptional specimens can attain 400 mm. A Pacific oyster may live up to thirty years. Key references: NIMPIS (2002) and ISSG (2005).

Native range
The Pacific oyster occurs naturally in estuarine and coastal marine waters of Japan and south-east Asia. Specimens are found in the intertidal and shallow subtidal zones (NIMPIS 2002).

Alien distribution

History of introduction and geographical spread.
More than once during the 19th century, attempts have been made to revive exploited stocks of the European oyster (*Ostrea edulis*) with American oysters (*Crassostrea virginica*) and 'Portuguese oysters *C. angulata*' at several sites in coastal waters of Northern Europe. These attempts largely failed (Wolff and Reise 2002). In 1964 Dutch oyster farmers imported spat of the Pacific oyster (*Crassostrea gigas*) from British Columbia for aquaculture activities in the Oosterschelde estuary. In the following years more imports of spat and adult specimens followed, starting in 1966 also from Japan. In 1975 and 1976 natural spatfalls occurred during very warm summers and resulted in millions of so-called weed oysters in the Oosterschelde estuary. Within several years the Pacific oyster has developed explosively and in the 1980's other Dutch estuaries started to be colonized (Wolff and Reise 2002). In 1983 first specimens were observed near the island of Texel in the Dutch Wadden Sea, probably brought there deliberately from the Oosterschelde in the 1970s (Bruins 1983, Wolff 2005). Since the 1990's this alien species was frequently observed along the entire Dutch coast and in the Dutch Wadden Sea (Dankers *et al.* 2004). In 1996 a first settlement of the Pacific oyster occurred in the western Wadden Sea area of Germany as well, which may have been dispersed from the Netherlands by natural means (Wehrmann *et al.* 2000).
In Germany 'Portuguese oysters *Crassostrea angulata*' were imported from Portugal and Spain and introduced into the Wadden Sea near Norddeich in 1913-14 and in the Jadebusen and near Sylt in 1954, 1961 and 1964. This did not lead to lasting cultures or establishment of the species (Meyer-Waarden 1964, Neudecker 1992, Wehrmann *et al.* 2000). Between 1971 and 1987 spat and larvae of the Pacific oyster were repeatedly imported from Scottish hatcheries for scientific aquacultural experiments and studies at different sites in the German Wadden Sea and at the German Baltic Sea coast in the Flensburg Fjord (Meixner and Gerdener 1976, Seaman 1985, Wehrmann *et al.* 2000). All these attempts, however, proved unsuccessful. Since 1986 commercial farming activities began in the northern area of the German Wadden Sea near the island of Sylt, primarily with spat taken from British and Irish hatcheries (Reise 1998, Nehring 1999). Oysters are cultivated in plastic mesh bags on trestles in the intertidal zone. It takes about 2 years until the oysters reach marketable size. Shortly after oyster farming had commenced, natural spatfalls occurred and in 1991 the first oysters were found outside the culture plot (Reise 1998). In the following years several, sometimes strong spatfalls were recorded and a significant dispersal with increasing abundances took place (Nehring 2003a, Diederich *et al.* 2005, Wehrmann and Schmidt 2005).
In Denmark Pacific oysters from German aquaculture experiments in the Flensburg Fjord were planted in the Little Belt of the Baltic Sea around the island Bogø in 1979. During the last thirty years of the last century large amount of *C. gigas* (> millions) seed oysters were imported from England, The Netherlands, and France to different Danish marine waters for culture in marine aquaculture experiments. The aquaculture took place in the Little Belt, in the waters south of the island Funen, in Horsens fjord, around the island Samsø in Kattegat and in Isefjorden (Kristensen, 1986, Kristensen and Hoffmann in press). In Isefjorden commercial production have taken place (between 100.000 to 300.000 oysters annually between 1986 and 1999). Apparently oysters were abandoned in the area, where they survived for several years but did not establish. Pacific oysters imported by the Limfjord Oyster Company were kept in basins for depuration. They were not cultured - though there are anecdotal information of finding escapees years after the company ceased its activities (Kathe Jensen, pers. comm.). At the end of the last century commercial

production have taken place in the Danish Wadden Sea (very limitted scale with a few thousands oysters annually) (Per Dolmer and Per Sand Kristensen, pers. comm.). In 1999 first freeliving specimens were observed, which may have been dispersed from the northern German Wadden Sea by natural means (Reise *et al.* 2005).
In the early 1970ties a few specimens of Pacific oysters were introduced and cultivated in Sweden, just south of the town Strömstad in the county of Bohuslän (J. Haamer, pers. comm.). In the summer of 2005 one live individual from this area was brought for examination to the Tjärnö Marine Biological Station (H.-G. Hansson, pers. comm.). It is not known if this could have been a surviving specimen from the original batch indicating that it may live longer than 30 years. It did not survive long, however, in the aquarium where it was placed. No survey of oysters have been performed in Sweden.
In autum 2005 two specimens of *C. gigas* were found alive on the Norwegian Skagerrak coast in the archipelago east of the town Kragerø. The oysters were 5 - 6 years old, and they seemed to have settled on local mussel shells. There is no aquaculture of this species in Norway up to now. That's why it is to assume that the occurrence is a result of larvae drift from southern regions, presumably from the Wadden Sea. However, it is not to exclude, that Pacific oysters are imported in Norway as food and relaid in the sea (Stene and Mortensen unpubl.).

Pathways of introduction
Today the Pacific oyster is an important aquaculture species worldwide. The majority of introductions of the Pacific oyster in Europe have been undertaken as a replacement/alternative for collapsed fisheries of native species, especially of the European oyster (*Ostrea edulis*) (Nehring 1999, Wolff and Reise 2002). To maintain viable hatchery broodstocks, different strains of the Pacific oyster have been used from various locations (Drinkwaard 1999). Depending on natural conditions, oysters are either placed directly on the bottom, on trestles or on longlines suspended off the bottom. In many regions, natural spatfalls occurred and wild oyster populations were established: e.g. British Columbia, California, South Africa, Australia, New Zealand, France, and British Isles (Reise 1998, Diederich 2005a).
In the case of the Dutch and German Pacific oysters importations, it was not predicted that offspring were to be expected. In 1966 the Dutch oyster farmers were informed that the introduction of the Pacific oyster as seed stock was acceptable since these oysters could not reproduce at the latitude of the Dutch coastal waters (Drinkwaard 1999). This assumption was probably also an important prerequisite for the permit given by German authorities for the setting up of the commercial aquaculture plot at Sylt in 1986 (Wehrmann *et al.* 2000). However, at present reviewing the old files is in progress (Koßmagk-Stephan pers. comm.). Nevertheless, the oysters reproduced successfully and permanent populations were unintentionally established. Considering the dominating meteorological and hydrographic conditions of the German Bight in The Netherlands pelagic oyster larvae are spreading in an eastwards direction along coastal sites and arrived the western German Wadden Sea in 1996 (Wehrmann *et al.* 2000). From the German culture plot at Sylt the oyster population slowly expanded its range north- and southwards along the coastline. The Danish Wadden Sea was reached in 1999 and since 2004 the distribution gap of the Pacific oyster between the western and northern Wadden Sea is closed (Reise *et al.* 2005).

Alien status in region
The Pacific oyster is found established in the Wadden Sea area of Denmark and Germany (as well as of The Netherlands) (Reise *et al.* 2005) (see table 1 and figure 6). The status of *Crassostrea* in Swedish and Norwegian waters is unclear (Susan Smith, pers. comm., Stein Mortensen, pers. comm.). In general the Pacific oyster has not yet established permanent populations in northern or eastern areas because most of the coastal waters of Northern Europe are probably too cold and especially most of the Baltic is probably too limnic for the Pacific oysters to survive.

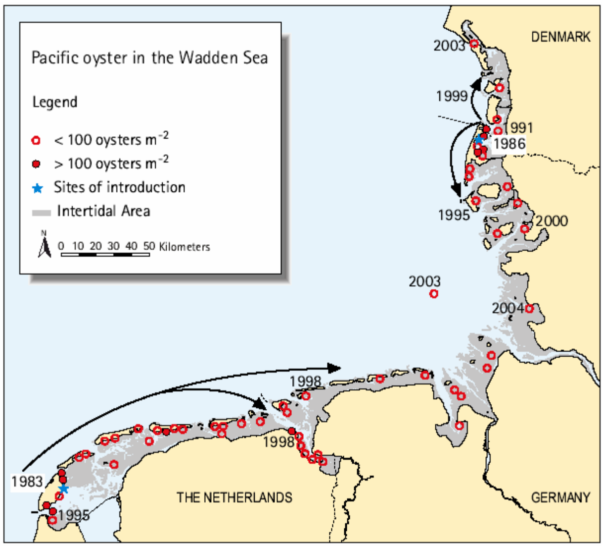

Fig 6. The Pacific oyster *Crassostrea gigas* in the Wadden Sea. Asterisks indicate sites and years (boxed) of introduction (Texel, Sylt). Other years indicate first records of settlement by larval dispersal for selected sites. Circles show mean abundance in 2003, map from Reise *et al.* (2005).

Country	**Not found**	**Not established**	**Rare**	**local**	**Common**	**Very common**	**Not known**
Denmark				X			
Estonia	X						
European part of Russia	X						
Finland	X						
Faroe Islands	X						
Germany					X		
Greenland	X						
Iceland	X						
Latvia	X						
Lithuania	X						
Norway		X					
Poland	X						
Sweden		X					

Table 1. The frequency and establishment of *Crassostrea gigas*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available.

Ecology

Habitat description

Pacific oysters will attach to almost any hard surface in sheltered waters. Whilst they usually attach to rocks in their native range, the oysters can also be found in muddy or sandy areas. Oysters will also settle on adult specimens of the same or other bivalvae species. In its native range they prefer sheltered waters in estuaries where they are found in the intertidal and shallow subtidal zones, to a depth of about three meters (NIMPIS 2002).

In the European Wadden Sea, however, hard surfaces are scarce on the extensive mud and sand flats. Mainly rocky dike foots, stone walls, harbor facilities, and especially dead shell material and epibenthic Blue mussel beds (*Mytilus edulis*) provide a secondary hard substrate for sessile species. Therefore, Pacific oysters are mainly found in the Dutch and German Wadden Sea as epibionts on Blue mussel beds, attached to the shells of living and dead mussels. Other bivalves were of minor importance as substrates (Reise 1998, Nehring 1999). The actual records imply that the Pacific oyster has achieved a continuous distribution throughout the entire Wadden Sea. Because of good spatfalls in the last years many oyster aggregations are now rapidly developing into solid reefs at several sites in the region (Reise *et al.* 2005). In 2003 maximum abundances reached over 300 oysters m^{-2} at Sylt (Diederich *et al.* 2005). Pacific oysters live primarily in the intertidal, the colonisation of the subtidal zone occurred much slower. Up until 2004 only scattered oysters were found in subtidal locations of the German Wadden Sea. However, the Pacific oyster might be able to generate subtidal oyster reefs in the next years as has happened in Dutch waters (Diederich 2005a).

Reproduction and life cycle

The Pacific oyster is a filter feeder and will ingest bacteria, protozoa, a wide variety of diatoms, larval forms of other invertebrate animals, and detritus. Oysters are able to reproduce and grow in salinities of 10-42 psu (23-36 psu optimum for fertilisation). They are able to grow in temperatures ranging from 4 to 35°C and to survive temperatures as low as -5°C; however, for reproduction they need more than 20°C. Some mortality is recorded at 30°C, 40°C for 1 hour results in 100% mortality. Pacific oysters have very high growth rates (in the Wadden Sea they can grow to 100 mm in their first 12 months). Pacific oysters which have not been harvested may live up to thirty years. Key references: NIMPIS 2002, Dankers *et al.* 2004, PWSRCAC 2004, Diederich 2005a.

Like most oyster species, Pacific oysters change sex during their life, usually spawning first as a male and subsequently as a female. Environmental conditions may affect the sex. When food supplies are plentiful, males tend to change their sex to become females, and vice versa when food supplies are scarce. A few individuals are hermaphroditic. The Pacific oyster reached their first reproductive period in the summer one year after settlement. In northern waters, this happens in July and August. During the breeding season the reproductive organs may constitute 50% of the body's volume. Pacific oysters are extremely fertile and typically produce between 50-100 million eggs which are released over several spawning bursts. The male oyster also discharges its sperm. Fertilization must occur within 10-15 hours after spawning. The larvae are planktonic and free swimming. The larval period ranges from 3 to 4 weeks, dependent of the water temperature. When settling, the larvae group together and crawl around the sea floor, searching for a suitable hard substratum to which they can partially or almost completely cement their lower shell valves. Key references: PSMFC 1996, Reise 1998, NIMPIS 2002, PWSRCAC 2004, ISSG 2005.

Dispersal and spread

Juveniles and adults of the Pacific oyster are sedentary and normally cemented to hard substrates. However, fertilization occurs externally and larvae are planktonic, spending about 3 to 4 weeks in this free-swimming phase. The larvae develop organs that allow it to swim, although water currents remain the dominant means by which it is dispersed naturally. According to Reise (1998) residual currents along the Wadden Sea coast rarely exceed 0.1 m s^{-1}, a larva of the Pacific oyster could theoretically travel 240 km in maximum before it attaches to a hard surface. However, the observed spread towards areas outside the surroundings of the culture plots occurred at a much slower rate (Nehring 2003a, Reise *et al.* 2005). This presumbly does not result from a lack of dispersal but from limited larval supply or poor initial survival after settlement. High recruitment events were erratic in the Wadden Sea area and occurred only in years with abnormally high summer water temperatures above 20°C. Since 1986 at Sylt significant recruitment success occurred only in 6 years (Diederich *et al.* 2005). In addition, food required for developing larvae, and the presence of predators, especially shore crabs, can influence its spread (Eno *et al.* 1997).

The spreading of larvae along the Dutch, German and Danish Wadden Sea and further north is very likely. In Denmark the larvae may even go through the canal at Thyborøn and into the Limfjorden. The spreading in the Kattegat and Belt area in Danish waters are most likely due to the imports of seed oysters and culture. During the ninety nineties mussels have been transported to the mussel industries in the Limfjorden area. All the landings have been sorted and rinsed for purification before preservation. Spreading of *C. gigas* to the Limfjorden through these transports cannot be ruled out.

Dutch mussel farmers have reported that Pacific oysters have been found in current transports of seed mussels (*Mytilus edulis*) from the German to the Dutch Wadden Sea (Wolff and Reise 2002). It follows from this that increasing commercial activities with seed mussels will become important sources for the inter - and intraregional spreading of Pacific oysters. Larvae prefer to attach themselfs to almost any type of hard surface, including ships' hulls. Local dispersal of Pacific oysters through this transport vector is also likely.

Impact

Affected habitats and indigenous organisms

The Pacific oyster has been introduced from Asia across the globe. In North America and the Australasia-Pacific regions the oyster is known to settle into dense aggregations, resulting in the limitation of food and space available for other intertidal benthic species. It has been documented destroying habitat and causing eutrophication of the water bodies it invades (NIMPIS 2002). In Dutch waters, at the same time as Pacific oysters increased, the stocks of Blue mussels and cockels decreased. This decrease was accompanied by a decrease of the population of an important shellfish-feeding bird, the oystercatcher (*Haematopus ostralegus*). However, it is not yet clear if this is a causal relationship (Wolff and Reise 2002). In oyster cultivation areas in France high oyster densities caused a severe decline in macrofauna and zooplankton but enhanced bacteria, microfauna and meiofauna which in turn promoted the more active trophic fluxes towards birds and nektonic fishes (Leguerrier *et al.* 2004).

In the Wadden Sea many Pacific oyster beds are now rapidly developing into solid reefs at several sites in the region. Thus the Pacific oyster is expected to take over in the mudflats on the German and Danish North Sea coast, both as an ecosystem engineer generating solid reefs and as a competitive suspension feeder (Reise *et al.* 2005). *C. gigas* tends to settle in the same locations and on the same tidal level as the native Blue mussel (*Mytilus edulis*) (Nehls *et al.* 2006). The overgrowth of mussels and pre-emption of space, and possibly also competition for phytoplankton and filtering of larvae, will probably diminish native species (Nehring 2003a). The Pacific oyster has a large filtration capacity and filters on average 5 l/g/h but values up to 25 l/g/h have been recorded (Ren *et al.* 2000). A possible top-down control of phytoplankton biomass may modify benthic-pelagic coupling by forcing a shift from pelagic to benthic consumers because of food depletion in the water column (Diederich 2005a). Whether or not birds will be able to use oysters as a food resource needs further study, especially in the face of impacts that a possible shift from mussel beds to oyster reefs might have on bird populations that use the Wadden Sea as an essential feeding ground (Diederich 2005a, Wehrmann and Schmidt 2005). As the oysters release nutrients and pseudofaeces into the environment, planktonic and benthic productivity in the Wadden Sea may increase (Diederich 2005a). However, quantified effects of Pacific oysters on native flora and fauna of the Wadden Sea are still not available.

There were reports of mass Pacific oyster deaths in an restricted area along the Dutch coast in August 2004 and in several harbour areas on the German Wadden Sea coast in September 2005. Up to 80% of oysters were found dead. There were no clear indications of the causes and there have been no indications of any disease or parasite. Possible explanations are a.o. high water temperatures, low water exchange and low plankton concentration during these periods (Wehrmann and Schmidt 2005).

Continued importation of Pacific oyster seed creates a potential risk for introduction of other alien species and diseases. In 1981 all importations of Pacific oysters from France to The Netherlands were stopped and all planting of such oysters in the Oosterschelde was prohibited, because a new disease, caused by a protozoan (*Bonamia ostreae*), had been introduced (Drinkwaard 1999). Reise *et al.* (2002) listed 32 alien species probably transferred with the Pacific oyster in the North Sea and the Channel. Several of these alien species are known be invasive, can negatively affect the native environment (Leppäkoski *et al.* 2002).

Genetic effects

Different strains of Pacific oysters are recognised. In 1970 'Portuguese oysters *Crassostrea angulata*' became the victim of disease in The Netherlands. The complete stock disappeared in Dutch waters, whereas it was replaced by Pacific oysters imported from British Columbia and Japan in the same areas without any problem (Wolff and Reise 2002, Wolff 2005). The genetic variablity in the introduced stocks and their offspring may be high. These genetic aspects need further study (Drinkwaard 1999). However, the multiple origins of imported seed oysters combined with the ability to hybridize makes it difficult to establish the actual origin of the established population (Kathe Jensen pers. comm.).

The Pacific oyster has been found to be capable of interbreeding with several other *Crassostrea* species (Gaffney and Allen 1993). The coexistence of two oyster species, the native European oyster (*Ostrea edulis*) and the Pacific oyster, in the Wadden Sea raises the possibility of natural hybridization and possible introgression. However, no hybrid individuals were observed yet.

Human health effects

Pacific oysters pose a direct threat to human safety because of their propensity to cut feet and shoes with their sharp shells. In The Netherlands they nowadays interfere with the recreational use of the Oosterschelde estuary (Wolff and Reise 2002). As the Pacific oyster is well adapted to the Wadden Sea ecosystem and competitive superior to their native congeners, a further increase of the oyster population in the Wadden Sea is expected, probably combined with an increase of cut injuries among walkers and swimmers.

Economic and societal effects (positive/negative)

In historic times, beds of the native European oyster (*Ostrea edulis*) were of wide-spread occurrence in the Wadden Sea and an important fisheries resource. However, overexploitation by oyster fishery since the 18^{th} century exterminated these populations. Several attempts to revive the former oyster stock in the Wadden Sea have failed (Drinkwaard 1999, Nehring 1999). The cultivation of Pacific oysters in recent years in a culture plot near Sylt gave a new and rising production. Fishery on wild Pacific oyster stocks is at present not allowed due to nature conservation directives. However, in July 2005 a first licence was given by German authorities for collecting of wild oyster spat in a small area of the Wadden Sea near Sylt. Whether such exploitation will be profitable compared to the importations of seed oysters is not yet known. However, collection of wild oyster spat instead of importing seed oysters may reduce the possible introduction of new invaders, like epibionts or parasites and pathogens. It may be that in the near future harvesting of adult oysters will also be allowed. However, once the oysters have developed reefs the product quality for the consumers decreases dramatically due to clumping, increase of shell size and decrease of meat content. Harvesting wild Pacific oysters is unlikely to be effective and profitable.

The actual records imply that the Pacific oyster has achieved a continuous distribution throughout the entire Wadden Sea (Reise *et al.* 2005). Spat settle on any hard substrate, but preferentially upon conspecifics and wild banks of the native Blue mussel (*Mytilus edulis*) (Diederich 2005b, Nehls *et al.* 2006). However, there is evidence that the recently observed decline of mussel beds near Sylt is mainly caused by failing spatfall possibly due to mild winters, whereas the increase in oysters is facilitated by mild winters and warm summers, respectively (Nehls *et al.* 2006). But it is to be expected that in the near future the traditional Blue mussel fishery might be even more hampered because still existing seed mussels and mussel beds become overgrown by oysters. This is estimated to result in a maximum loss in the German Blue mussel fishery of bout 25 Mio Euro per annum (Nehring in press).

Solid calcareous reefs of Pacific oysters are a completely new biogenic structure for the intertidal area of the Wadden Sea. Whether or not oyster reefs may facilitate coastal protection is not yet investigated and estimated. In this context, Pacific oysters in northern Europe may benefit from global warming and may become more abundant than mussel beds have ever been (Nehring 2003b). Due to a further increase of the oyster population Pacific oysters will interfere with the recreational use of the Wadden Sea because of their razor-sharp shells. Analyses about the potential economic effects are needed.

Management approaches

Prevention methods

The analysis on overall impact potential on environmental, economic and human interests suggests that the Pacific oyster in Danish and German waters is one of the most damaging species. For the importation of the Pacific oyster into Europe as a commercial species the framed decision-models came too late to be of use. In 1994 the ICES Code of Practise on the Introductions and Transfers of Marine Organisms was adopted. However, in practice, recommended procedures prior to reaching a decision regarding introductions are not applied to introductions or transfers which are part of current commercial aquaculture activities (Drinkwaard 1999). Because of the high potential for natural dispersal in introduced aquatic species, and many human vectors for secondary dispersal along European coasts, adequate precautionary measures are needed beyond an international management plan. A decision not to introduce Pacific oysters for culturing would have merely postponed the invasion unless the same decision would have been for European coasts outside the Wadden Sea (Reise *et al.* 2005, Nehring and Klingenstein 2005).

Continued importation of Pacific oyster seed creates a potential risk for introduction of other alien species and diseases. To avoid the introduction of non-native species into Dutch coastal waters a new policy on the importation of shellfish and crustaceans was developed in 1996. Since the year 2001 the introduction of native species from populations outside the North Sea area (boreal) into

Dutch coastal waters is no longer allowed.
To prevent natural spatfalls of Pacific oysters in aquaculture plots sterile triploid seed oysters can be used. There are two methods to produce triploid animals. One is via chemical induction and the other is crossing of tetraploids with diploid broodstock. The dangers in the former technique are that less than 100% of the animals produced are triploid while the dangers of the latter technique would be the unintentional release of tetraploids into the marine environment, which could potentially interact with natural diploids producing sterile triploids. However, in 1999/2000 triploid Pacific oysters made up 30% of all Pacific oysters farmed on the West Coast of North America (Mariculture Committee 2003).

Eradication, control and monitoring efforts
Handpicking was used between 1976 and 1981 in The Netherlands to reduce the wild stock of Pacific oysters in the Oosterschelde estuary. These attempts failed and from that time on the new inhabitant was accepted as belonging to the Dutch fauna (Drinkwaard 1999). In Germany and in Denmark no eradication or control programmes were carried out up to now. There was unanimous agreement that after an extensive establishment of Pacific oysters no eradication or control methods are feasible which would not also harm other components of the native ecosystem, especially of the Wadden Sea ecosystem (Reise *et al.* 2005).
The Pacific oyster is one of the most damaging species in the Wadden Sea. However, no coordinated international monitoring programme to document the spreading and impacts is designed and realized yet. Thus, it is still a challenge to act on the Pacific oyster. Therefore, an unlimited observance of existing management initiatives and instruments as well as the implementation of new and purposeful ones is absolutely essential (Nehring and Klingenstein 2005).

Information and awareness
When the Pacific oyster extensively covered native Blue mussel beds in the German Wadden Sea, it caught the public attention and was followed by a broad media interest. However, a purposeful information platform is not yet installed in Germany. Education and awareness raising is needed. In Denmark there is no formal program for public information. However, in the summer of 2005 local TV, radio and newspaper campaigned for local people and tourists to collect all the oysters they wanted. The campaign reached national newsmedia in September 2005 (Kathe Jensen, pers. comm.).

Knowledge and research
Together with an r-selected life history trait (high fecundity and dispersal capacity, fast growth), the broad environmental tolerances predispose the Pacific oyster as a species likely to be a successful invader. Thus, research is ongoing on the establishment success of the Pacific oyster in different areas of the German Wadden Sea (Karsten Reise pers. comm., Gerd Liebezeit, pers. comm.).
The Danish Institute of Fisheries Research are planning a larger investigation in 2006 of the distribution of *C. gigas* in Limfjorden. The purpose with the project will be to map the Pacific oyster distribution and development in Limfjorden, and to evaluate if reproduction take place annually or as sporadic events. Stakeholders with a good knowledge to local conditions in Limfjorden (spare time fishermen, hunters etc.) will be asked to give informations on the distribution and production of *C. gigas*. A biological monitoring program will be implemented on basis of these informations aiming to clarify if the stock can be controlled through commercial fishery, which are considered the most efficient control measure (Per Dolmer and Per Sand Kristensen, pers. comm.).

Recommendations or comments from experts and local communities
Until now the introduction, establishment and spreading of alien species in the Wadden Sea has been perceived only on a descriptive level in some ways. A purposeful strategy in dealing with the phenomenom in regard to the protection and conservation of the Wadden Sea is missing. The development of an alien species plan on the level of the Trilateral Cooperation on the Protection of the Wadden Sea is absolutely essential (Nehring and Klingenstein 2005).

References and other resources

Contact persons (preferably one from each country the species is found**)**
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Links
Global Invasive Species Data Base - *Crassostrea gigas*, a world overview
ISSG - Invasive Species Specialist Group

Species Fact sheet - *Crassostrea gigas*, a world overview
FAO - Food and Agriculture Organization of the United Nations

Species Fact Sheet - *Crassostrea gigas* in Great Britian
JNCC - Joint Nature Conservation Committee

Species Fact Sheet - *Crassostrea gigas* in the Mediterranean Sea
CIESM - International Commission for the Scientific Exploration of the Mediterranean Sea

Species summary of *Crassostrea gigas* (Australia)
NIMPIS - National Introduced Marine Pest Information System

Species Fact Sheet - Pacific (Japanese) Oyster *Crassostrea gigas* (Alaska)
PWSRCAC - Prince William Sound Regional Citizens' Advisory Council

Species Fact Sheet - Pacific oyster *Crassostrea gigas* in USA
PSMFC - Pacific States Marine Fisheries Commission

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