Risk assessment on the possible introduction of three predatory snails (*Ocinebrellus inornatus, Urosalpinx cinerea* , *Rapana venosa)* in the Dutch Wadden Sea

F. Fey, A.M. van den Brink, J.W.M. Wijsman, O.G. Bos

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IMARES Wageningen UR

Client: Dr. T.M. van der Have
Plantenziektekundige Dienst LNV / Team Invasieve Exoten
PO Box 9102
6700 HC Wageningen
The Netherlands

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Cover photos: *Ocinebrellus inornatus* (Recluz, 1851) (taken from Faasse & Ligthart 2009), *Urosalpinx cinerea* (http://www.exoticsguide.org/species_pages/u_cinerea.html) and *Rapana venosa* (http://upload.wikimedia.org/wikipedia/commons/f/fb/Rapana_Black_Sea_2008_G1.jpg)

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Contents

Summary

Recently three alien invasive predatory snails have been found in the Dutch marine waters, which are identified by the Ministry of Agriculture, Nature and Food Quality as potential high risk species due to their possible impact on bivalve species (TRCPD/2009/3587). These are:

1) Japanese oyster drill *Ocinebrellus inornatus (syn: Ceratostoma inornatum, Ocenebra japonica*)
2) American oyster drill *Urosalpinx cinerea*
3) Asian rapa whelk *Rapana venosa*

The Japanese oyster drill and the American oyster drill have established in parts of the Oosterschelde (Delta area, SW Netherlands), where they have been recorded since 2007, both as adult and eggs. The Asian rapa whelk was found once in the Southern Dutch part of the North Sea in 2005, but the species has not been recorded there since. Until now these predatory snail species have not been found in the Natura 2000 Wadden Sea area. In this report we describe the potential ecological and economical risks of introduction of the three alien invasive predatory snails in the Nature 2000 Wadden Sea area.

For both oyster drill species the most important transportation vector is through commercial shellfish transports. The species can be transported both as juveniles, adult snails, and as egg capsules. The larvae do not have a pelagic phase, so that natural transportation through the water column or with ballast water is limited. The Asian rapa whelk, however, does have a pelagic larval stage and may therefore also be dispersed with water movement or ballast water in ships. Introduction of these predatory snails in the Wadden Sea could potentially affect the realization of the conservation targets of the Natura 2000 framework.

Once arrived, the question is whether the snails are able to establish themselves in the Wadden Sea. The environmental conditions in the Wadden Sea do not seem to pose problems for the three species. The three species will probably be able to survive, feed and reproduce in this area. The lack of a pelagic phase in their lifecycle will restrict the natural spread of the oyster drills to the immediate local area. The primary vector of translocation of the oyster drills within the Dutch Wadden Sea will most probably be through mussel transfers from infected mussel culture plots to other culture plots. As natural occurrences of mussels and oysters lay in close proximity of the culture plots, natural dispersal from the culture plots to nearby natural shellfish beds might take place. The Asian rapa whelk could probably spread quickly throughout the Wadden Sea as pelagic larvae.

The three predatory snails prey on bivalves (e.g. oysters, mussels and clams), barnacles and occasionally other snails. In some areas, the American oyster drill is a common and important pest to the commercial oyster industry. Prior to its drastic reduction due to the use tributyl tin (TBT) antifouling biocides in Britain the species did cause 50%-58% local mortality of the annual oyster seed crop in infested locations (Essex and river Blackwater). In Delaware Bay, USA, 33%, 41% and 50% mortality has been found on different oyster beds. In East Coast oyster beds (USA, native range) they commonly killed 60-70% of the young oysters. The Japanese oyster drill caused 25% mortality in infested oyster stocks in British Columbia and Washington and predation by the Asian rapa whelk has been identified as the primary cause of the collapse of several mussel and oyster banks in the Black Sea since the 1950's. The current knowledge on the impact of the three predatory snails on mussel culture plots is not sufficient to calculate the possible economic impact on the mussel culture plots in the Wadden Sea, without making many assumptions. The yearly yield of the mussel culture in the Wadden Sea amounts to 18-50 million Euros (2002-2009).

In other areas the three predatory snails are known to prey on several bivalve species, including mussels and cockles and compete with native predatory snails. This might have considerable impact on the environment. As a result, significant effects on the Natura 2000 Habitat directive conservation targets of the Wadden Sea cannot be excluded with the introduction of these predatory snails. We conclude this on the basis of described invasions in other regions in combination with favourable environmental conditions of the Wadden Sea area for the survival and reproduction of the species.

To estimate the effects in a standard way, two different risk assessments for invasive species were applied: the FAO and the ISEIA system. On the ISEIA risk assessment scale, American and Japanese oyster drill ended on the "B: watch list" which includes species with a moderate environmental risk on the basis of current knowledge, and the Asian rapa whelk on the "A: black list" which includes species with a high environmental risk. According to the FAO protocol all three species fell in the highest risk category which resulted in the following recommendations

for each of the three species: Introduction should be banned; Prevention rather than mitigation is mandated, and control measures should be considered.

1 Introduction

Recently three alien invasive predatory snails have been found in the Dutch marine waters, which are identified by the Ministry of Agriculture, Nature and Food Quality as potential high risk species due to their possible impact on bivalve species (TRCPD/2009/3587).

These are:

1) *Japanese oyster drill Ocinebrellus inornatus (syn: Ceratostoma inornatum, Ocenebra japonica*)
2) American oyster drill *Urosalpinx cinerea*
3) Asian rapa whelk *Rapana venosa*

The Japanese oyster drill and the American oyster drill have established in parts of the Oosterschelde, where they have been recorded since 2007 (data: Faasse & Ligthart 2007, Faasse & Ligthart 2009). The Asian rapa whelk was found once in the Dutch part of the North Sea in 2005, but the species has not been recorded there since. Until now these species have not been found in the Natura 2000-area Wadden Sea. Introduction of these predatory snails could potentially affect the realization of the conservation goals of the Natura 2000 framework in this area.

The risk assessment on the possible introduction of the three predatory snails in the Dutch Wadden Sea takes place in the framework of the implementation plan 'Convention transition mussel culture and nature restoration Dutch Wadden Sea'. The Ministry of Agriculture, Nature and Food quality, works on the formulation of a risk assessment on mussel transfer from the Oosterschelde towards the culture plots in the Dutch Wadden Sea. At the moment direct shellfish transports from the culture plots in the Delta area (Oosterschelde) to the culture plots in the Wadden Sea ('south-north transport') are prohibited without a Nature Conservation (NB-wet) permit.

Recently a risk assessment of introduction of invasive species in the Wadden Sea by south-north transports has been performed by Wijsman and Mesel (2009). In this report the American oyster drill is indicated as one of the species with a relative high risk (PRIMUS-score 2.1). In addition, on eleven species with the highest risk (risk score > 2.0) of being introduced in the Wadden Sea with the transport of mussels, an extensive literature review was performed (van den Brink & Wijsman 2010), including distribution and spread, impact and control methods. In the review both the American oyster drill and the Japanese oyster drill were included. Underlying report is a supplement to these studies, including international risk assessment protocols for the three predatory snails, a review on economical impacts of an introduction of the predatory snails and an assessment of the possible effects on the conservation targets of the Natura 2000 area Wadden Sea.

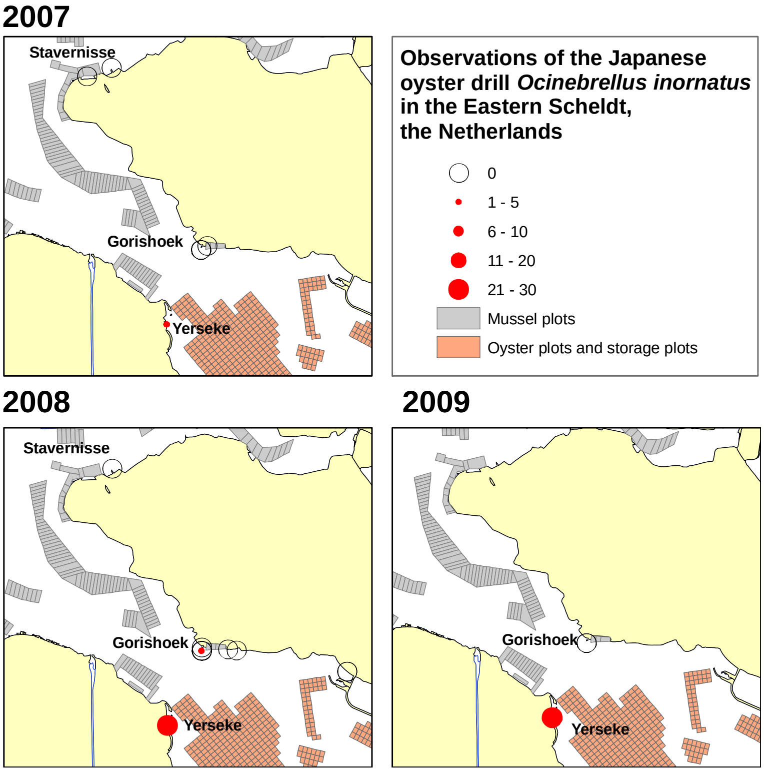


Figure 1. Observations of the Japanese oyster drill (*Ocinebrellus inornatus*) in the Oosterschelde in the Netherlands (data: (Faasse & Ligthart 2009a)). In 2009 *O. inornatus* has also been found in Gorishoek (A. van den Brink, pers. com.) (not included in picture)

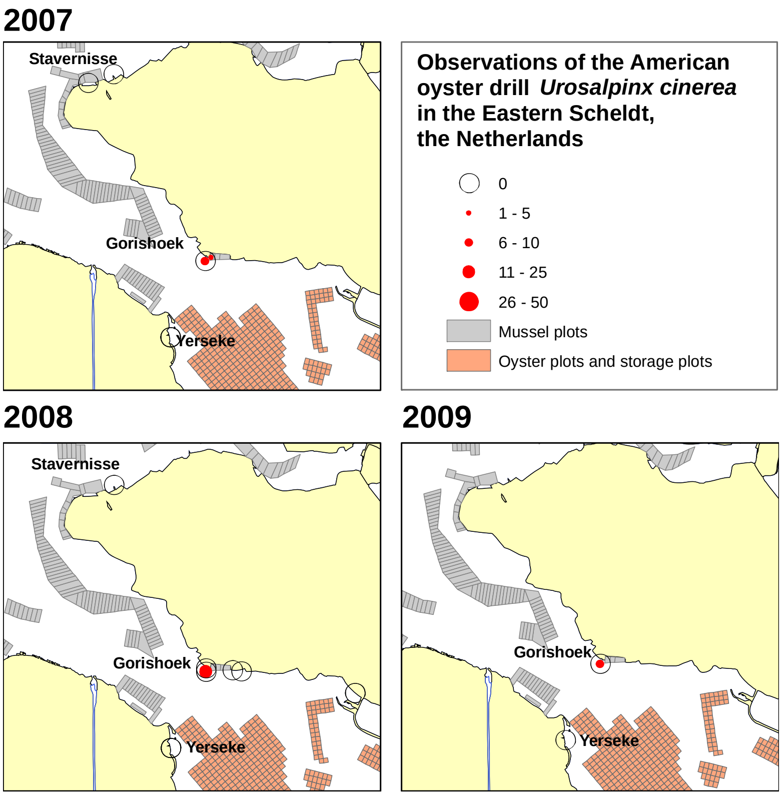


Figure 2. Observations of the American oyster drill (*Urosalpinx cinerea*) in the Oosterschelde in the Netherlands (data: Faasse & Ligthart 2009a).

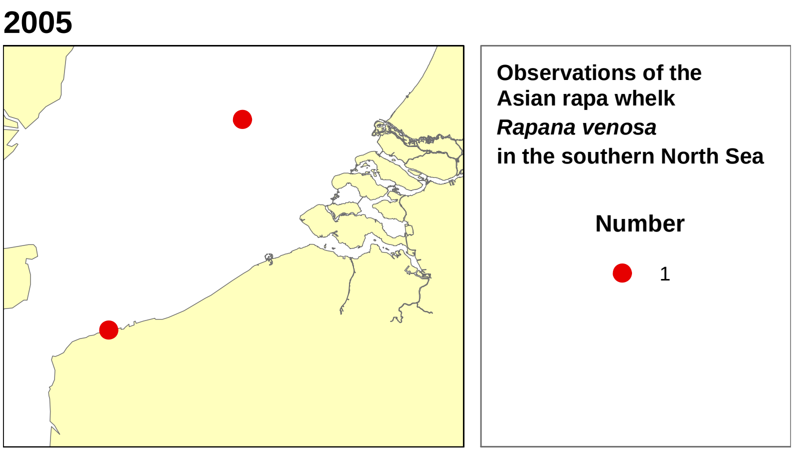


Figure 3. Observations of the Asian Rapa whelk (*Rapana venosa*) in the southern North Sea (Kerckhof et al. 2006a)

1.1 Invasive species

Invasive alien species are non-native species whose introduction and/or spread outside their natural past or present ranges can pose a threat to biodiversity (CBD guiding principles and the European strategy on IAS). Although many examples are known of introduced alien species, which had an irreversible and devastating impact on the invaded ecosystem, not all introduced non-native species pose a threat to their new surroundings. Most introduced species fail to survive or spread, and not all that become established necessarily have a noticeable impact. As a rule of thumb it is often stated that from every 1000 exotic species that enter a new area, a hundred find a suitable habitat and will manage to settle. From these 100 species, the settlement of 10 species will be permanent. On average, 1 of these species will develop as an ecological and/or economical problem (Williams 1996).

The task of detecting, identifying and assessing the potential impact of invasive marine animals is daunting, because there are a high variety of organisms that can become invasive. Virtually any species has the potential to become invasive, but characteristics as: (1) abundant over a large native range, (2) diverse diet and habitat preferences, (3) short generation time, (4) high genetic variability and (5) wide physiological tolerance, seem common to successful invasive estuarine and marine animals (Williams and Meffe, 1999). But these characteristics refer to many animals and not all become invasive. Factors associated with the new habitat also influence the invasive potential of a species, including predation, diseases, parasites and competition. Habitats which are (1) in climate similar to the source area of the invading species, (2) recently disturbed, (3) with low natural diversity, (4) do not contain likely predators on invading species, (5) do not have native species morphologically similar to the invading species, (6) poses a relatively simple food web and (7) are anthropogenically disturbed, contain characteristics of typical invaded communities (Williams and Meffe, 1999). Estuaries and sheltered coastal areas are amongst the most invaded habitats as they are naturally disturbed, have low diversity systems and they are historically the centre of anthropogenic disturbance.

For a successful invasion the species has to be (1) introduced, (2) be able to colonize and establish and has to (3) disperse (Sakai et al. 2001). While being introduced, the initial survival of the new species may simply be a matter of coincidence. The species has to be introduced in a suitable habitat with suitable abiotic characteristics and suitable and sufficient food. In addition a sufficient number of other individuals of the same species has to be present in the new habitat at any one time. Once an introduced species has survived initial colonization, it may experience a lag time prior to population expansion. This is a function of the time necessary to adjust to the new environment, to mature and to produce sufficient new individuals to initiate population growth. When there are unsuitable abiotic characteristics, no or not enough suitable food sources and when there are sufficient native competitors, the population growth may be restrained and the species will not become invasive. Non-native species often escape from their pathogens, parasites and predators in their new environment ("Enemy release", Torchin et al. 2003), which may contribute to the success of invasive alien species.

2 Assignment

This report focuses on the ecological and economical risks of introduction of the three invasive predatory snails in the Dutch Wadden Sea, and the risk for the realization of the conservation goals of the Habitat directive of the Natura 2000 area when mussel transfer from the Delta area to the Dutch Wadden Sea would be allowed.

3 Materials and Methods

For the risk assessment a literature study was performed on the three invasive predatory snails. Special attention was given to (1) physical circumstances in which the species can survive, (2) reproduction biology, and (3) known effect in other areas where the snails have been introduced. The occurrence of the species in the Dutch marine waters was mapped together with culture plots and mussel transfer routes in GIS-databases to identify transfer risks of the invasive predatory snails. The actual risk assessments were performed with the help of the FAO (Leung & Dudgeon 2008) and ISEIA (Belgium Forum on Invasive Species 2009) regulations for invasive species. The systems are schematically shown in Figure 4 and Figure 5. In addition the possible effects on the conservation goals of the Habitat directive of the Natura 2000 area Wadden Sea were assessed. The LEI estimated the economical consequences for mussel growers (for benthic culture plots and pelagic mussel seed collectors) of introduction of the predatory snails in the Dutch Wadden Sea.

The system follows the diagram below and is explained in detail in Leung & Dudgeon (2008).

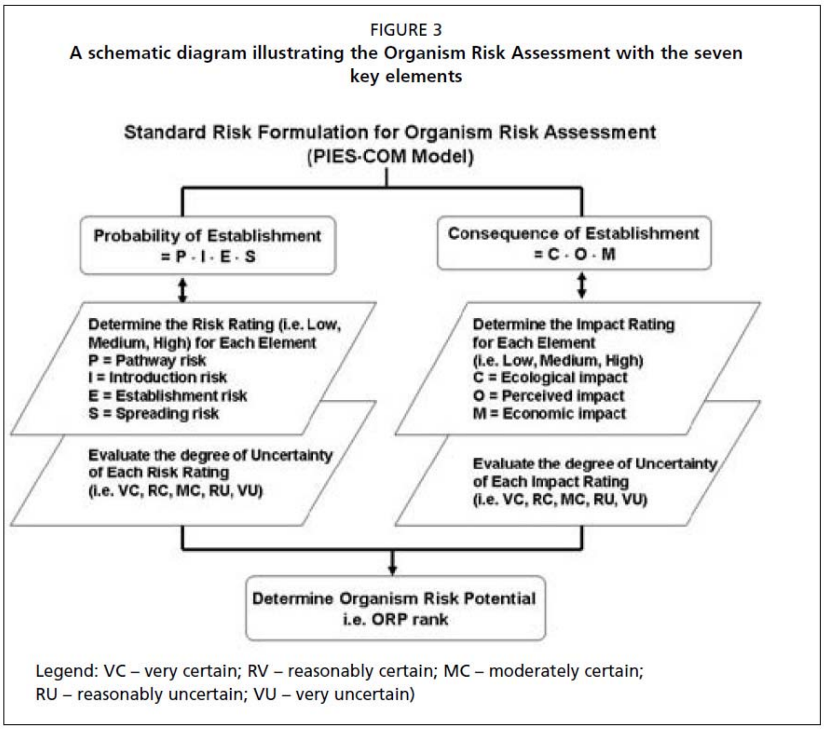
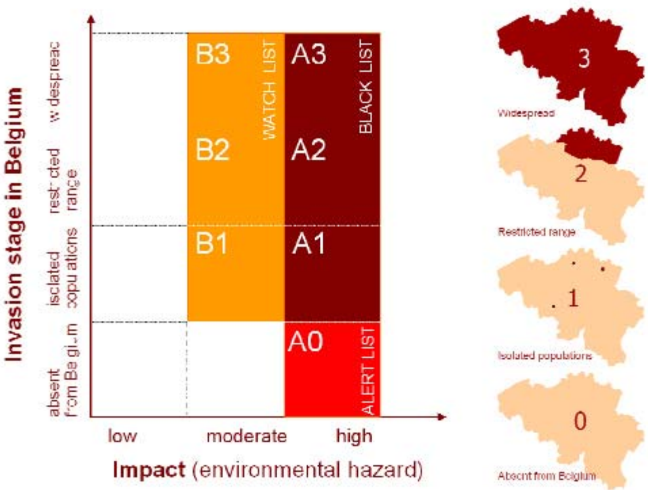


Figure 4. Scheme for FAO Organism risk assessment (Leung & Dudgeon 2008)



List system proposed by the Belgian Forum on Invasive Species to identify organisms of most concern for preventive and mitigation actions.

Figure 5. Scheme of ISEIA (Belgium Forum on Invasive Species 2009)

4 Species description and biology

4.1 *Urosalpinx cinerea* (Say, 1822)

Common names: Eastern oyster drill, American oyster drill, American tingle, American whelk tingle, Atlantic oyster drill

Figure 6. Left: *Urosalpinx cinerea* (Image: BISHOGAI Data Base http://shell.kwansei.ac.jp). Right: *Urosalpinx cinerea* egg capsules with juvenile snails in Gorishoek, The Netherlands. Image: A.H.M. Ligthart (Faasse & Ligthart 2009b).

Phylum: Chordata
Class: Gastropoda
Order: Neogastropoda
Family: Muricidae

4.1.1 Description and Biology

The American oyster drill, *Urosalpinx cinerea*, is a small muricid gastropod, growing up to 35 mm long with larger specimens generally found to be female. It has a knobbly, rugged shell of 5-6 whorls with rounded shoulders and 9-12 longitudinal ridges. The shell is often streaked and may be yellow, gray, white, brown and occasionally orange. It has an oval aperture with a short, open canal at the base containing 2-6 teeth. The flesh is grey, yellow, reddish-brown, or purple in colour (Williams 2002, Cohen 2005, Global-Invasive-Species-Database 2008).

The diet of *Urosalpinx cinerea* consists generally of oysters, barnacles, mussels and occasionally snails, but prefers smaller, softer shelled sessile molluscs. To feed, *U. cinerea* crawls over its prey (e.g. an oyster) and grips with its foot from which it secretes a softening agent onto the shell and bores a hole through the shell of its prey using its file-like radula. It then inserts its proboscis into the tissue of the oyster and secretes a muscle relaxant which induces the oyster the open, leaving the animal exposed. *U. cinerea* can then easily feed on the soft tissue of its victim (Nichols & Cooke 1971, Buchsbaum et al. 1987, Williams 2002, Cohen 2005).

Breeding in *Urosalpinx cinerea* occurs in the spring and summer when the water temperature rises. After fertilisation, the female deposits 20-40 translucent capsules, containing 5-12 eggs each, on a suitable substrate. In the British waters, this is done primarily during May and June, but it is not uncommon for freshly laid capsules to be found in August (Cole 1942). Cole (1942) reported that spawning increased as temperatures rose above 12° C while Cohen (2005) reports that spawning only begins when the water temperature exceeds 20° C for at least a week. After approximately 6-8 weeks the well developed but tiny young emerge from the eggs and begin feeding on various shellfish species and occasionally diversify to include encrusting ectoprocta. This diverse diet of juveniles reduces intra-specific competition for food (Franz 1971). Sexual maturity is reached after one-two years and individuals can live for up to eight years (Williams 2002, Cohen 2005, Ruesink, 2009).

Urosalpinx cinerea occurs in intertidal and shallow subtidal waters in bays, marshes and estuaries, to a maximum depth of about 15 m. It flourishes particularly well in rocky areas and oyster beds and in high salinities, but can tolerate salinities as low as 13 ppt (Williams 2002, Cohen 2005).

4.1.2 Distribution and spread

The native range of *Urosalpinx cinerea* is reportedly the Northwestern Atlantic from the Gulf of St. Lawrence to southeastern Florida (Williams 2002, Gittenberger 2009). It has been introduced to the Pacific Coast of North America, southern Great Britain and recently the Netherlands (Global-Invasive-Species-Database 2008).

Urosalpinx cinerea, was introduced to Willapa Bay, Washington, USA prior to 1948, most likely with imported eastern oysters (*Crassostrea virginica*) in the early 1900s. The species is now established and widespread in Willapa Bay and has become an economically significant pest of oyster aquaculture that is particularly damaging to juveniles. Oyster growers have attempted to control *U. cinerea* by manually removing adults and egg capsules, but even local eradication has proven difficult and in some cases growers have abandoned oyster beds due to the intense predation (Cohen 2005). Despite this, unauthorised movement of shellfish has also occurred and facilitated the potential spread of unwanted organisms. In 1997 a seized importation of *C. virginica* at Shannon Airport, Ireland, coming from Long Island Sound, USA and flown from New York, contained eggs of *U. cinerea* (Leppakoski *et al.* 2002).

U. cinerea is thought to have been introduced into the Thames Estuary, England from eastern North America with the translocation of the eastern oyster *Crassostrea Virginica* around 1880. At the time, identification of the species was problematic and it was not officially identified as non-indigenous in England until 1928 (Locke & Hanson 2009). By the 1950s *U. cinerea* was abundant along the Essex coast and was reported for the first time as a problem to oyster growers in Essex and parts of Kent (Edwards 2006). Over the next decade *U. cinerea* had a devastating effect on the mortalities of juvenile European flat oysters (*Ostrea edulis*) so that by 1954 large-scale control methods were being investigated (Edwards 2006, Locke & Hanson 2009). The introduction of tributyl tin (TBT) antifouling biocides reduced the population of *U. cinerea* drastically and the species is now rare on the Essex coast. The decline of native oyster fisheries, resulting in poor spatfalls and inappropriately muddy substratum also prevented population recovery to the point where during a population survey in 2006 Edwards (2006) did not find a single specimen; adult, juvenile or egg capsule and in a questionnaire survey shellfish aquaculturalists also reported an absence of *U. cinerea* (Edwards 2006).

4.1.2.1 The Netherlands

Urosalpinx cinerea has established in parts of the Oosterschelde (Faasse & Ligthart 2007, 2009). The date and means of the introduction of *Urosalpinx cinerea* to the Netherlands is unknown, but there is no record of its presence in the Netherlands prior to 2007 (Faasse & Ligthart 2007). The species was found on boulders, overgrown with oysters, at the low water mark (Faasse & Ligthart 2007). Faasse and Ligthart (2009) reported that the population of *U. cinerea* at Gorishoek has been steadily growing despite regular collections by hand. In the Gorishoek area, egg capsules have not been counted since mid 2008, but at that time more egg capsules than adult individuals were recorded. Faasse and Ligthart also suggest that cold weather poses no problem for the species as, after a particularly cold spell in the winter 2009 where water temperatures dropped to 0-1 °C, eight specimens were collected within two hours searching.

Urosalpinx cinerea is established in Gorishoek in the Oosterschelde and the population is growing, but until 2009 the distribution remained relatively localised and there is little evidence to suggest it has spread to locations further than a few hundred meters away (Faasse & Ligthart 2009). Until now there are no documented records of the species on mussel culture plots in the Oosterschelde.

4.1.3 Vectors of translocation

Due to the lack of a pelagic phase in its lifecycle, and therefore reduced risk of translocation via natural means, the primary vector of translocation of *Urosalpinx cinerea* is through commercial shellfish transfers (Faasse & Ligthart 2007, Global-Invasive-Species-Database 2008, Buhle & Ruesink 2009a, Locke & Hanson 2009).

4.2 *Ocinebrellus inornatus* (Recluz, 1851)

Common names: Japanese oyster drill, Asian drill, Asian oyster drill
Synonyms: *Ocenebra japonica* (Dunker, 1860), *Ceratostoma inornatum* (Recluz, 1851)

Figure 7. Above: *Ocinebrellus inornatus* (Recluz, 1851) (Image: L. Schroeder, found at http://www.bily.com). Below: *Ocinebrellus inornatus* (Recluz, 1851) with egg capsules (Image: http://www.cryptosula.nl).

Phylum: Mollusca
Class: Gastropoda
Order: Neogastropoda
Family: Muricidae

Although this species is more commonly known as its synonym *Ceratostoma inornatum*, in this report it will be referred to as *Ocinebrellus inornatus*.

4.2.1 Description and Biology

The Japanese oyster drill, *Ocinebrellus inornatus*, is a muricid gastropod with a range of phenotypic variation in the species, but generally it has a solid looking, knobbly shell which can grow up to 50 mm long. Females tend to be larger with a higher growth rate compared to males (Martel *et al.* 2004). The shell has 5-6 whorls, each with about eight low axial ribs that come to points at the apical edge of the body whorl, but less so on the whorls of the spire. Faint spiral ridges can often been seen on the shell as well. The Aperture is oval with a thick outer lip and the canal is relatively short and open in the early stages of development, but close as the individual matures (Global-Invasive-Species-Database 2007, Goud et al. 2008, Eissinger 2009, Faasse & Ligthart 2009b). The colour of the shell ranges from white to yellow to brown and there is no exterior periostracum (Eissinger 2009).

The diet of *O. inornatus* consists of benthic bivalves, including young oysters, mussels, clams and cockles, as well as barnacles. Feeding is most likely similar to that of *U. cinerea* which grips its prey with its foot and secretes a softening agent onto the shell before boring a hole with its radula. It then inserts its proboscis into the tissue of the prey and secretes a muscle relaxant to induce the bivalve the open, leaving the animal exposed for feeding. (Nichols & Cooke 1971, Buchsbaum et al. 1987, Williams 2002, Cohen 2005). Predation of a bivalve by *O. inornatus* is easily identified by the distinctive 2 mm hole left in the shell (Global-Invasive-Species-Database 2007, Buhle & Ruesink 2009a, Eissinger 2009). To drill through the shell of a Pacific oyster (*Crassostrea gigas*), an adult *O. inornatus* can take between one day on oysters 2.5 cm in diameter, to around two weeks for an oyster 5 cm long (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, McCoy 2009).

Ocinebrellus inornatus has a simple two stage life history. Mature adults aggregate in both Spring and Autumn and lay clumps of bright yellow egg capsules (each containing about 10 young about 2 mm long) on any emergent hard substratum they can find. In France the snail had two laying peaks (in spring and autumn) and produced 27 000 eggs/female during a sixteen month survey (Martel et al 2004). After about three weeks juveniles emerge looking like miniature adults and begin to feed. Juveniles grow rapidly (more than 2 mm per month, although growth rates decrease with increasing size), and reach reproductive maturity the following year when they are about 27 mm long (Buhle et al. 2004, Martel et al. 2004, Eissinger 2009, McCoy 2009). McCoy (2009) reported that adult survival rates of *O. inornatus* were low (less than 10 % annually) and suggested that this short life span was compensated for by high fecundity.

The oyster drills are usually found in estuarine and benthic marine habitats at a range of temperatures. The species is capable of surviving cold winters in the Netherlands with temperatures of 0-1° C (Faasse & Ligthart 2009b). It is typically found on substratum including gravel, mud, sand and shells, particularly where the *C. gigas* is present (Buhle *et al.* 2004). Although adult *C. gigas* are not preyed upon by *O. inornatus* because they have shells too thick to drill through, they are highly conducive to the survival of *O. inornatus*. The oysters provide complex, three-dimensional habitats and offer a refuge from predation and abundant food source in terms of juvenile oysters and attached barnacles (Buhle & Ruesink 2009a).

4.2.2 Distribution and spread

Ocinebrellus inornatus is native to the Sakhalin and Kurile Islands up to Japan and from North of China to Korea (Garcia-Meunier et al. 2003, Global-Invasive-Species-Database 2007). Its presence has been reported in Australia, but it is unknown whether it is native there or introduced (Global-Invasive-Species-Database 2007). In the 20th century, it was accidentally introduced to the Pacific coasts of North America, including Pugnet Sound (1924), British Columbia (1931), Oregon (1930-1934) and California (1941) (Garcia-Meunier *et al.* 2003). *O. inornatus* was then introduced into the bay of Marennes-Oléron on the French Atlantic coast in 1995 and later spread northward to the Golfe de Morbihan, south Brittany (Garcia-Meunier et al. 2003, Martel et al. 2004, Faasse & Ligthart 2009b). Genetic studies found the source population of the French introduction probably came from the United States (Martel *et al.* 2004). Recently the Japanese oyster drill has been found on oysters (*O. edulis*) from Limfjorden Denmark (pers. comm., A. Gittenberger; Lützen et al., in prep.; Gittenberger et al 2010). DNA-analysis indicated that these individuals most probably originate from the French population (or the population from the United States), indicating a secundairy introduction (Gittenberger in prep.).

Natural dispersal of *Ocinebrellus inornatus* is limited by its lack of free-swimming larval stages. Without the ability to travel in the water column, juveniles are restricted to the immediate local area (Buhle & Ruesink 2009a). However, this limitation is easily counter-balanced by aquaculture activities, which play an important role in expanding the range of the species (Martel *et al.* 2004). The intensive oyster translocation activity that followed the introduction of *O. inornatus* into France via the transportation of live oysters from the USA and the success of the Pacific oyster in the new environment reportedly facilitated the spread of *O. inornatus* within and beyond Marennes-Ole´ron Bay (Martel et al. 2004, Faasse & Ligthart 2009b). Similarly, Buhle (2009) reported that the spatial spread of *O. inornatus* within Willapa Bay, Washington, USA, was largely the result of transferring oysters and shells by growers.

4.2.2.1 The Netherlands

Ocinebrellus inornatus was first reported in the Netherlands in the Oosterschelde in 2007 but had been misidentified as the European oyster borer *Ocenebra erinacea* (Faasse & Ligthart 2007), so it may have been present in the area prior to this time. *O. inornatus* can be easily found in the oyster pits (on the landside of the dike, with a connection to the water of the Oosterschelde) in Yerseke (pers. obs. Anneke van den Brink and Jeroen Wijsman). The population appears to be growing in the Oosterschelde. Faasse and Ligthart (2009) reported that more *O. inornatus* were found during two hour searches in the oyster pits in Yerseke in 2008 and 2009 than in 2007, despite temperatures as low as 0-1° C in 2009. Furthermore, in 2008 the species was found in a new location near Gorishoek on boulders and oyster clumps. Until now there are no documented records of this species on mussel culture plots in the Oosterschelde.

4.2.3 Vectors of translocation

Due to the lack of a pelagic phase in its lifecycle, and therefore reduced risk of translocation via natural means, the primary vector of translocation of *Ocinebrellus inornatus* is accidental transfer with the movement of commercial shellfish (Martel et al. 2004, Faasse & Ligthart 2009b).

4.3 *Rapana venosa* (Valenciennes, 1846)

Common names: Asian rapa whelk, rapa whelk, veined rapa whelk, veined whelk
Synonyms: *Rapana pontica* (Nordsieck, 1969), *Rapana thomasiana* (Crosse, 1861)

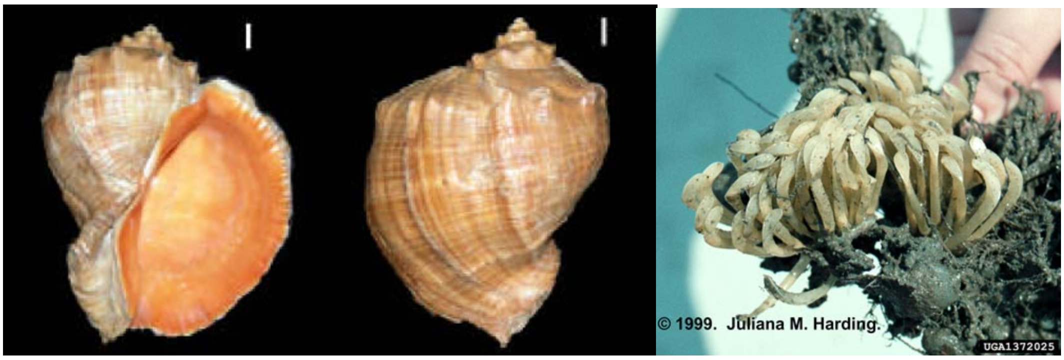


Figure 8 Left: *Rapana venosa* , scale 10 mm (Valenciennes, 1846) (Image: Culha (2009)). Right: *Rapana venosa* egg cases (Image: Juliana M. Harding, Virginia Institute of Marine Science, Bugwood.org)

Phylum: Mollusca
Class: Gastropoda
Order: Hypsogastropoda
Family: Muricidae

4.3.1 Description and Biology

The Rapa whelk, *Rapana venosa* is a large mucrid gastropod, which can grow to about 180 mm in shell length. The shell is globose, forming a short spire and a large body whorl. It is usually grey to reddish-brown in colour, with dark dashes on the spiral ribs and most specimens have black veins running across the shell. The aperature and columa of this species is often distinctly deep orange in colour (USGS 2009).

Rapana venosa is a voracious predator with a diet consisting of various molluscs, often of commercial interest, such as oysters, mussels and clams (Bay off Vladivostok in the north Harding & Mann 2002, Savini et al. 2004). Although like most whelks, *R. venosa* feeds by drilling a hole into the shell of their prey, large individuals of this species can also feed by wrapping their foot around the hinged section of the shell and rasping the shell margins or suffocating the bivalve by covering it with mucus until it gasps, when the whelk can then access the prey between the opened valve (Savini & Occhipinti-Ambrogi 2006, USGS 2009). Savini and Occhipinti-Ambrogi (2006) reported that adult *R. venosa* in the Northern Adriatic Sea consumed an average of one bivalve per day (or 1.2g wet weight per day). However the whelk showed a species and size preference for small specimens of the Indo-Pacific invasive clam *Anadara inaequivalvis* and consumption rates for the commercially important Mediterranean mussel *Mytilus galloprovincialis* and the introduced carpet clam *Tapes philippinarum* were lower.

Rapana venosa is dioecious with separate sexes. Mating occurs over an extended period during the winter and spring preceding egg laying (ICES 2004). Yellow egg capsules, each containing 200-1000 eggs are laid in mats of between 50-500 capsules on hard surfaces such as rocks or artificial structures (Global-Invasive-Species-Database 2006). Adult females can lay multiple egg masses throughout the course of one summer without intervening mating events (ICES 2004).

Unlike *Ocinebrellus inornatus* and *Urosalpinx cinerea*, *R. venosa* has a planktonic larval stage. After 14-21 days (depending on temperature and salinity) pelagic larvae hatch from the eggs and spend between 14 to 80 days in the plankton before settling to the bottom where they develop into hard-shelled snails (Kerckhof et al. 2006b). Veligers can settle successfully on various attached macrofauna such as bryozoans and barnacles as well as other hard surfaces. The young whelks grow quickly on a diet of algae, reaching over 0.5 mm in 21 days (Global-Invasive-Species-Database 2006, USGS 2009, Richerson 2010). The whelks reach reproductive maturity in 1-3 years at 50-70 mm in size and can live to be over ten years old (Savini et al. 2004, USGS 2009).
Rapana venosa favours compact sandy bottoms in which it can almost completely bury itself, but can also be found on artificial and natural rocky bottoms (Savini *et al.* 2004). The species has many characteristics of a

successful invader. It is fast growing, has a high fertility and a high tolerance to lower salinities, water pollution and oxygen deficiency (Zolotarev 1996, Kerckhof et al. 2006b). The whelk can tolerate a wide range of temperatures (4-27 °C) although it tends to migrate from cold water to warmer, deeper waters in winter (Giberto et al. 2005, Culha et al. 2009). In the Black Sea it occurs at salinities of 25 to 32 PSU and at lower salinities in the Sea of Azov (ICES, 2004)

4.3.2 Distribution and spread

Rapana venosa is native to marine and estuarine waters of the western Pacific, from Peter the Great Bay off Vladivostok in the north, the Sea of Japan, the Yellow Sea, the East China sea and the Bohai Sea to Taiwan in the south (Mann & Harding 2003).

Due to the long pelagic larval stage (up to 80 days (Kerckhof et al. 2006b)), *R. venosa* has the potential to spread long distances naturally via ship ballast water (Savini *et al.* 2004). It was introduced into the Black Sea via shipping in the 1940s and, over the following decade, it spread along the Caucasian and Crimean coasts and to the Sea of Azov. Since then its range has extended quickly into the northwest Black Sea to the coasts of Romania, Bulgaria and Turkey since 1947. This species has become established in the northern Adriatic Sea since 1973 and Aegean Sea since 1990 and has also invaded and become established in Chesapeake Bay on the Atlantic coast of the United States since 1998. Isolated adults and egg masses have been reported from the Brittany coast of France and in the Rio del Plata between Uruguay and Argentina since 1999 (Mann & Harding 2003, Global-Invasive-Species-Database 2006, Savini & Occhipinti-Ambrogi 2006, USGS 2009).

4.3.2.1 <u>The Netherlands</u>

Two full grown *Rapana venosa* were recorded in the North Sea (Netherlands and UK waters) for the first time in 2005 but the species has not been recorded there since (Harding & Mann 2005, Kerckhof et al. 2006b).

4.3.3 Vectors of translocation

The introduction of *R. venosa* to new environments is most likely to be a result of transportation of pelagic larvae in ballast water. Other likely vectors include the accidental introduction of egg cases with aquaculture products, bivalve stocks or spat, or as hull fouling on ships (Savini et al. 2004, Kerckhof et al. 2006b).

Once a founder population is established in an area, range extension can occur quickly as a result of larval dispersal via tidal currents, migration of juvenile and adult whelks, or human mediated means such as ballast water, dredge spoils or transport of seed oysters. (Harding & Mann 2005)

5 Risk assessment

The risk and potential impact of introduction of three alien invasive predatory snails in the Dutch Wadden Sea was assessed using the FAO (Leung & Dudgeon 2008) and ISEIA (Belgium Forum on Invasive Species 2009) regulations for risk assessments on invasive species. The risk assessment was performed based on the assumption that no measures are taken to prevent or control the invasive species. The assessment concerns the potential risks in a situation where the species can develop without human hindrance, but with human help (mussel transfer).

5.1 Likelihood of entrance in Dutch Wadden Sea

5.1.1 Japanese oyster drill and American oyster drill

Both the Japanese oyster drill and the American oyster drill lack a pelagic phase in their lifecycle. This reduces the risk of translocation via natural means. The primary vector of translocation of the oyster drills is through commercial shellfish transfers (Faasse & Ligthart 2007, Global-Invasive-Species-Database 2008, Buhle & Ruesink 2009b, Locke & Hanson 2009).

Both species of oyster drills have been found in parts of the Oosterschelde (Delta area) on boulders and clumps of oysters. Until now there are no documented records of these species on mussel culture plots in the Oosterschelde.

Direct transfer from the Oosterschelde to the Dutch Wadden Sea needs a permit by the Dutch Nature Protection Law. However, mussel transfer from the Danish and German Wadden Sea to the Dutch Wadden Sea is allowed without permit and mussel transfer from the Oosterschelde to the Danish and German Wadden Sea took place until recently, as regulations where not widely known (Figure 9). This allowed an indirect transfer route from the Oosterschelde to the Dutch Wadden Sea. As mussel transfer from the Oosterschelde to the German and Danish Wadden Sea or from the Danish and German Wadden Sea tot the Dutch Wadden Sea was not officially registered, no indication can be made of the extent of this former vector of translocation. Until now neither the Japanese oyster drill nor the American oyster drill have been found in the Danish or German Wadden Sea. Recently the Japanese oyster drill has been found on oysters (*O. edulis*) from Limfjorden Denmark (pers. comm., A. Gittenberger; Lützen et al., in prep.; Gittenberger et al 2010). As for several years no official transports of oysters from other countries (United Kingdom or Netherlands) to Limfjorden have taken place, the contamination might therefore originate from other introduced shellfish species in the area, illegal oyster transport or via other transport routes (pers. comm., A. Gittenberger). In the past years several mussel farmers have been caught performing illegal mussel transports from the Oosterschelde to the Wadden Sea (Ministry of Agricuture, Nature and Food Quality). The illegally introduced mussels where returned to the Oosterschelde within several days. Recently high fines have been connected to these illegal transports.

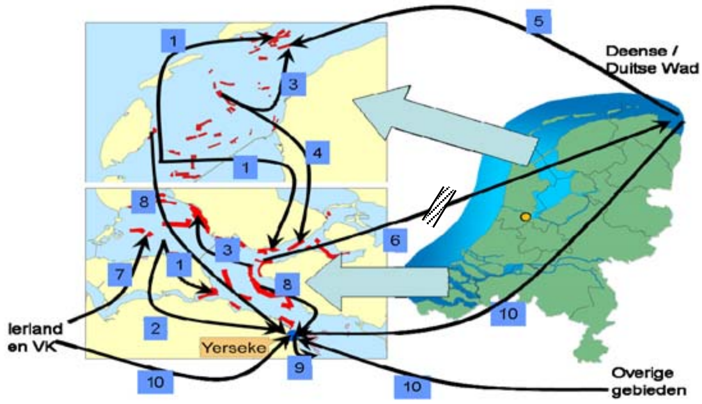


Figure 9. Schematic transfer routes of mussels (Wijsman & De Mesel 2009). Although mussels have been transported from the Oosterschelde to the German Wadden Sea, the Fisherei Ambt Bremerhaven has recently stated that these transports are not allowed anymore.

5.1.2 Asian rapa whelk

The Asian rapa whelk has a pelagic phase of 14 to 80 days, when it floats in the water column as larvae. Introduction to new environments is therefore likely to be a result of natural dispersion by currents or of transportation of pelagic larvae in ballast water of ships. Other possible vectors include the accidental introduction of egg cases or juvenile or adult snails with aquaculture products, bivalve stock or spat, or as hull fouling on ships (Savini et al. 2004, Harding & Mann 2005, Kerckhof et al. 2006a)
The Asian rapa whelk has been found once in the Dutch part of the North Sea in 2005. In the same year one individual was found in the central southern North Sea (the wider Thames estuary). After these findings no more recordings exist on the whelk in the North Sea, although the seafloor of the southern North Sea is probably a very suitable habitat for the species (Kerckhof et al. 2006a). The Asian rapa whelk has not been found in the Oosterschelde or the Danish or German Wadden Sea. As no shellfish culture takes place in the Dutch part of the North Sea, direct transportation through mussel transport seems unlikely at the moment. When the Asian rapa whelk becomes established in the North Sea natural introduction in the Wadden Sea through currents seems more likely. Also ballast water from ships coming from areas where the Asian rapa whelk occurs poses a risk for the Wadden Sea, especially through large harbours like Groningen Seaport or the sea harbours of Harlingen and Den Helder. As this report assesses the risk of the introduction through shellfish transfer, no assessment on the risk of natural dispersion or introduction through ballast water has been made.

5.2 Likelihood of establishment in the Dutch Wadden Sea

5.2.1 Characteristics of the Dutch Wadden Sea

The Wadden Sea consists of a network of tidal channels, sandbars, mudflats, salt marshes and islands. The area creates a transition zone between land and sea, characterized by daily changing flood and ebb tides and high dynamics in salinity, light, oxygen and temperature. The mean yearly water temperature at the Marsdiep inlet ranges from slightly higher than 12°C to less than 9°C (Van Aken 2001), but because of the flood and ebb tides and high range in water depth, local water temperature can range from less than -1°C to more than 25 °C. The mean yearly salinity in the Marsdiep inlet ranges from 27 ppt to 32 ppt (Van Aken 2001), but because of flood and ebb tides and regular discharges of freshwater from sluices of the mainland, local salinity can range from 7 ppt to 33 ppt. The Wadden Sea is an open system and there are many interactions with the adjacent North Sea. The quality of water, sediment and marine habitats is to an important degree influenced by the North Sea and activities in the catchment area of the debouching rivers. Water depth ranges from 0 meters > 20 meters. In the Wadden Sea sandy sediments prevail, although parts contain high concentrations of silt. Natural rock formations do not occur, but pebbles and boulders are scattered locally. On some locations patches with peat occur and large stretches of dead shell banks can be found. The area is known for its high productivity and supports a huge number of bivalves, such as blue mussel (*Mytilus edulis*), the common cockle (*Cerastoderma edule*) and non-native Pacific oyster (*Crassostrea gigas*), American jack-knife clam (*Ensis directus*) and the soft shell clam (*Mya arenaria*). The most important natural predators of these bivalves, as with the blue mussel, include several invertebrates such as the common starfish (*Asterias rubens*) and the shore crabs (*Carcinus maenas*), and diving dukes such as the common eider (*Somateria mollissima)*. In the Wadden Sea two predatory snails exist, the Whelk (*Buccinum undatum*) and the Dog whelk (*Nucella lapillus),* although both exist in very low numbers due to fisheries and the use of tributylin-based (TBT) antifouling paints in the past.

5.2.2 Preferences and tolerance of the invasive predatory snails

5.2.2.1 American oyster drill (*Urosalpinx cinerea)*

The snail preys on smaller soft shelled sessile molluscs, such as mussel and oyster (spat) (Nichols & Cooke 1971, Buchsbaum et al. 1987, Williams 2002, Cohen 2005). The American oyster drill occurs in intertidal and shallow subtidal waters in bays, marshes and estuaries, to a maximum depth of about 15 m. It flourishes particularly well in rocky areas and oyster beds and in high salinities, but can tolerate salinities as low as 13 ppt (Williams 2002, Cohen 2005).
In an experiment on feeding and survival rates at different salinities and temperatures (Manzi 1970), the oyster drill remained active from 12.5 ppt until 26.5 ppt (the maximum salinity tested), but feeding rates at these salinities increased with temperature (ranging from 15°C until 25°C). The optimum feeding temperature lay near 25°C and feeding at temperatures lower than 10°C almost stops (Hanks 1957).
Drill mortality was highest at 25°C in combination with salinity of 12.5 ppt (34% mortality). The lowest mortality at all temperatures was at a salinity of 26.5 ppt. Low temperatures do not seem to pose a problem for the oyster

drill. After the cold spell in the winter of 2009 in the Netherlands (Oosterschelde), Faasse and Ligthart (2007) still counted 8 specimens in two hours during a search in the Oosterschelde.
During the experiment no egg capsules were deposited at salinities of 15 ppt or lower. At 26.5 ppt the oyster drill deposited egg capsules at all temperatures tested (15, 20 and 25 °C). Ganaros (1958) found the incubation time of the oyster drill eggs varied with temperature. No development occurred at temperatures of 7.5°C, and only 65% hatched at temperatures of 10°C. At temperatures ranging from 15 to 30°C almost all eggs hatched. At 15°C it took 56-78 days to hatch, while at 25°C it took 22 to 38 days. The optimum temperature for development seemed to lay between 20 and 25°C (Ganaros 1958).
The snail seems highly susceptible to tributyl tin (TBT) antifouling biocides and development of the debilitation condition known as 'imposex' has depleted populations on the Essex oyster beds since the early 1970's (Eno 1997). The ban on anti-fouling paints containing tributyl for ships shorter than 25 m in the Netherlands might have increased the potential for successful establishment in the area (Faasse and Ligthart 2007).

According to the current knowledge the American oyster drill will be able to survive, feed and reproduce in the Dutch Wadden Sea (table 1).

5.2.2.2 Japanese oyster drill (*Ocinebrellus inornatus)*

The diet of the Japanese oyster drill consists of benthic bivalves, including young oysters, mussels, clams and cockles (Nichols & Cooke 1971, Buchsbaum et al. 1987, Williams 2002, Cohen 2005). The oyster drills are usually found in estuarine and benthic marine habitats at a range of temperatures. The species is capable of surviving cold winters in the Netherlands with temperatures of 0-1°C (Faasse & Ligthart 2009a). In the Oosterschelde egg-laying individuals have been found (Faasse & Ligthart 2009a). Water temperature in the Oosterschelde (Yerseke, 1981) ranges from 1 to 19 and salinity ranges from 26 to 31 (Gorishoek, 1981 en Yerseke, 2008). The Japanese oyster drill is typically found on substratum including gravel, mud, sand and shells, particularly where the *C. gigas* is present (Buhle *et al.* 2004).

Not much data is available on preferences and tolerance of the Japanese oysterdrill. The available data, and the fact that this species can survive, feed and reproduce in the Oosterschelde, indicate that the Japanese oyster drill will be able to survive and reproduce in the Dutch Wadden Sea.

5.2.2.3 Asian rapa whelk *(Rapana venosa)*

This predatory snail feeds on various molluscs, such as oysters, mussels and clams (Harding & Mann 2002, Savini et al. 2004). *Rapana venosa* favours compact sandy bottoms in which it can almost completely bury itself, but can also be found on artificial and natural rocky bottoms (Savini *et al.* 2004).
The whelk can tolerate a wide range of temperatures (4-27 °C), although it tends to migrate from cold water to warmer, deeper waters in winter (Giberto et al. 2005, Culha et al. 2009). Surface freezing is tolerated by migration into deeper water. In the Black Sea it occurs at salinities of 25 to 32 PSU and at lower salinities in the Sea of Azov (ICES, 2004). In its native range the Asian rapa whelk reproduces at water temperatures ranging from 13°C until 26°C (ICES, 2004). Chung et al (1993) report a 17 day incubation period between egg laying and first hatching at 18.3°C to 20.4°C. All larval stages exhibit 48 h tolerance to salinity as low as 15 ppt with minimal mortality. Below this salinity, survival grades to lower levels (Mann and Harding 2003).

According to the current knowledge the Asian rapa whelk will be able survive, feed and reproduce in the Dutch Wadden Sea.

Table 1. Summary of temperature and salinity characteristics of the Wadden Sea and tolerances of the invasive predatory snails (see the text above for details and references). The temperature range of the Oosterschelde is also

included. Both the American oyster drill and the Japanese oyster drill are known to survive and reproduce in the temperature and salinity range of this area.

Temperature	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Wadden Sea												mean																									
Oosterschelde												mean																									
Tolerance																																					
American oyster drill	?	?																				?	?														
Japanese oyster drill	?																																				
Asian rapa whelk	?	?	?	?	?																																
Reproduction																																					
American oyster drill	?	?																						mean													
Japanese oyster drill	?	?																																			
Asian rapa whelk	?	?																																			
Salinity	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Wadden Sea																									mean												
Oosterschelde																														mean							
Tolerance																																					
American oyster drill									?	?	?	?	?	?																				?			
Japanese oyster drill									?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?							?			
Asian rapa whelk									?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?											

Range in Wadden Sea (Salinity: Vliestroom 2008, Marsdiep 2008, Malzwin 2008,Inschot 1981, Harlingen 2008, Blauwe Slenk 1981, Doove Balg 2008; Temperature: Breezanddijk 1981, Den Oever 1981 , Harlingen 1981)

Range in Oosterschelde (Gorishoek 1981, Yerseke 1981 en 2008)

Tolerance known from literature (see chapter 5.2.2)

Tolerance known from survival and reproduction in Easternscheldt (Yerseke and Gorishoek)

? No indication of possible intolerance from literature

? Indication of possible intolerance from literature

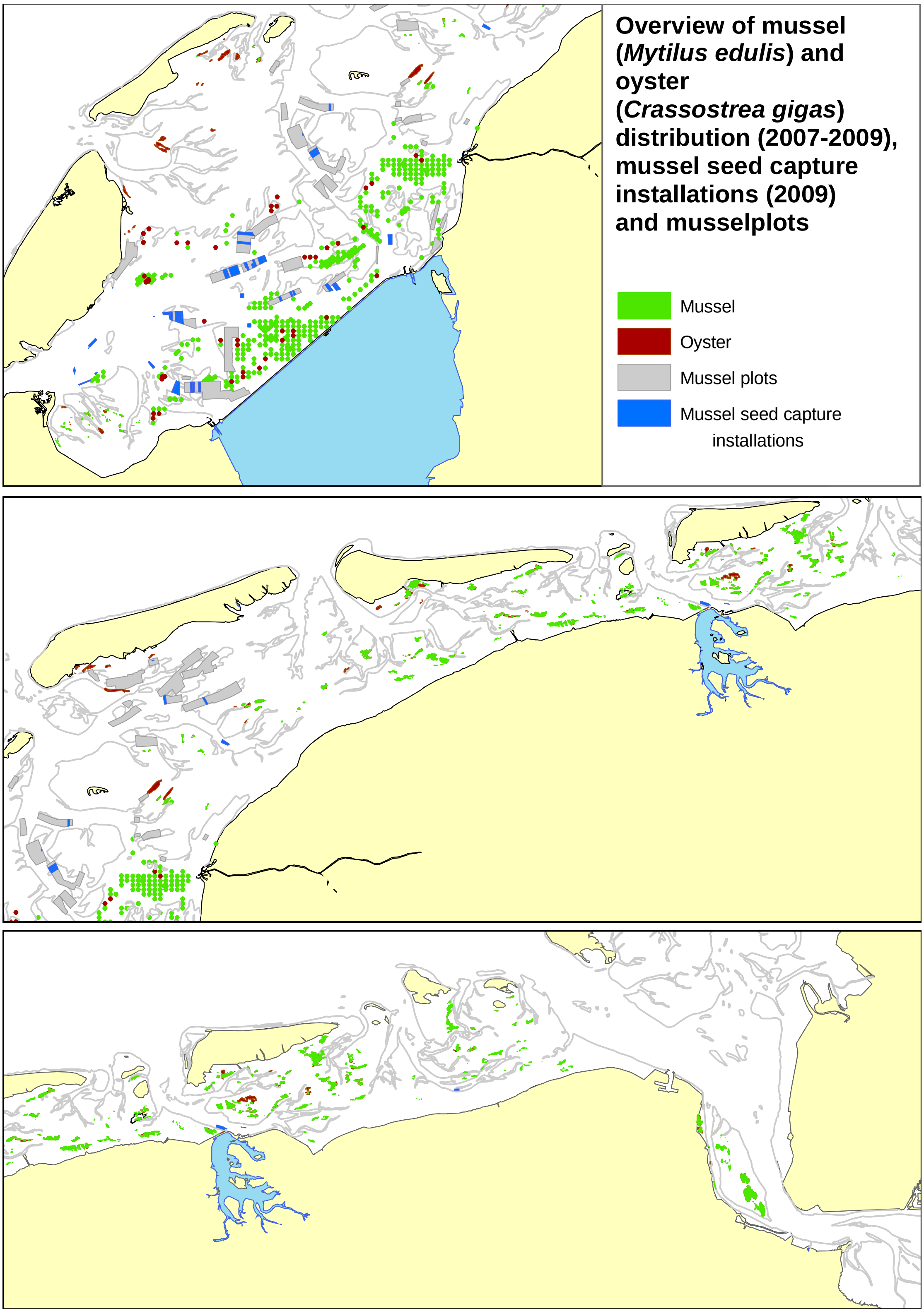


Figure 10. Overview of natural mussel (*Mytilus edulis*) and oyster (*Crassostrea gigas*) distribution (2007-2009), mussel seed capture installations (2009) and mussel culture plots (data: IMARES).

5.3 Likelihood of distribution in Dutch Wadden Sea

5.3.1 Japanese oyster drill and American oyster drill

When the predatory snails are introduced through commercial mussel transports, they will start their distribution from the mussel culture plots in the western part of the Dutch Wadden Sea. The lack of a pelagic phase in their lifecycle will restrict the natural spread of the oyster drills to the immediate local area (neighbouring culture plots or wild bivalve occurrences). The primary vector of translocation of the oyster drills in the Dutch Wadden Sea will be through mussel transfers between culture plot groups. As natural occurrences of mussels and oysters lay in close proximity of the culture plots (Figure 10), natural dispersal from the culture plots to nearby natural shellfish beds might easily take place. Distribution in the Dutch Wadden Sea will, at least in the first few years, be restricted to the culture plots and their immediate surroundings. As culture plots are restricted to the western part of the Dutch Wadden Sea, the spread to the Eastern part of the area will take more time.

5.3.2 Asian rapa whelk

When this predatory snail is introduced through commercial mussel transportation, the further spread will start from the culture plots in the western part of the Wadden Sea. Because of the relatively long pelagic larval phase of this species, spreading through the area could be quick and far. As Japanese oysters are present at almost every corner of the area, the settling larvae will easily find a suitable habitat. As stated before, the introduction of the Asian rapa whelk will be more likely to be the result of ballast water from ships originating from areas where the whelk has established or through natural dispersal via currents when the Asian rapa whelk becomes established in the North Sea. Although in that case the location of the founder population might be different, the result will be the same. Due to larval dispersal the Asian rapa whelk could spread relatively quickly through the Dutch Wadden Sea area with the water movement.

5.4 Endangered areas

All Dutch marine areas where bivalve species occur are potentially endangered areas. These are Natura 2000 habitat types 1110 (permanently submerged sandbanks) and 1140 (Mudflats and sandflats not covered by seawater at low tide) of the Natura 2000 framework. In the case of the oyster drills, the immediate surroundings of the culture plots suffer the highest risk (mainly habitat type 1110A). The Asian rapa whelk will have a wider range of initial distribution and could also disperse easily to the North Sea coastal zone (habitat type 1110B). For habitattype 1110A and 1110B in the Nature2000-area Wadden Sea applies a 'maintain' (area target) and 'improve' (quality target) target. The status of conservation of the quality of both habitat types is assessed as 'mediocre unfavourable'.

5.5 Impact of introduction

5.5.1 American oyster drill

- Environmental

The diet of the American oysters drill consists generally of oysters, barnacles, mussels and occasionally snails, but they prefer smaller, softer shelled sessile molluscs. Where the species is introduced and has no natural predators, pathogens or parasites, it can have a competitive advantage over the native species (Torchin et al. 2003) and affect the structure of local communities.

- Economical

The American oyster drill is a common and important pest to the commercial oyster industry, both in their native range and invaded areas. In England, for example, the American oyster drill has been reported to feed on the native oyster (*Ostrea edulis*), with each snail estimated to consume about 40 spat per year (Eno et al. 1997, Cohen 2005). During its lifetime (at least six years (Cole 1966) a single individual is capable of consuming 240 young oysters. The consumption rate of *U. cinerea* on the mussel *Mytilus edulis* has been shown to vary with temperature. Hanks (1957) reported that at temperatures ranging between 15-20 °C, the drill consumed 0.5-1 mussel per individual, per week.
On local oyster beds in invaded areas or in their native range the American oyster drill consumed on average 50% (33%-75%) of oyster spat. In Delaware Bay, USA, 33%, 41% and 50% mortality has been found on individual oyster beds (Nelson 1922). In East Coast oyster beds (USA, native range) they commonly killed 60-70% of the young oysters (Alford 1975). In Great Britain mortalities ranged from 50% on oyster beds in river Blackwater to

58% of visible mortality on spat on Essex oyster beds. Cole (1951) and Hancock (1954) stated that in the Essex river 75% would probably not be an overestimate of the percentage of spat destroyed by the American oyster drill during the first year of its life.

As the species most probably will be able to survive, feed and reproduce in the Dutch Wadden Sea (Chapter 5.2), there is no reason to assume that the (environmental end economical) impact of introduction in this area will be different from other invaded areas.

5.5.2 Japanese oyster drill

- Environmental

In Netarts Bay, Oregon a major component of the diet of the Japanese oyster drill is the native clam *Macoma balthica* and the native cockle *Clinocardium nuttalli* (Carlton 1979). If the prey of the drill is fundamental to the local ecosystem, providing habitats and food for other native species, the predation may alter the local environment. Additionally, if the Japanese oyster drill outcompetes and replaces native species, it may indirectly cause a trophic cascade that ultimately alters the community structure and biomass of the coastal ecosystem (Williams & McDonald 2008). Williams and McDonald (2008) report anecdotal evidence that the Japanese oyster drill has replaced the native dogwhelk *Nucella lamellosa* in Willapa Bay.

Furthermore, the drill can prevent the restoration of native environments recovering from a disturbance (Buhle & Ruesink 2009a). On the coast of British Columbia and Washington the drill was reported to hamper efforts to restore beds of native Olympia oysters (*Ostreola conchaphila*) (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004).

- Economical

The Japanese oyster drill can decimate stocked shellfish populations (Cole 1942). In British Columbia and Washington, where the drill was introduced in cases of oyster seed from Japan, it began attacking the farmed oysters as well as the Manila clam (*Venerupis philippinarum*). The drill caused about 25 % mortality in local oyster stocks. Productions costs increased by about 20 % and profits decreased by about 55 % (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-Database 2007, Buhle & Ruesink 2009a). In Netarts Bay, Oregon the Japanese clam (*Venerupis philippinarum*) was introduced for aquaculture purposes, but due to predation by the Japanese oyster drill, it only became established after an intensive planting programm (Carlton 1992). Williams and McDonald (2008) reported that in Puget Sound the drill consumed mussels (*Mytilus edulis*) at a rate of almost one mussel per drill per day, almost double that of the native drill *Nucella Lamellosa*.

As the species most probably will be able to survive, feed and reproduce in the Dutch Wadden Sea (Chapter 5.2), there is no reason to assume that the (environmental end economical) impact of introduction in this area will be different from other invaded areas.

5.5.3 Asian rapa whelk

- Environmental

Due to its predatory nature the Asian rapa whelk is considered as one of the most unwelcome marine invaders worldwide (ICES 2004). The whelk's active predation of epifaunal bivalves, and its proliferation is a serious threat to cultivated and natural populations of oysters and mussels (Global-Invasive-Species-Database 2006). The whelk is considered responsible for the decline (by almost half) of the native, edible bivalve fauna in the Black Sea (Zolotarev 1996). The species has caused significant changes in the ecology of benthic organisms and is blamed for the near extinction of the Gudaut oyster (Harding & Mann 2003). Although scientists are still studying the impacts of the Asian rapa whelk, there is grave concern about its potential damage to native species (Global-Invasive-Species-Database 2006).
Studies are currently under way to help determine the spread of the Asian rapa whelk in Chesapeake Bay in the Mid-Atlantic, United States to develop a model to define potential impacts to the ecosystem. The whelk has been reported to impact populations of shellfish such as *Mya arenaria*, *Ensis directus* and *Cyrtopleura costata* as well as a range of commercially valuable shellfish species (Global-Invasive-Species-Database 2006).
With the introduction of the Asian rapa whelk in Chesapeake Bay there are concerns that the native oyster drill, *Urosalpinx cinerea*, will suffer from direct competition with the invader. There is now competition for the same

suitable substrate between the two species and as *U. cinerea* lacks a pelagic larval stage, the Asian rapa whelk has a distinct advantage in dispersal and population spread (ICES 2004).
Another ecological change perpetuated by the alien whelk in Chesapeake Bay is that the presence of large empty *R. venosa* shells in the area has increased population numbers of the local hermit crab *Clibanarius vittatus*. These crabs use empty shells of the Asian rapa whelk as shelters and are reaching previously unrecorded sizes allowing them to eat significant numbers of oyster spat (ICES 2004).
Kerckhof et al. (2006) predicted that in the North Sea the Asian rapa whelk could become a severe competitor for the native whelk *Buccinum undatum*, a species already suffering from organotin water pollution and heavy fishing pressure.

- Economical

The introduction of the Asian rapa whelk has impacted commercial shellfish industries in various locations. The intense predation by the whelk has been identified as the primary cause of the collapse of several mussel and oyster banks in the Black Sea since the 1950's (Zolotarev 1996, Giberto et al. 2005, Savini & Occhipinti-Ambrogi 2006).
In Chesapeake Bay populations the abundance of available food for the whelks, and the fact that there is successful local recruitment of the Asian rapa whelk has raised concerns about the threat to the native hard clam, *Mercenaria mercenaria*, population that supports a local fishery worth in excess of $US 3 million per year (Global-Invasive-Species-Database 2006). The whelk is also known to easily and frequently consume commercial oysters (*Crassostrea virginica*) and mussels (*Mytilus edulis*) in the area (ICES 2004). Kerckhof et al. (2006a) predicted that successful establishment of the whelk in the North Sea may threaten the industry on edible bivalves such as mussels *Mytilus edulis*, Pacific oysters *Crassostrea gigas* and cockles *Cerastoderma edule*. The whelk has been shown to consume the mussel *Mytilus galloprovincialis* at a rate of 5±4 mussels in 44 days per individual in the Northern Adriatic Sea (Savini & Occhipinti-Ambrogi 2006).
Predation by the Asian rapa whelk is considered the main reason for the decline of *M. galloprovincialis* in Bulgarian waters, the Kerch Strait and the Caucasian shelf. Furthermore, the near extinction of the native bivalves *Ostrea edulis*, *Pecten ponticus*, and *M. galloprovincialis* on the Gudaut (Black Sea) is attributed to predation by the Asian rapa whelk (Global-Invasive-Species-Database 2006).

As the species most probably will be able to survive, feed and reproduce in the Dutch Wadden Sea (Chapter 5.2), there is no reason to assume that the (environmental end economical) impact of introduction in this area will be different from other invaded areas.

5.6 Risk assessment score

To estimate the ecological effects in a standard way, two internationally used risk assessment protocols for invasive species were applied: the FAO and the ISEIA protocol.

The ISEIA protocol (Invasive Species Environmental Impact Assessment) was developed to classify non-native species and to identify those of most concern for preventive and mitigation actions. The protocol consists of four sections matching the last steps of the invasion process, i.e. the potential for spread, colonisation of natural habitats and adverse ecological impacts on native species and ecosystems (ISIEA Guidelines, Harmonia information system, version 2.5). It has to be noted that this protocol aims to assess environmental risks only and that impacts on human interests (like economical impacts) are not explicitly taken into account. The ISEIA protocol allocates species in three risk categories:

- Category A (black list): includes species with a high environmental risk
- Category B (watch list): includes species with a moderate environmental risk on the basis of current knowledge
- Category C: includes other non-native species, that are not considered as a threat for native biodiversity and ecosystems (low environmental risks).

The FAO protocol contains seven essential elements (PIES-COM elements). The risk assessment is based on the probabilities of the pathway associated with the particular species, successful introduction, successful establishment and spread of the species in the new environment. The consequence of establishment includes the ecological impact potential, perceived impact from social and political points of view and the economic impact potential. The final estimate provides a summary of the entire risk assessment and results in guidance for the decision about whether or not an exotic species should be introduced, or whether control measures should be in place for introductions that are allowed or whether measures should take place to mitigate the effects of exotic species that have already become established (Lung and Dudgeon 2008).

The protocols differ mainly in the consideration of human interests. The ISEIA protocol does not consider human interest in the assessment, while the FAO protocol explicitly includes perceived impact by humans and economic impact potential.

Table 2. Overview of ISEIA scores for the three species (Appendix C).

	Japanese oyster drill	score	American oyster drill	score	Asian rapa whelk	score
1. Dispersion potential or invasiveness	Medium risk	2	Medium risk	2	High risk	3
2. Colonisation of high conservation value habitats	High risk	3	High risk	3	High risk	3
3. Adverse impacts on native species	Medium risk	2	Medium risk	2	High risk	3
4. Alteration of ecosystem functions	Medium risk	2	Medium risk	2	High risk	3
5. Global environmental risk	B (watch list)	9	B (watch list)	9	A (black list)	12

On the ISEIA risk assessment scale, the American and Japanese oyster drill ended on the “B: watch list” which includes species with a moderate environmental risk on the basis of current knowledge, and the Asian rapa whelk on the “A: black list” which includes species with a high environmental risk.

Table 3. Overview of FAO Organism risk assessment ratings for the three species (Appendix B).

	Japanese oyster drill		**American oyster drill**		**Asian rapa whelk**	
	Rating	Uncertainty code	Rating	Uncertainty code	Rating	Uncertainty code
3. Rating elements for the PIES.COM model						
3.1 propability of establishment						
pathway risk	M	RC	M	RC	L	RC
introduction risk	H	RC	H	RC	H	RC
establisment risk	H	RC	H	RC	H	RC
spreading risk	M	VC	M	VC	H	VC
3.2 Consequence of Establishment						
ecological impact	M	MC	M	MC	H	VC
economic impact	H	RC	H	RC	H	MC
percieved impact	L	MC	L	MC	M	RU
4. Risk Characterization						
4.1 Probability of Establishment (PE)	M		M		L	
4.2 Consequences of establishment (CE Score)	H		H		H	
4.3 Organisms Risk Potential (ORP)	H		H		M	
4.4 Pathway risk potential (PRP)	M		M		H	
4.5. Recommendations	• Introduction should be banned		• Introduction should be banned		• Introduction should be banned	
	• Prevention rather than mitigation is mandated, and control measures should be considered.		• Prevention rather than mitigation is mandated, and control measures should be considered.		• Prevention rather than mitigation is mandated, and control measures should be considered.	

According to the FAO protocol all three species fell in the highest risk category which resulted in the following recommendations for each of the three species: Introduction should be banned; Prevention rather than mitigation is mandated, and control measures should be considered.

6 Risk management

6.1 Prevention

6.1.1 American oyster drill and Japanese oyster drill

Both oyster drills need human assistance for long distance dispersal. Because of the lack of a pelagic phase in their life cycle, natural dispersal is restricted to the immediate surrounding of the initial establishment. The primary vector of translocation of the oyster drills is through commercial shellfish transfers (Faasse & Ligthart 2007, Global-Invasive-Species-Database 2008, Buhle & Ruesink 2009a, Locke & Hanson 2009). Banning of shellfish introductions from areas where the species occur is probably the best way to prevent introduction of the invasive oyster drills. As no permits are issued for transportation of shellfish from other areas to the Wadden Sea (including south-north transports), there will be no direct costs involved in this prevention. The mussel farmers state however, that transportation of seed from Seed Mussel Capture (SMC's) devices and bottom culture mussels in the Oosterschelde to the culture plots in the Wadden Sea would increase their profits.

Other ways of preventing introduction might involve removal of snails and egg capsules from the shellfish transfer. Between the 1940s and 1970s, over 1000 chemical compounds were investigated as eradication methods (Locke & Hanson 2009). These involved immersing *U. cinerea* and their host oysters in solutions of freshwater, formalin, potassium permanganate, chlorol (10% chlorine), phenol (0.15% in seawater) and copper sulphate or as chemically impregnated barriers (McEnnulty *et al.* 2000). However, all resulted in either killing the oysters as well or having severe environmental costs (Locke & Hanson 2009).

For the American oyster drill immersion in fresh water has been successful (McEnnulty *et al.* 2001). The salinity at which the animals die depends on the environment they are acclimatised to (Federighi 1931). Federighi (1931) reported on 10 day salinity tolerance experiments from populations originating in habitats with differing salinities. Drills from areas in Hampton Roads, Virginia, where the salinity in summer was 15-20 ppm had a salinity death point of 11.7-12.5 ppm. However, drills collected from Beaufort, North Carolina, where salinity was over 30 ppm had salinity death points of 15.6-17.6 ppm. He concluded that with lower environmental salinity, the smaller the difference between environmental salinity and the salinity death point becomes (Federighi 1931). Van den Brink and Wijsman (2010) found that 24 hours exposure to 100 % freshwater was far from adequate to cause any harm to American oyster drills acclimatised to the environmental conditions of the Oosterschelde in the Netherlands.

For Japanese oyster drills immersion in freshwater can be a successful method. This simple and cost-effective technique targets the eggs of the oyster drills without harming the oysters (Mueller & Hoffmann 1999). However, immersion in freshwater can cause juvenile mussels to drop off mussel ropes as well as killing other epibiota (McEnnulty *et al.* 2001). Van den Brink and Wijsman (2010) found that 24 hours exposure to 100 % freshwater was far from adequate to cause any harm to Japanese oyster drills acclimatised to the environmental conditions of the Oosterschelde in the Netherlands. Mueller and Hoffmann (1999) reported that the drills would detach from the substrate when immersed in water with salinity between 7.2-18 ppt and experimented with immersing drills in freshwater (0 ppt). The length of time required for immersion before the drills detached increased with increase size of the drill. They suggested that drills with shells equal to or larger than 40 mm in length took between 1.4 to 20.2 minutes to detach when immersed in freshwater, although one in 10 was expected to remain attached after this time.

Several other methods to remove Japanese oyster drills on a larger scale have also been investigated. Buhle et al. (2004) reported that destroying the eggs of the drills by burning effectively controlled their numbers. However, the obvious risks involved with this technique are likely to become and issue.

The West Coast states of the USA adopted regulations in 1945 to prohibit the transfer of oyster drills among oyster plantings within the state. An inspection programme was implemented in Washington and California in 1947 where authorities in Japan checked oyster seed shipments for pest species prior to packing. Inspections were again made when the shipment arrived in the USA. Along with these regulations and inspections, the transition to hatchery-produced seed has helped to prevent the spread of the Japanese oyster drill (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, McCoy 2009).

6.1.2 Asian rapa whelk

Snails, larvae and eggs of the Asian rapa whelk could be transported by commercial shellfish transfers. Banning of shellfish introductions from long distance areas where the species occurs is probably the best way to prevent introduction through this route. The primary vector of introduction of this species to new environments is most likely to be a result of transportation of pelagic larvae in ballast water. Closing of this route will involve banning of ships from known invaded areas or the native range.

There are no proven methods currently available for control or eradication of *Rapana venosa* should it become established in a receptor environment (ICES 2004). With no effective means of eradication, the prevention of the further spread of *R. venosa* is important. The Global Ballast Water Management Programme (GloBallast) is assisting developing countries to reduce the transfer of harmful aquatic organisms and pathogens in ships' ballast water and implement the International Maritime Organisation (IMO) ballast water guidelines. Increased knowledge of the potential spread of the whelk will highlight areas at risk of invasion and indicate the areas appropriate to prioritise in prevention activities (Global-Invasive-Species-Database 2006).

6.2 Elimination

6.2.1 American oyster drill

Various control methods have been implemented in areas invaded and affected by the American oyster drill. For example, in England these methods included mechanical or suction dredging, but these proved ineffective (Locke & Hanson 2009). Traps have been used during the summer to control the species and on the Essex oyster beds, bounties were paid for bucket loads of the American oyster drill (Eno *et al.* 1997). However, individual removal by hand was considered too labour-intensive and experimental traps were impractical for large-scale removal.
Between 1987 and 1990 the population of the American oyster drill in England was almost wiped out due to the use of vessel antifouling paints containing TBT (Edwards 2006, Faasse & Ligthart 2007). TBT was found to cause imposex, a masculinisation in females to the point where oviducts were deformed, copulation and egg capsule formation was inhibited so that females were effectively sterile. No viable spawn was observed during the four summers of 1987-1990 (Gibbs *et al.* 1991). In the Netherlands, there is a ban on the use of TBT since 1993 for ships shorter than 25 m.

6.2.2 Japanese oyster drill

There have been several attempts to control the impact of the Japanese oyster drill where it is introduced. The most common control method for the drill is manual removal (Buhle et al. 2004, McCoy 2009). McCoy (2009) reported that oyster growers in Puget Sound and Willapa Bay, Washington would go out on the tide-flat with buckets and pick up as many drills as they could. Unfortunately these efforts were not successful in eradicating or reducing the distribution of the drills (McCoy 2009). White (intern communication 2007) suggested that the eggs of Japanese oyster drills could be easily removed from oyster shells with a screwdriver (in: Global-Invasive-Species-Database 2007)

Due to the life stage history of the Japanese oyster drill, manual removal of eggs and adults can differ in efficiency. The destruction of eggs decreases fecundity, while the removal of adults reduces adult survival. Removal of juveniles is not feasible because of the difficulty in finding them due to their small size. Modelling by McCoy (2009) showed that removal of egg capsules is more effective in reducing the population than removal of adults (although removal of both is obviously optimal). However, Buhle *et al.* (2004) reported that although eggs are more numerous (they found about 150 eggs to each adult) and have a higher population elasticity, so that removing them would have a greater impact on the population, it is much more effective to control the Japanese oyster drills invasions by reducing adult survival rather than by reducing fecundity. This is because adults are much easier to find than the eggs (particularly in low reproduction seasons) and therefore decrease the costs of the technique.

6.2.3 Asian rapa whelk

There are no proven methods currently available for control or eradication of the Asian rapa whelk should it become established in a receptor environment (ICES 2004). Control efforts in Chesapeake Bay currently include offering a bounty for collected whelks and encouraging local restaurants to develop recipes incorporating this species (Mann & Harding 2003).

Attempts to target a species for control or eradication must focus on the most susceptible lifecycle stage. Egg case mats, although visible and often concentrated, may be spread over vast areas, and, given the large numbers of developing embryos contained in each case, they represent considerable propagule pressure when present even in small numbers (ICES 2004). Pelagic larval forms are too dispersed to be considered possible targets, while identification and collection of post-settlement forms on hard substrates is difficult in complex community structures, due to the high probability of confusion with other gastropods. Although large epifaunal individuals are identified with comparative ease, collection by hand costs a considerable amount of diver time and collection through the use of commercial dredges targets only disparate populations and could cause unacceptable damage to the environment and populations of native species (ICES 2004).

The concept of natural controls has been briefly investigated. In Chesapeake Bay it was suggested that the blue crab, *Callinectes sapidus*, could be a control for the Asian rapa whelk through predation (Harding & Mann 2003), but this crab (which is another exotic species in this estuary) has been shown to have a diet mainly based on the introduced golden mussel, *Limnoperna fortunei* (Giberto *et al.* 2005). Other possible natural controls are demersal fishes that prey on the infauna. The whitemouth croaker, *Micropogonias furnieri*, is the dominant species in terms of biomass and sustains the coastal and artisanal fisheries in Argentina and Uruguay (Giberto *et al.* 2005).

6.3 Management

There are few options to manage an established population of the invasive predatory snails. Ones they are introduced individual removal by hand will be too labour intensive and only helpful in tidal areas. In subtidal areas (where the culture plots are situated), the established snails will be literally out of sight. Regular fishing of cultured mussels and removal of visible snails will be very labour intensive and snails, which moved to close by natural shellfish occurrences, could easily reinvade the plots. Along with removal by hand, regular submerging of mussels from culture plots in fresh water does not seem to be effective.

7 Discussion

For both the American as the Japanese oyster drill it is known that the most important introduction vector is through commercial shellfish transports, as these species lack a pelagic stage. The Asian rapa whelk does have a pelagic larval stage, and the most likely vector of introduction is ballast water in ships and natural dispersal via water movement. Other likely vectors include introduction of egg cases with aquacultural products, bivalve stock or spat or as fouling on ships. Both oyster drills have established in parts of the Oosterschelde since 2007 where they have been found on oyster clumps and boulders. The Asian rapa whelk was found ones in the Southern Dutch part of the North Sea in 2005. Until now none of these predatory snails has been found in the Natura 2000 area Wadden Sea.

Once arrived in the Wadden Sea, the environmental conditions in the area do not seem to pose problems for the oyster drills nor the Asian rapa whelk. The three species will most probably be able to survive, feed and reproduce in this area. The lack of a pelagic phase in their lifecycle will restrict the natural spread of the two oyster drills to the immediate local area. The most important vector of translocation of the oyster drills within the Dutch Wadden Sea will be through mussel transfers from infected culture plots to other culture plots. As natural occurrences of mussels and oysters lay often in close proximity to the culture plots, natural dispersal from the culture plots to nearby natural shellfish beds might easily take place. The Asian rapa whelk could probably spread quickly throughout the Wadden Sea by natural dispersal of the pelagic larvae.

In other areas, the American oyster drill is a common and important pest to the commercial oyster industry. Prior to its drastic reduction due to the use tributyl tin (TBT) antifouling biocides in Britain the species did cause locally 50%-58% mortality of the annual oyster seed crop on infested locations (Essex and river Blackwater). In Delaware Bay, USA, 33%, 41% and 50% mortality has been found on different oyster beds. In East Coast oyster beds (USA, native range) they killed 60-70% of the young oysters. The Japanese oyster drill caused 25 % mortality at infested oyster stocks in British Columbia and Washington and predation by the Asian rapa whelk has been identified as the primary cause of the collapse of several mussel and oyster banks in the Black Sea since the 1950s. The current knowledge on the impact of the three predatory snails on mussel culture plots is not sufficient to calculate the possible economic impact on the mussel culture plots in the Wadden Sea, without making many assumptions. Based on current knowledge on the economic impact reported in other invaded areas on other shellfish species in other circumstances, we tried to estimate the possible economical consequences for mussel growers (for benthic culture plots and pelagic mussel seed collectors) of introduction of the predatory snails in the Dutch Wadden Sea with the help of the LEI (Appendix A). In case of similar 'worst case' economic impacts as in other reported invaded areas (50% reduction of the oyster stock), the possible economic damage on a culture plot in the Dutch Wadden Sea invaded by the American oyster drill or the Asian rapa whelk could reach on average 146 000 Euro per infested culture plot. In the case of an invasion by the Japanese oyster drill, the economic damage on a culture plot in the Dutch Wadden could reach 73 000 Euro per infested culture plot. For this species the worst case reported impact was a reduction of 25% of the oyster stocks. In these calculations it is assumed that the worst case reported consumption of oysters could be directly translated to mussels. As the culture plots in the Wadden Sea are grouped in 15-50 neighbouring plots, infestation might spread gradually from culture plot to culture plot. Spread to other culture plot groups needs transportation through mussel farming in the case of the oyster drills, but can take place through water movement in the case of the Asian rapa whelk.

To estimate the ecological effects in a standard way, two different risk assessment protocols for invasive species were applied: the FAO and the ISEIA protocol. On the ISEIA risk assessment scale, the American and Japanese oyster drill ended on the "B: watch list" which includes species with a moderate environmental risk on the basis of current knowledge, and the Asian rapa whelk on the "A: black list" which includes species with a high environmental risk. According to the FAO protocol all three species fell in the highest risk category which resulted in the following recommendations for each of the three species: Introduction should be banned; Prevention rather than mitigation is mandated, and control measures should be considered. In a recent report on risks of shellfish transports to and within the Wadden Sea (Wijsman and Mesel 2009), the American oyster drill was assessed using the PRIMUS protocol (Wijsman and Smaal 2006). This protocol categorises the risk of a successful introduction and the potential effects on the ecosystem. Out of the 65 target species, 10 species scored higher than 2.0 and were considered as the exotic species posing the highest risk. The American oyster drill scored 2.1 in the PRIMUS protocol (Wijsman and Mesel 2009). The difference in assessments between the FAO protocol which places the American oyster drill in the highest category, and the ISEIA protocol which places the potential impact of this oyster drill a bit lower can probably be found in the consideration of potential impacts on human interest. The ESEIA protocol does not take human interest into account, while the FAO protocols does.

The possible effects on the conservation targets of the Natura 2000 area Wadden Sea were also assessed (Appendix D). Significant effects on the Natura 2000 Habitat directive conservation targets cannot be excluded with the introduction of these predatory snails. We conclude this on the basis of described invasions in other regions in combination with favourable environmental conditions of the Wadden Sea area for the survival and reproduction of the species. The current knowledge on the extent of colonisation in the Wadden Sea and the impact of the predatory snails on the conservation targets are, however, not sufficient to asses the actual size of these impacts.

8 Conclusions

- Due to the lack of a pelagic stage, the most important introduction vector of the American and the Japanese oyster drill is through commercial shellfish transports. Both drills have established in some parts of the Oosterschelde; Gorishoek and the oyster pits in Yerseke.

- The Asian rapa whelk does have a pelagic larval stage and important introduction vectors may therefore be water movement of with ballast water of ships. Other likely vectors include introduction of egg cases with aquacultural products, bivalve stock or spat or as fouling on ships. The Asian rapa whelk was found once in the Southern Dutch part of the North Sea in 2005, but has not been recorded there since.

- The environmental conditions in the Wadden Sea do not seem to pose problems for the three species. They will probably be able to survive, feed and reproduce in the area.

- In other areas the oyster drills and the Asian rapa whelk are common and important pests to the commercial shellfish industry, mainly on oysters. The current knowledge on the impact of the three predatory snails on mussel culture plots is not sufficient to calculate accurately the possible economic impact on the mussel culture plots in the Wadden Sea.

- In other areas the three predatory snails are known to prey on several bivalve species, including mussels and cockles and compete with native predatory snails. Based on this information, introduction of the species might have considerable impact on the environment. On the basis of described invasions in other regions in combination with favourable environmental conditions of the Wadden Sea area, significant effects on the Natura 2000 Habitat directive conservation targets cannot be excluded with the introduction of these predatory snails.

- To estimate the impacts in a standard way, two different internationally used risk assessments for invasive species were applied: the FAO and the ISEIA protocols. On the ISEIA risk assessment scale, the American and Japanese oyster drill were classified as “B: watch list” and the Asian rapa whelk was classified as “A: black list”. According to the FAO protocol all three species fell in the highest risk category which resulted in the following recommendations for each of the three species: Introduction should be banned; Prevention rather than mitigation is mandated, and control measures should be considered.

9 Quality Assurance

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 March 2010. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

References

Arts FA, Berrevoets CM (2005) Monitoring van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat 1991 - 2005: Verspreiding, seizoenspatroon en trend van zeven soorten zeevogels en de Bruinvis. Report No. RIKZ/2005.032, Rijksinstituut voor Kust en Zee/RIKZ, Middelburg

Belgium Forum on Invasive Species (2009) Guidelines for environmental impact assessment and list classification of non-native organisms in Belgium. ISEIA Guidelines, Harmonia information system, version 2.6. http://ias.biodiversity.be/ias/documents/ISEIA_protocol.pdf.

Buchsbaum R, Buchsbaum M, Pearse J, V. P (1987) Animals Without Backbones Vol, Third Edition. Chicago: The University of Chicago Press.

Buhle ER, Margolis M, Ruesink JL (2004) Bang for the Buck: Cost-Effective Control of Invasive Species with Different Life Histories, Washington, D.C.

Buhle ER, Ruesink JL (2009a) Impacts of Invasive Oyster Drills on Olympia Oyster (Ostrea lurida Carpenter 1864) Recovery in Willapa Bay, Washington, United States. Journal of Shellfish Research 28:87-96

Buhle ER, Ruesink JL (2009b) Impacts of Invasive Oyster Drills on Olympia Oyster (Ostrea lurida Carpenter 1864) Recovery in Willapa Bay, Washington, United States. Journal of Shellfish Research 28:87-96

Carlton JT (1979) Biogeographical ecology of the introduced marine and estuarine invertebrates of the Pacific coast of North America, Vol, University of California, Davis

Carlton JT (1992) Introduced marine and estuarine molluscks of North America: an end-of-the-20th-century perspective. Journal of Shellfish Research 11:489-505

Carranza A, de Mello C, Ligrone A, González S, Piriz P, Scarabina F (2009) Observations on the invading gastropod *Rapana venosa* in Punta del Este, Maldonado Bay, Uruguay. Biological Invasions 1387-3547 (Print) 1573-1464 (Online)

Chung, E., Kim, S., and Y. Kim. 1993. Reproductive ecology of the purple shell, *Rapana venosa* (Gastropoda: Muricidae), with special reference to the reproductive cycle, depositions of egg capsules and hatchings of larvae. Korean J. Malacol. 9(2): 1-15.

Cohen AN (2005) Guide to the Exotic Species of San Francisco Bay San Francisco Estuary Institute, Oakland, CA, wwwexoticsguideorg

Cole HE (1942) The American whelk tingle, *Urosalpinx cinerea* (Say) on British oyster beds

Cole HE (1966) Protecting British Shellfisheries, Fisheries Laboratory, Burnham on Crouch Essex

Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay (2004) Nonnative Oysters in the Chesapeake Bay, Vol. The National Academies Press, Washington D.C.

Culha M, Bat L, Dogan A, Dagli E (2009) Ecology and Distribution of the Veined Rapa Whelk *Rapana venosa* (Valenciennes, 1846) in Sinop Peninsula (Southern Central Black Sea), Turkey. Journal of Animal and Veterinary Advances 8:51-58

Dame RF, Olenin S (2005) The comparative roles of suspension-feeders in ecosystems, Vol Volume 47 of NATO Science Series: IV: Earth and Environmental Sciences. Springer

Edwards E (2006) Notes on the American oyster drill (*Urosalpinx cinerea*)

Elston R (1997) Pathways and Management of Marine Nonindigenous Species in the Shared Waters of British Columbia and Washington. Prepared for Puget Sound Water Quality Authority U.S. Environmental Protection Agency

Eissinger A (2009) Marine Invasive Species Identification Guide: For the Puget Sound area, Puget Sound Marine Invasive Species Volunteer Monitoring Program (MISM). Publication number: PSP09-02

Eno NC, Clark RA, Sanderson WG (1997) Non-native marine species in British waters: a review and directory. Peterborough: Joint Nature Conservation Committee. Peterborough: Joint Nature Conservation Committee

Faasse M, Ligthart M (2009a) American (*Urosalpinx cinerea*) and Japanese oyster drill (*Ocinebrellus inornatus*) (Gastropoda: Muricidae) flourish near shellfish culture plots in The Netherlands. Aquatic Invasions 4:321-326

Faasse MA, Ligthart M (2007) The American oyster drill, *Urosalpinx cinerea* (Say, 1822), introduced to The Netherlands - Increased risks after ban on TBT? Aquatic Invasions 2:402-406

Faasse MA, Ligthart M (2009b) American (*Urosalpinx cinerea*) and Japanese oyster drill (*Ocinebrellus inornatus*) (Gastropoda: Muricidae) flourish near shellfish culture plots in The Netherlands. Aquatic Invasions 4:321-326

Federighi H (1931) Death-poins of teh oyster drill snail *Urosalpinx cinerea* Say. Ecology 12:346-353

Franz DR (1971) Population age structure, growth and longevity of the marine gastropod *Urosalpinx cinerea* Say. Biological Bulletin 140:63-72

Ganaros AE (1958) On Development of early stages of Urosalpinx cinerea (Say) at constant temperatures and their tolerance to low temperatures Biological bulletin, vol 114, no. 2, pp 188-195

Garcia-Meunier P, Martel C, Trichet C (2003) Comparisons of Demographic Features of an Invasive Species, Ocinebrellus inornatus, versus an Indigenous Species, Ocenebra erinacea, University of La Rochelle. Proceedings of the Third International Conference on Marine Bioinvasions, La Jolla, California, March 16-19, 2003:43

Gibbs PE, Spencer BE, Pascoe PL (1991) The American oyster drill, Urosalpinx cinerea (Gastropoda): Evidence of decline in and imposex-affected population (R. Blackwater, Essex). . Journal of the Marine Biological Association of the United Kingdom 71:827-838

Giberto DA, Bremec CS, Schejter L, Schiariti A, Mianzan H, Acha EM (2005) The invasive Rapa whelk (Valenciennes 1846): Status and potential ecological impacts in the Río de la Plata Estuary, Argentina-Uruguay. Journal of Shellfish Research 25:381-385

Gittenberger A (2009) Botrylloides violaceus Oka, 1927. Accessed through the World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=148715 on 2009-08-07

Gittenberger, A., Korthof, R.E.M., Stegenga, H., Schrieken, N. & M. Rensing, 2010. Inventarisatie van de soortendiversiteit in tarra van mosselen uit Ierland, Verenigd Koninkrijk en Denemarken voorjaar 2010.GiMaRIS rapport 2010.04: 49 pp

Gittenberger, A. et al., in prep. Expansion of the Japanese oyster drill Ocinebrellus inornatus into Danish waters, confirmed by instant DNA-analysis.

Global-Invasive-Species-Database (2006) *Rapana venosa* (mollusc). Accessed at: http://www.issg.org/database/species/ecology.asp?si=691 10/02/2010

Global-Invasive-Species-Database (2007) *Ceratostoma inornatum* (mollusc). Available at http://www.issg.org/database/species/ecology.asp?si=1185&fr=1&sts=&lang=EN 02/09/09

Global-Invasive-Species-Database (2008) *Urosalpinx cinerea* (mollusc). Available at http://www.issg.org/database/species/ecology.asp?si=1383&fr=1&sts=sss&lang=EN 07/08/09

Goud J, Titselaar F, Mulder G (2008) Weer een 'verstekeling': de Japanse Stekelhoren Ocinebrellus inornatus (Recluz, 1851) (Gastropoda, Muricidae) levend aangetroffen in de oosterschelde. Spirula 365

Hanks JE (1957) The rate of feeding of the common oyster drill *Urosalpinx cinerea* (Say), at controlled water temperatures US Fish and Wildlife Service, Milford, Conn Accessed at: http://wwwbiolbullorg/cgi/reprint/112/3/330pdf 12/02/10, p 330-335

Harding JM (2006) Growth and development of veined rapa whelk *Rapana venosa* veligers. Journal of Shellfish Research 25:941-946

Harding JM, Mann H (2003) Rapa whelks (Rapana venosa) as prey items for Chesapeake Bay fauna: Natural controls for an invasive species? Third International Conference of Marine Bioinvasions March 16-19, Scripps Institution of Oceanography, La Jolla, California

Harding JM, Mann R (2002) Current status and potential establishment range for the predatory marine gastropod Rapana venosa on the U.S. East Coast. Presentation at the American Fisheries Society Annual meeting, Baltimore, MD. August 2002. From: Veined rapa whelk (*Rapana venosa*) research in North America: Summary of research activity through February 2002.

Harding JM, Mann R (2005) Veined rapa whelk (Rapana venosa) range extensions in the Virginia watesr of Chesapeake Bay, USA. Journal of Shellfish Research 24:381-385
Harding JM, Mann R (2002) Current status and potential establishment range for the predatory marine gastropod Rapana venosa on the U.S. East Coast. Presentation at the American Fisheries Society Annual meeting, Baltimore, MD. August 2002. From: Veined rapa whelk (*Rapana venosa*) research in North America: Summary of research activity through February 2002.
ICES (2004) Alien Species Alert: Rapana venosa (veined whelk). Edited by Roger Mann, Anna Occhipinti-Ambrogi and Juliana M. Harding. ICES Cooperative Research Report No. 264. 14pp.

Kerckhof F, Vink RJ, Nieweg DC, Post JNJ (2006a) The veined whelk *Rapana venosa* has reached the North Sea. Aquatic Invasions 1:35-37

Kerckhof F, Vink RJ, Nieweg DC, Post JNJ (2006b) The veined whelk *Rapana venosa* has reached the North Sea Aquatic Invasions 1:35-37

Leppakoski E, Gollasch S, Olenin S (2002) Invasice Aquatic Species of Europe. Distribution, Impacts and Management, Vol. Kluwer Academic Publishers, Printed in the Netherlands

Leung KMY, Dudgeon D (2008) Ecological Risk Assessments and management of exotic organisms associated with aquaculture activities. In: Bondad-Reantaso MG, Arthur JR, Subasinghe RP (eds) Understanding and applying risk assessment in aquaculture FAO Fisheries and Aquaculture Technical Paper No 519 FAO, Rome

Locke A, Hanson JM (2009) Rapid response to non-indigenous species. 1. Goals and history of rapid response in the marine environment. Aquatic Invasions 4:237-247

Mann R, Harding JM (2003) Complex life history and the dynamics of range extension in a novel environment: Lessons from 5 years of observation of invading gastropod *Rapana venosa*. Third International Conference on Marine Bioinvasions, March 16-19, 2003, Scripps Institution of Oceanography La Jolla, California

Martel C, Guarini JM, Blanchard G, Sauriau PG, Trichet C, Robert S, Garcia-Meunier P (2004) Invasion by the marine gastropod *Ocinebrellus inornatus* in France. III. Comparison of biological traits with the resident species *Ocenebra erinacea*. Marine Biology 146:93-102

Manzi J (1970) Combined effects of Salinity and Temperature on the Feeding, Reproductive and Survival Rates of *Eupleura caudata* (Say) and *Urosalphinx cinerea* (Say) (Prosobranchia: Muricidae). Biological Bulletin, vol. 138, no 1, pp35-46

McCoy L (2009) Ruesink Lab: Oyster Drills Available at http://deptswashingtonedu/jlrlab/oysterdrillsphp 03/09/09
McEnnulty FR, Bax NJ, Schaffelke B, Campbell ML (2000) A literature review of rapid response options for the control of ABWMAC listed species and related taxa in Australia, CSIRO Marine Research, Hobart, Tasmania 7001 Australia
McEnnulty FR, Jones TE, Bax NJ (2001) The Web-Based Rapid Response Toolbox. Web publication. Available at: http://www.marine.csiro.au/crimp/nimpis/controlDetail.asp?ID=69 04/09/09
Mueller KW, Hoffmann A (1999) Effect of freshwater immersion on attachment of the Japanese oyster drill, *Ceratostoma inornatum* Journal of Shellfish Research 18:788
Nichols D, Cooke J (1971) The Oxford Book Of Invertebrates., Vol, New York: Oxford University Press.
Richerson M (2010) *Rapana venosa*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1018> Revision Date: 4/24/2006

Saglam H, Duzgunes E, Ogut H (2009) Reproductive ecology of the invasive whelk *Rapana venosa* Valenciennes, 1846, in the southeastern Black Sea (Gastropoda: Muricidae). ICES Journal of Marine Sciences 66:1865-1867
Sakai AK, Allendorf FW, Holt JS, Lodge DM, Molofsky J, With KA, Baughman S, Cabin RJ, Cohen JE, Ellstrand NC, McCauley DE, O'Neil P, Parker IM, Thompson JN, Weller SG (2001) The population biology of invasive species. Annu Rev Ecol Syst 32:305-332
Savini D, Castellazi M, Favruzzo M, Occhipinti-Ambrogi A (2004) The alien mollusc *Rapana venosa* (Valenciennes 1846; Gastropoda, Muricidae) in the northern Adriatic Sea: population structure and shell morphology. Chemistry and Ecology 20:411-424
Savini D, Occhipinti-Ambrogi A (2006) Consumption rates and prey preference of the invasive gastropod *Rapana venosa* in the Northern Adriatic Sea. Helgological Marine Resources 60:153-159
USGS (2009) Non-indigenous Species Information Bulletin: Veined Rapa Whelk, Asian Rapa Whelk, *Rapana venosa* (Valenciennes, 1846) Mollusca: Gastropoda, Muricidae. Accessed at http://fl.biology.usgs.gov/Nonindigenous_Species/Rapa_whelk/rapa_whelk.html 10/02/10
Van Aken HM (2001) 140 years of daily observations in a tidal inlet (Marsdiep). Online available at: http://www.nioz.nl/public/fys/realtime_observations/jetty_t-s/akenrev2.pdf. ICES Marine Science Symposia 219:359-361
Van Den Brink A and Wijsman JWM (2010) High risk exotic species with respect to shellfish transports from the Oosterschelde to the Wadden Sea. Report C025/10 IMARES
Van Den Brink A, Wijsman JWM (2010) Freshwater immersion as a method to remove *Urosalpinx cinerea* and *Ocinebrellus inornatus* from mussel seed. Report No. C020/10, IMARES
Wijsman JWM, De Mesel I (2009) Duurzame schelpdiertransporten. Report No. C067/09, IMARES
Wijsman JWM, Smaal AC (2006) Risk analysis of mussels transfer. Wageningen Imares. Report number C044/06
Williams B (2002) "*Urosalpinx cinerea*" (On-line), Animal Diversity Web. Accessed at http://animaldiversity.ummz.umich.edu/site/accounts/information/Urosalpinx_cinerea.html. 07/08/09
Williams RC, McDonald S (2008) Investigation of Trait-Mediated Interactions in a Trophic Cascade Involving Native and Invasive Drills. Available at http://www.champwilliams.com/images/manuscripts/investigation%20of%20trait-mediated%20interactions%20in%20a%20trophic%20cascade%20involving%20native%20and%20invasive%20drills.pdf 04/09/09
Williams JD, and GK Meffe (1999) Nonindigenous species: Status and trends of the nation's biological resources. United States Geological Survey.
Zolotarev V (1996) The Black Sea ecosystem changes related to the introduction of new mollusks species. PSZNI: Marine Ecology 17:227-236

Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved: Dr. Norbert Dankers
Senior Onderzoeker

Signature:

Date: 12 mei 2010

Approved: Floris Groenendijk
Head of Dept. of Ecosystems

Signature:

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Appendix A. Economic impact on mussel plots and mussel seed capture installations (SMCs)

1. Economic impact of the introduction of invasive predatory snails

Little is known about the economic damage caused by the American oyster drill, the Japanese oyster drill and the Asian rapa whelk in invaded areas. However, there has been considerable speculation regarding the damage caused by these predatory snails. The American oyster drill is descibed to be a major pest to the commercial oyster industry. This oyster drill is stated to pose a threat to oyster native populations and cultures wherever it exists (Global Invasive Species Database 2007). The Japanese oyster drill is stated to be a threat to stocked and native oyster populations (Ray, 2005). The Asian rapa whelk is described as a veracious predator an is stated to be a serious limitation to cultivated and natural populations of oysters and mussels (Global Invasive Species Database 2007). There are few studies with actual quantitative statements on economic damage;

- The American oyster drill consumed on average 50% (33%-75%) of oyster spat on local oyster beds on different locations. In Delaware Bay, USA, 33%, 41% and 50% mortality has been found on different oyster beds (Nelson 1922). In East Coast oyster beds (USA, native range) they commonly killed 60-70% of the young oysters (Alford 1975). In Great Britain mortalities range from 50% on oyster beds in river Blackwater to 58% on Essex oyster beds. Cole (1951) and Hancock (1954) state that in the Essex river 75% would probably not be an overestimate of the percentage of spat destroyed by the American oyster drill during the first year of its life.
- The Japanese oyster drill caused about 25% mortality of planted oyster seed in drill infested areas of Washington, USA (Elston, 1997). As a result of the infestation of the Japanese oyster drill in this area production costs increased by 20% and profits decreased by about 55%.
- The Asian rapa whelk is held responsible for the decline by almost 50% of the native edible bivalve fauna (Zolotarev 1996).

When these invasive predatory snails are introduced in the Wadden Sea, they might cause similar mortalities in commercial shellfish stocks in that area. As there are no quantitative data on mortality rates in mussel stocks available in literature, it is assumed in this estimationn that mortality rates on mussel seed are comparable with mortality on young oysters (for the American oyster drill it is reported that in water temperatures of 5-30°C one individual consumed about 0-1.47 oyster spat (*Crassostrea virginica*) per week, compared to 0.01-0.87 mussels (*Mytilus edulis*) of 20-30 mm per week. Mussel seed from seed mussel capture devises ranges in size from several millimeters to about 20 mm and feeding rates on SMC mussels placed on culture plots is therefore expected to be a bit higher.)

2. Estimated economic impact on mussel plots and seed mussel capture devices (SMC's) in the Dutch Wadden Sea

Rik Beukers - LEI

To estimate the economic impact of introduction of invasive predatory snails the quantitative information on economic damage in other (invaded) areas is translated to the shellfish cultures in the Wadden Sea. As it is not known how the snails will develop in the Wadden Sea and if damage on mussel seed will be comparable to the reported damage on oyster spat, many assumptions have been made (see section above) for this translation.

Based on these assumption that the invasive predatory snails will develop in a similar way in the Wadden Sea as they did in other invaded areas and that they will have similar economic effects on mussel seed as they had on oyster spat, the following 'worst case' translation is made:

- The American oyster drill (*Urosalpinx cinerea)* causes a mortality of 50% of the local mussel stocks in the Wadden Sea;
- The Japanese oyster drill *(Ocinebrellus inornatus)* causes a mortality of 25% of the local mussel stocks in the Wadden Sea;
- The Asian rapa whelk *(Rapana venosa)* causes a mortality of 50% of the local mussel stocks in the Wadden Sea.

When the predatory snails become introduced, it will most likely be from a single (or multiple) culture plot on which infested mussel seed is planted. From there the snails will spread to adjacent culture plots or adjacent wild mussel beds. In the case of the two oyster drills the natural spread to other areas will take some time, although transportation of oyster drills might be facilitated by mussel farming activities.

In the Wadden Sea currently 7 000 hectares of culture plot area is allocated, of which about 3 500 hectares are suitable for the production and growth of mussel seed. The size of an average culture plot is about 10 hectares and has an annual production of 200 000 kg (ranging from 50 000 – 1 000 000 kg) of mussels (Wadden-Unit LNV). When the predatory snails are able to settle and reproduce on the culture plot in the time that the mussel seed grows to consumption size, and when the assumption is made that the entire production on a culture plot could have been used for consumption, the occurrence of the American oyster drill (*Urosalpinx cinerea)* or the Asian rapa whelk (*Rapana venosa*) could lead to a loss of 100 000 kg on a single infested culture plot and the occurrence of the Japanese oyster drill (*Ocinebrellus inornatus)* will lead to a loss of 50.000 kg of mussels on a single infested culture plot. When using the average auction price the financial loss of introduction of *Urosalpinx cinerea* or *Rapana venosa* on a culture plot will be 146.000 euro and the financial loss of *Ocinebrellus inornatus* on a culture plot will be 73.000 euro.

As the infestation of a culture plot might eventually spread to other culture plots in the same culture plot group and later to other culture plot groups, a worst case scenario estimation of the possible economic impact when all culture plots are infested is made:

The average landings of Dutch mussels from the Wadden Sea in the period 2002/2003-2008/2009 was 26 million kg with a corresponding auction price of 1.46 euro/kg (Taal et al, 2009). When price increases are not taken into account the introduction of each of the species to all culture plots will result in a decrease in landings and therefore also a decrease in value:

- *Urosalpinx cinerea* causes a loss of 13 million kg with a corresponding value of almost 19 million Euro;
- *Ocinebrellus inornatus* causes a loss of 6.5 million kg with a corresponding value of 9.5 million Euro;
- *Rapana venosa* causes a loss of 13 million kg with a corresponding value of almost 19 million Euro.

Furthermore *Rapana venosa* also can have a possible impact on the seed mussel capture devises (SMC's) in the Wadden Sea, as it lives a considerable time in a larval stage in the water column. At the moment there are several different seed mussel capture devises (SMC's). In 2010 The Ministry of LNV has allocated 205 hectares for SMC's. To measure the impact, the economic data of an average SMC system are used as has been described in Van Oostenbrugge et al (2009). An average SMC system of 40 hectares has an annual production of 15.000 Mussel ton. Because the selling price of mussel seed can fluctuate throughout the year an average price of 0.60 Euro/kg has been taken. When 205 hectares are used for SMC's this results in almost 7.7 million kg of mussel seed. Assuming that *Rapana venosa* also leads to a mortality of 50% at mussel seed on SMC's the total loss in value amounts to 2,3 million Euro when all devices are infested.

	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	Gemiddelde
Aanvoer Waddenzee (mn kg)	33	32	30	26	11	28	22	26
Prijs (Euro/kg)	1,14	1,59	1,1	1,11	1,69	1,82	1,8	1,46
Opbrengst (mn Euro)	38	50	34	30	18	50	39	37

Oostenbrugge, J.A.E. van, Keus, B.J., Smit, J.P.G. *Economische effecten van MZI's op de visserijsector.* Rapport 2009-105. LEI Wageningen UR, Den Haag, 2009.

Taal, C. Bartelings, H. Beukers, R. Duijn, A.P. van, Klok, A.J. Oostenbrugge, J.A.E. Smit, J.P.G. *Visserij in Cijfers 2009.* Rapport 2009-070. LEI Wageningen UR, Den Haag, 2009.

Appendix B. FAO Organism risk assessments forms
(Leung & Dudgeon 2008)

On the following pages the FAO Organism risk assessments forms (Leung & Dudgeon 2008) have been completed for the three species under consideration:.

1) Japanese oyster drill *Ocinebrellus inornatus*
2) American oyster drill *Urosalpinx cinerea*
3) Asian rapa whelk *Rapana venosa*

Japanese oyster drill -*Ocinebrellus inornatus*

Date:	1 April 2010
Organism (Scientific and common names)	*Ocinebrellus inornatus* - Japanese oyster drill - Japanse oesterboorder
Analyst(s):	FE Fey, AM van den Brink, JWM Wijsman
Pathway:	Commercial shellfish transfers
Origin of the Organism:	Western Pacific; Sakhalin and Kurile Islands up to Japan and from North of China to Korea (Garcia-Meunier et al. 2003, Global-Invasive-Species-Database 2007).

1. Literature review and background information

Life history

Growth rate
Juveniles grow rapidly (more than 2 mm per month, although growth rates decrease with increasing size, and reach reproductive maturity in their second year when they are about 27 mm long Adults can grow to about to 50 mm long (Buhle et al. 2004, Martel et al. 2004, Eissinger 2009, McCoy 2009).

Egg size
Approx. 2 mm long, approximately 10 eggs laid in each egg capsule (Buhle et al. 2004, Martel et al. 2004, Eissinger 2009, McCoy 2009).

Diet breadth
Benthic bivalves, including young oysters, mussels, clams and cockles, as well as barnacles. (Nichols & Cooke 1971, Buchsbaum et al. 1987, Williams 2002, Cohen 2005).

Reproduction strategy
Ocinebrellus inornatus has a simple two stage life history. Mature adults aggregate in both Spring and Autumn and lay clumps of bright yellow egg capsules (each containing about 10 young about 2 mm long) on any emergent hard substratum they can find. After about three weeks juveniles emerge looking like miniature adults and begin to feed. Juveniles grow rapidly (more than 2 mm per month, although growth rates decrease with increasing size), and reach reproductive maturity the following year when they are about 27 mm long (Buhle et al. 2004, Martel et al. 2004, Eissinger 2009, McCoy 2009). McCoy (2009) reported that adult survival rates of *O. inornatus* were low (less than 10 % annually) and suggested that this short life span was compensated for by high fecundity.

Distribution

Tolerable range of temperature
>0 °C (Faasse & Ligthart 2009b).

Tolerable range of salinity
Unknown

Invasion history
The presence of *Ocinebrellus inornatus* has been reported in Australia, but it is unknown whether it is native there or introduced (Global-Invasive-Species-Database 2007). In the 20th century, it was accidentally introduced to the Pacific coasts of North America, including Pugnet Sound (1924), British Columbia (1931), Oregon (1930-1934) and California (1941) (Garcia-Meunier et al. 2003). *O. inornatus* was then introduced into the bay of Marennes-Oléron on the French Atlantic coast in 1995. and later spread northward to the Golfe de Morbihan, south Brittany

(Garcia-Meunier et al. 2003, Martel et al. 2004, Faasse & Ligthart 2009b). Genetic studies found the source population of the French introduction probably came from the United States (Martel et al. 2004).

Ocinebrellus inornatus was first reported in the Netherlands in the Oosterschelde in 2007 but had been misidentified as the European oyster borer *Ocenebra erinacea* (Faasse & Ligthart 2007), so it may have been present in the area prior to this time. *O. inornatus* can now be easily found in the mussel pits around Yerseke (pers. obs.) and the population appears to be growing in the Oosterschelde. Faasse and Ligthart (2009) reported that more *O. inornatus* were found during two hour searches in Yerseke in 2008 and 2009 than in 2007, despite temperatures as low as 0-1° C in 2009. Furthermore, in 2008 the species was found in a new location near Gorishoek. So far *O. inornatus* has not spread as far north as the Wadden Sea (Dame & Olenin 2005).

Pathway Information

Natural dispersal of *Ocinebrellus inornatus* is limited by its lack of free-swimming larval stages. Without the ability to travel in the water column, juveniles are restricted to the immediate local area (Buhle & Ruesink 2009a). However, this limitation is easily counter-balanced by aquaculture activities, which play an important role in expanding the range of the species. Eggs and adults attached to transported bivalves can survive transportation to a new environment. (Martel et al. 2004).

The intensive oyster translocation activity that followed the introduction of *O. inornatus* into France via the transportation of live oysters from the USA and the success of the Pacific oyster in the new environment reportedly facilitated the spread of *O. inornatus* within and beyond Marennes-Ole´ron Bay (Martel et al. 2004, Faasse & Ligthart 2009b). Similarly, Buhle (2009) reported that the spatial spread of *O. inornatus* within Willapa Bay, Washington, USA, was largely the result of transferring oysters and shells by growers.

Control

In the aquaculture industry, prevention of the introduction of *Ocinebrellus inornatus* is obviously the preferred method of control. The West Coast states of the USA adopted regulations in 1945 to prohibit the transfer of oyster drills among oyster plantings within the state. An inspection programme was implemented in Washington and California in 1947 where authorities in Japan checked oyster seed shipments for pest species prior to packing. Inspections were again made when the shipment arrived in the USA. Along with these regulations and inspections, the transition to hatchery-produced seed has helped to prevent the spread of *O. inornatus* (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, McCoy 2009).

There have been several attempts to control the impact of *O. inornatus* where it is introduced. The most common control method for the drill is manual removal (Buhle et al. 2004, McCoy 2009). McCoy (2009) reported that oyster growers in Puget Sound and Willapa Bay, Washington would go out on the tide-flat with buckets and pick up as many drills as they could. Unfortunately these efforts were not successful in eradicating or reducing the distribution of the drills (McCoy 2009). White (2007) suggested that *O. inornatus* eggs could be easily removed from oyster shells with a screwdriver (in (Global-Invasive-Species-Database 2007))

Due to the two stage life history of *O. inornatus*, manual removal of eggs and adults can differ in efficiency. The destruction of eggs decreases fecundity, while the removal of adults reduces adult survival. Removal of juveniles is not feasible because of the difficulty in finding them due to their small size. Modeling by McCoy (2009) showed that removal of egg capsules is more effective in reducing the population than removal of adults (although removal of both is obviously optimal). However, Buhle *et al.* (2004) reported that although eggs are more numerous (they found about 150 eggs to each adult) and have a higher population elasticity, so that removing them would have a greater impact on the population, it is much more effective to control *O. inornatus* invasions by reducing adult survival rather than by reducing fecundity. This is because adults are much easier to find than the eggs (particularly in low reproduction seasons) and therefore decrease the costs of the technique.

Several other methods to remove *O. inornatus* on a larger scale have also been investigated. Buhl *et al.* (2004) reported that destroying the eggs of *O. inornatus* by burning effectively controlled their numbers. However, the obvious risks involved with this technique are likely to become an issue.

Immersion in freshwater can be a successful method for killing *O. inornatus*. This simple and cost-effective technique targets the eggs of *O. inornatus* without harming the oysters (Mueller & Hoffmann 1999). However, immersion in freshwater can cause juvenile mussels to drop off mussel ropes as well as killing other epibiota (McEnnulty *et al.* 2001). Van den Brink and Wijsman (2010) found that 24 hours exposure to 100 % freshwater was far from adequate to cause any harm to *O. inornatus* acclimatised to the environmental conditions of the Oosterschelde in the Netherlands. Mueller and Hoffmann (1999) reported that the drills would detach from the substrate when immersed in water with salinity between 7.2-18 ppt and experimented with immersing drills in freshwater (0 ppt). The length of time required for immersion before the drills detached increased with increase size of the drill. They suggested that drills with shells equal to or larger than 40 mm in length took between 1.4 to 20.2 minutes to detach when immersed in freshwater, although one in 10 was expected to remain attached after this time.

2. Rating elements for the PIES.COM model

Rate statements as L: Low, M: Medium, or H: High. Place specific biological information in descending order of risk with reference(s) under each element that relates to your estimation of probability or impact. Cite the literature (i.e. author, year) or use the reference codes of the biological statement (G: General knowledge, J: Judgment evaluation and E: Extrapolation) where appropriate and the uncertainty codes (VC: Very certain, RC: Reasonably certain, MC: Moderately certain, RU: Reasonably uncertain and VC: Very uncertain) after each element rating.

2.1 Probability of Establishment

Risk Element	Element Rating (L, M, H)	Uncertainty Code (VC, RC, MC, RU, VU)	Reference Codes (G, J, E)
Pathway risk	M Eggs or adults attached to transported oysters or other bivalves can survive until the bivalve is relocated to a new environment. However, there is little information on its whereabouts in the Oosterschelde and no evidence that *O. inornatus* is present on SMC cultures in the Oosterschelde, thus the risk of transport of SMC-seed to the Wadden Sea is not rated high.	RC	(Martel et al. 2004, Buhle & Ruesink 2009a).
Introduction risk	H Introduction is risked with transport of commercial shellfish.	RC	(Martel et al. 2004, Faasse & Ligthart 2009b)
Establishment risk	H Individual longevity, a wide range of prey species, frequent reproduction with relatively high fecundity and wide environmental tolerances allow it to successfully establish in a new environment.	RC	(Global-Invasive-Species-Database 2007, Buhle & Ruesink 2009a, Eissinger 2009); Faasse and Ligthart 2009

Spreading risk	M Unless assisted by humans, the lack of pelagic larval phase restricts the natural dispersal, but can become locally invasive due to strong reproductive potential.	VC	(Buhle & Ruesink 2009a)
* L: Low M: Medium H: High		** VC: Very certain, RC: Reasonably certain MC: Moderately certain RU: Reasonably uncertain VU: Very uncertain	*** G: General knowledge J: Judgment evaluation E: Extrapolation

2.2 Consequence of Establishment

Impact element	Element Rating (L, M, H)	Uncertainty Code (VC, RC, MC, RU, VU)	Reference Codes (G, J, E)
Ecological impact	M This species can alter communities at local scales. If prey is fundamental to the local ecosystem, providing habitats and food for other native species, predation of *O. inornatus* may alter the local environment.	MC	(Williams & McDonald 2008)
Economic impact	H The species can decimate stocked shellfish populations, significantly increasing costs and decreasing profits.	RC	(Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-Database 2007, Buhle & Ruesink 2009a).
Perceived impact	L The species is relatively small and obscure, but its predation may affect recreational mussel and oyster fishing. If numbers become high, fouling on equipment may become noticeable.	MC	J
* L: Low M: Medium H: High		** VC: Very certain, RC: Reasonably certain MC: Moderately certain RU: Reasonably uncertain VU: Very uncertain	*** G: General knowledge J: Judgment evaluation E: Extrapolation

3. Risk Characterization

3.1 Probability of Establishment (PE)

Determination of a combined rating for the probability of establishment (PE) by taking the lowest rating among the four elements.

	Pathway	Introduction	Establishment	Spreading
Risk rating (L, M, H)	M	H	H	M
	PE Score: M			

3.2 Consequences of establishment (CE Score)

Determination of a combined rating for the probability of the consequence of establishment (CE Score) by matching one of the listed scenarios with the current study. **CE rating = H**

Scenario	Ecological	Economic	Percieved	CE Score
Impact Rating for this study (L, M, H)				
1	H	L, M, H	L, M, H	H
2	L, M, H	H	L, M, H	H
3	M	M	L, M, H	M
4	M	L	L, M, H	M
5	L	M	L, M, H	M
6	L	L	M, H	M
7	L	L	L	L

3.3 Organisms Risk Potential (ORP)

Determination of the final rating of organisms risk potential (ORP) by putting the values of PE and CE determined from 4.1 and 4.2, and matching with one of the listed cases with this study. **ORP Rating (L, M, H) = H**

Case	Probability of Establishment	Consequence of Establishment	OPR Rating
Rating for this study (L, M, H)			
1	High	High	=High
2	Medium	High	=High
3	Low	High	=Medium
4	High	Medium	=High
5	Medium	Medium	=Medium
6	Low	Medium	=Medium
7	High	Low	=Medium
8	Medium	Low	=Medium
9	Low	Low	=Low

3.4 Pathway risk potential (PRP)

Determination of the pathway risk potential (PRP) based on the rating distribution of the seven elements used for deriving the organism risk potential (ORP), by matching one of the following listed scenarios.

PRP Rating (L, M, H) = H

Characteristics of the Rating Distribution of the Seven Elements for Deriving ORP	PRP Rating
1 or more scored with High rating(s) out of the	High

seven	
5* or more scored with Medium rating(s) out of the seven	High
1–5* scored with Medium rating(s) out of the seven	Medium
All scored with Low ratings	Low

*Note: The number, 5 used in this table is arbitrary. The selection of value 4 or 5 is possible when the number of Medium risk organisms reaches a level at which the total risk of the pathway becomes high.

3.5. Recommendations

Recommendations on the proposed introduction and mitigation measures based on the definition given below.

Rating of ROP or PRP	Definition	Actions
Low	Acceptable risk: organism(s) of little concern	• Introduction may be permitted • No mitigation is required
Medium	Unacceptable: organism(s) of moderate concern	• Introduction should be banned or should be controlled via risk management • Mitigation is justified
High	Unacceptable: organism(s) of high concern	• Introduction should be banned • Prevention rather than mitigation is mandated, and control measures should be considered.

Recommendations:

• Introduction should be banned
• Prevention rather than mitigation is mandated, and control measures should be considered.

4. Specific Management Questions

The mussel farmers in the Netherlands would like to have the possibility to transport mussels from the Oosterschelde towards the Wadden Sea. In general the growth of the mussels and especially the quality is better in the Wadden Sea, but the (winter)survival is higher in the Oosterschelde. The recent developments of Seed Mussel Capture devices (SMC's) in the Netherlands has urged this demand. At present the transfer of mussels from the Oosterschelde to the Wadden Sea is not allowed because of the risk of introducing invasive exotic species. *Urosalpinx cinerea* and *Ocinebrellus inornatus* are two species that might pose a risk of being introduced into the Wadden Sea with the shellfish transfers.

Although the populations within the Oosterschelde seem to occur very locally (Gorishoek and Oyster pits in Yerseke) it is not feasible to remove the oyster drills from the system. From a management point of view the question arises if mitigating measures are possible:

- Treatment (mechanically or chemically) on board to remove oyster drills from the mussel loads. A study carried out in 2009 ((Van Den Brink & Wijsman 2010) showed that treatment with freshwater is not effective to remove the oyster drills. Mechanical treatment is not investigated yet.
- Control expansion: Since the oyster drills seem to be located within relative confined areas within the Oosterschelde, the expansion of the oyster drills within the Oosterschelde might be reduced by minimizing shellfish transfers from Gorishoek and the Oysterponds in Yerseke to other locations in the Oosterschelde.
- Zonation: Since the oyster drills seem to be located in confined areas in the eastern part, the oysters drills might be absent in other locations in the Oosterschelde. Risks of introducing the oyster drills into the Wadden Sea with mussel stocks from the western, northern or the central part of the Oosterschelde may be lower. This also accounts for the mussels from SMC's, although in practice these mussels from the suspended system might often be stored at a culture plot before transported to the Wadden Sea.

At present no dramatic effect of the oyster drills are observed yet in the Oosterschelde. However, the development of these relative new populations could take some time. It is essential to monitor the development, spread and the possible effects of the oyster drills within the coming years.

American oyster drill - *Urosalpinx cinerea*

Date:	1 April 2010
Organism (Scientific and common names)	*Urosalpinx cinerea* - American oyster drill - Amerikaanse oesterboorder
Analyst(s):	FE Fey, AM van den Brink, JWM Wijsman
Pathway:	Commercial shellfish transfers
Origin of the Organism:	Northwestern Atlantic; from the Gulf of St. Lawrence to southeastern Florida

1. Literature review and background information

Life history

Growth rate

Grows up to 35 mm in shell length. Sexual maturity is reached after one to two years and individuals can live for up to eight years (Williams 2002, Cohen 2005, Ruesink 2009).

Egg size

Each egg capsules (approx. 4-5 mm long pers. obs.), contains 5-12 eggs each (Cole 1942).

Diet breadth

Oysters, barnacles, mussels and occasionally snails, but prefers smaller, softer shelled sessile molluscs (Nichols & Cooke 1971, Buchsbaum et al. 1987, Williams 2002, Cohen 2005).

Reproduction strategy

Breeding in *Urosalpinx cinerea* occurs in the spring and summer when the water temperature rises. After fertilisation, the female deposits 20-40 translucent capsules, containing 5-12 eggs each, on a suitable substrate. Cole (1942) reported that spawning increased as temperatures rose above 12° C while Cohen (2005) reports that spawning only begins when the water temperature exceeds 20° C for at least a week. After approximately 6-8 weeks the well developed, but tiny young emerge from the eggs and begin feeding on various shellfish species and occasionally diversify to include encrusting ectoprocta. This diverse diet of juveniles reduces intra-specific competition for food (Franz 1971). Sexual maturity is reached after two years and individuals can live for up to eight years (Williams 2002, Cohen 2005).

Distribution

Tolerable range of temperature

9-25 °C (Global-Invasive-Species-Database 2008).

Tolerable range of salinity

>13 ppt (Williams 2002, Cohen 2005).

Invasion history

Urosalpinx cinerea has been introduced to the Pacific Coast of North America, southern Great Britain and recently the Netherlands (Global-Invasive-Species-Database 2008).

The date and means of the introduction of *Urosalpinx cinerea* to the Netherlands is unknown, but the species was first recorded in Gorishoek, Zeeland (51º31'27" N, 04º04'35"E) in 2007. This is an area of former oyster culture and present mussel culture and is known for its high number of introduced algae (Faasse and Ligthart 2007, 2009). Faasse and Ligthart (2009) reported that the population of *U. cinerea* at Gorishoek has been steadily growing despite regular collections by hand. In the Gorishoek area, egg capsules have not been counted since mid 2008, but at that time more egg capsules than adult individuals were recorded.

Pathway Information

Due to the lack of a pelagic phase in its lifecycle, and therefore reduced risk of translocation via natural means, the primary vector of translocation of *Urosalpinx cinerea* is unintentionally through commercial shellfish transfers (Faasse & Ligthart 2007, Global-Invasive-Species-Database 2008, Buhle & Ruesink 2009a, Locke & Hanson 2009). Eggs or adults attached to transported oysters or other bivalves can survive until the bivalve is relocated to a new environment.

Urosalpinx cinerea, was introduced to Willapa Bay, Washington, USA prior to 1948, most likely with imported eastern oysters (*Crassostrea virginica*) in the early 1900s. The species is now established and widespread in Willapa Bay and has become an economically significant pest of oyster aquaculture that is particularly damaging to juveniles. Oyster growers have attempted to control *U. cinerea* by manually removing adults and egg capsules, but even local eradication has proven difficult and in some cases growers have abandoned oyster beds due to the intense predation (Cohen 2005). Despite this, unauthorised movement of shellfish has also occurred and facilitated the potential spread of unwanted organisms. In 1997 a seized importation of *Crassostrea virginica* at Shannon Airport, Ireland, coming from Long Island Sound, USA and flown from New York, contained eggs of *U. cinerea* (Leppakoski et al. 2002).

U. cinerea is thought to have been introduced into the Thames Estuary, England from eastern North America with the translocation of the eastern oyster *Crassostrea Virginica* around 1880. At the time, identification of the species was problematic and it was not officially identified as non-indigenous in England until 1928 (Locke & Hanson 2009). By the 1950s *U. cinerea* was abundant along the Essex coast and was reported for the first time as a problem to oyster growers in Essex and parts of Kent (Edwards 2006). Over the next decade *U. cinerea* had a devastating effect on the mortalities of juvenile European flat oysters (*Ostrea edulis*) so that by 1954 large-scale control methods were being investigated. (Edwards 2006, Locke & Hanson 2009). The introduction of tributyl tin (TBT) antifouling biocides reduced the population of *U. cinerea* drastically and the species is now rare on the Essex coast. The decline of native oyster fisheries, resulting in poor spatfalls and inappropriately muddy substratum also prevented population recovery to the point where during a population survey in 2006 Edwards (2006) did not find a single specimen; adult, juvenile or egg capsule, and in a questionnaire survey shellfish aquaculturists also reported an absence of *U. cinerea* (Edwards 2006).

Control

Various control methods have been implemented in areas invaded and affected by *Urosalpinx cinerea*. For example, in England these methods included mechanical or suction dredging, but these proved ineffective (Locke & Hanson 2009). Traps have been used during the summer to control the species and on the Essex oyster beds, bounties were paid for bucket loads of *U. cinerea* (Eno et al. 1997). However, individual removal by hand was considered too labour-intensive and experimental traps were impractical for large-scale removal.

In the 1970s, the Ministry of Agriculture & Fisheries in England developed legislation to control the import and export of molluscs into and around the UK. The Molluscan Shellfish (Control of Deposit) Order was released in 1974 introducing a strict licensing system to help control and reduce the risks of pests and diseases in the country. *Urosalpinx cinerea* was one of the three species of prime importance and highest risk in this legislation (Cole 1966, Edwards 2006).

Between the 1940s and 1970s, over 1000 chemical compounds were investigated as eradication methods (Locke & Hanson 2009). These involved immersing *U. cinerea* and their host oysters in solutions of freshwater, formalin, potassium permanganate, chlorol (10% chlorine), phenol (0.15% in seawater) and copper sulphate or as chemically impregnated barriers (McEnnulty et al. 2000). However, all resulted in either killing the oysters as well or having severe environmental costs (Locke & Hanson 2009).

Immersion in fresh water has been successful in killing the drills (McEnnulty et al. 2001). The salinity at which the animals die depends on the environment they are acclimatised to (Federighi 1931). Federighi (1931) reported on 10 day salinity tolerance experiments with *U. cinerea* from populations originating in habitats with differing salinities. Drills from areas in Hampton Roads, Virginia, where the salinity in summer was 15-20 ppm had a salinity death point of 11.7-12.5 ppm. However, drills collected from Beaufort, North Carolina, where salinity was over 30 ppm had salinity death points of 15.6-17.6 ppm. He concluded that with lower environmental salinity, the smaller the difference between environmental salinity and the salinity death point becomes (Federighi 1931). Van den Brink and Wijsman (2010) found that 24 hours exposure to 100 % freshwater was far from adequate to cause any harm to *U. cinerea* acclimatised to the environmental conditions of the Oosterschelde in the Netherlands.

After the attempt of eradication was abandoned in England, the oyster industry had to alter its husbandry methods. Juvenile oysters were reared in trays or bags, behind barriers or under plastic netting for protection from predators, increasing the costs of maintenance and equipment required for the industry. Furthermore, in 1974 the Molluscan Shellfish (Control of Deposit) Order prohibited further transfer all molluscs between specific areas except under highly restrictive license conditions. This order was effective in controlling further spread of *U. cinerea* (Locke & Hanson 2009).

Between 1987 and 1990 the population of *U. cinerea* in England was almost wiped out due to the use of vessel antifouling paints containing TBT (Edwards 2006, Faasse & Ligthart 2007). TBT was found to cause imposex, a masculinisation in females to the point where oviducts were deformed, copulation and egg capsule formation was inhibited so that females were effectively sterile. No viable spawn was observed during the four summers of 1987-1990 (Gibbs et al. 1991). This appears to have been the only method somewhat successful in the control of the species. In the Netherlands, there is a ban on the use of TBT since 1993 for ships shorter than 25 m.

2. Rating elements for the PIES.COM model

Rate statements as L: Low, M: Medium, or H: High. Place specific biological information in descending order of risk with reference(s) under each element that relates to your estimation of probability or impact. Cite the literature (i.e. author, year) or use the reference codes of the biological statement (G: General knowledge, J: Judgment evaluation and E: Extrapolation) where appropriate and the uncertainty codes (VC: Very certain, RC: Reasonably certain, MC: Moderately certain, RU: Reasonably uncertain and VC: Very uncertain) after each element rating.

2.1 Probability of Establishment

Risk Element	Element Rating (L, M, H)	Uncertainty Code (VC, RC, MC, RU, VU)	Reference Codes (G, J, E)
Pathway risk	M Eggs or adults attached to transported bivalves can survive until the bivalve is relocated to a new environment. However there is little information on its whereabouts in the Oosterschelde and there is no evidence that U. cinerea is present on SMC cultures in the Oosterschelde, thus the risk of transport of SMC-seed to the Wadden Sea is not rated high.	RC	(Faasse & Ligthart 2007, Global-Invasive-Species-Database 2008, Buhle & Ruesink 2009a, Locke & Hanson 2009).
Introduction risk	H Introduction is risked with transport of commercial shellfish.	RC	(Leppakoski et al. 2002)
Establishment risk	H	RC	(Williams 2002, Cohen 2005).

	Individual longevity, a wide range of prey species, frequent reproduction with relatively high fecundity and wide environmental tolerances allow it to successfully establish in a new environment.		
Spreading risk	M Unless assisted by humans, the lack of pelagic larval phase restricts the natural dispersal, but can become locally invasive due to strong reproductive potential.	VC	(Global-Invasive-Species-Database 2008)

2.2 Consequence of Establishment

Impact element	Element Rating (L, M, H)	Uncertainty Code (VC, RC, MC, RU, VU)	Reference Codes (G, J, E)
Ecological impact	M Can have a competitive advantage over the native species and affect the structure of communities at local scales	MC	(Global-Invasive-Species-Database 2008)
Economic impact	H The species may affect commercial shellfish industries where it occurs in large numbers.	RC	(Williams 2002, Global-Invasive-Species-Database 2008); (Eno et al. 1997, Cohen 2005); (Cole 1966)
Perceived impact	L The species is relatively small and obscure, but its predation may affect recreational mussel and oyster fishing. If numbers become high, fouling on equipment may become noticeable.	MC	J

3. Risk Characterization

3.1 Probability of Establishment (PE)

Determination of a combined rating for the probability of establishment (PE) by taking the lowest rating among the four elements.

	Pathway	Introduction	Establishment	Spreading
Risk rating (L, M, H)	M	H	H	M
	PE Score: M			

3.2 Consequences of establishment (CE Score)

Determination of a combined rating for the probability of the consequence of establishment (CE Score) by matching one of the listed scenarios with the current study. **CE rating = H**

Scenario	Ecological	Economic	Perceived	CE Score
Impact Rating for this study (L, M, H)				
1	H	L, M, H	L, M, H	H
2	L, M, H	H	L, M, H	H
3	M	M	L, M, H	M
4	M	L	L, M, H	M
5	L	M	L, M, H	M
6	L	L	M, H	M
7	L	L	L	L

3.3 Organisms Risk Potential (ORP)

Determination of the final rating of organisms risk potential (ORP) by putting the values of PE and CE determined from 4.1 and 4.2 and matching with one of the listed cases with this study. **ORP Rating (L, M, H) = H.**

Case	Probability of Establishment	Consequence of Establishment	OPR Rating
Rating for this study (L, M, H)			
1	High	High	=High
2	Medium	High	=High
3	Low	High	=Medium
4	High	Medium	=High
5	Medium	Medium	=Medium
6	Low	Medium	=Medium
7	High	Low	=Medium
8	Medium	Low	=Medium
9	Low	Low	=Low

3.4 Pathway risk potential (PRP)

Determination of the pathway risk potential (PRP) based on the rating distribution of the seven elements used for deriving the organism risk potential (ORP), by matching one of the following listed scenarios.
PRP Rating (L, M, H) = H

Characteristics of the Rating Distribution of the Seven Elements for Deriving ORP	PRP Rating
1 or more scored with High rating(s) out of the seven	High
5* or more scored with Medium rating(s) out of the seven	High
1–5* scored with Medium rating(s) out of the seven	Medium
All scored with Low ratings	Low

*Note: The number, 5 used in this table is arbitrary. The selection of value 4 or 5 is possible when the number of Medium risk organisms reaches a level at which the total risk of the pathway becomes high.

3.5. Recommendations

Recommendations on the proposed introduction and mitigation measures based on the definition given below.

Low	Acceptable risk: organism(s) of little concern	• Introduction may be permitted • No mitigation is required
Medium	Unacceptable: organism(s) of moderate concern	• Introduction should be banned or should be controlled via risk management • Mitigation is justified
High	Unacceptable: organism(s) of high concern	• Introduction should be banned • Prevention rather than mitigation is mandated, and control measures should be considered.

Recommendations:

• Introduction should be banned
• Prevention rather than mitigation is mandated, and control measures should be considered.

4. Specific Management Questions:

The mussel farmers in the Netherlands have would like to have the possibility to transport mussels from the Oosterschelde towards the Wadden Sea. In general the growth and the quality of the mussels is better in the Wadden Sea, but the (winter)survival is higher in the Oosterschelde. The recent developments of Seed Mussel Capture devices (SMCs) n the Netherlands has urged this demand. At present the transfer of mussels from the Oosterschelde to the Wadden Sea is not allowed because of the risk of introducing invasive exotic species. *Urosalpinx cinerea* and *Ocinebrellus inornatus* are two species that might pose a risk of being introduced into the Wadden Sea with the shellfish transfers.

Although the populations within the Oosterschelde seem to occur very locally (Gorishoek and Oyster pits in Yerseke) it is not feasible to remove the oyster drills from the system. From a management point of view the question arises if mitigating measures are possible:

- Treatment (mechanically or chemically) on board to remove oyster drills from the mussel loads. A study carried out in 2009 ((Van Den Brink & Wijsman 2010) showed that treatment with freshwater is not effective to remove the oyster drills. Mechanical treatment is not investigated yet.
- Control expansion: Since the oyster drills seem to be located within relative confined areas within the Oosterschelde, the expansion of the oyster drills within the Oosterschelde might be reduced by

minimizing shellfish transfers from Gorishoek and the Oyster ponds in Yerseke to other locations in the Oosterschelde.

- Zonation: Since the oyster drills seem to located in confined areas in the eastern part, the oysters drills might be absent in other locations in the Oosterschelde. Risks of introducing the oyster drills into the Wadden Sea with mussel stocks from the western, northern or the central part of the Oosterschelde may be lower. This also accounts for the mussels from SMC's, although in practice these mussels from the suspended system might often be stored at a culture plot before transported to the Wadden Sea.

At present no dramatic effect of the oyster drills have been observed yet in the Oosterschelde. However, the development of these relatively new populations could take some time. It is essential to monitor the development, spread and the possible effects of the oyster drills within the coming years.

Asian rapa whelk - *Rapana venosa*

Date:	1 April 2010
Organism (Scientific and common names)	*Rapana venosa* - Veined Rapa whelk - Geaderde stekelhoorn
Analyst(s):	FE Fey, AM van den Brink, JWM Wijsman
Pathway:	Most likely to be transportation of pelagic larvae in ballast water. Other possible vectors include the accidental introduction of egg cases with aquaculture products, bivalve stocks or spat, or as hull fouling on ships (Savini et al. 2004, Kerckhof et al. 2006a).
Origin of the Organism:	Western Pacific; from Peter the Great Bay off Vladivostok in the north, the Sea of Japan, the Yellow Sea, the East China sea and the Bohai Sea to Taiwan in the south (Mann & Harding 2003).

1. Literature review and background information

Life history

<u>Growth rate</u>
After settling, young whelks can grow over 0.5 mm in 21 days (Global-Invasive-Species-Database 2006, USGS 2009, Richerson 2010). The whelks reach reproductive maturity in 1-3 years at 50-70 mm in size and can live to be over ten years old and about 180 mm in shell length (Savini et al. 2004, USGS 2009).

<u>Egg size</u>
About 200-1000 eggs are laid in mats of between 50-500 egg capsules about 30 mm high (Global-Invasive-Species-Database 2006).

<u>Diet breadth</u>
Rapana venosa is a voracious predator with a diet consisting of various bivalve molluscs, such as oysters, mussels and clams (Harding & Mann 2002, Savini et al. 2004).

<u>Reproduction strategy</u>
Rapana venosa is dioecious with separate sexes. Mating occurs over an extended period during the winter and spring preceding egg laying (ICES 2004). Yellow egg capsules, each containing 200-1000 eggs are laid in mats of between 50-500 capsules on hard surfaces such as rocks or artificial structures (Global-Invasive-Species-Database 2006). Adult females can lay multiple egg masses throughout the course of one summer without intervening mating events (ICES 2004).

Unlike *Ocinebrellus inornatus* and *Urosalpinx cinerea*, *R. venosa* has a planktonic larval stage. After 14-21 days (depending on temperature and salinity) pelagic larvae hatch from the eggs and spend between 14 to 80 days in the plankton before settling to the bottom where they develop into hard-shelled snails (Kerckhof et al. 2006a). Veligers can settle successfully on various attached macrofauna such as bryozoans and barnacles as well as other hard surfaces. The young whelks grow quickly on a diet of algae, reaching over 0.5 mm in 21 days (Global-Invasive-Species-Database 2006, USGS 2009, Richerson 2010). The whelks reach reproductive maturity in 1-3 years at 50-70 mm in size and can live to be over ten years old (Savini et al. 2004, USGS 2009).

Distribution

Tolerable range of temperature

4-27 °C. The whelk tends to migrate from cold water to warmer, deeper waters in winter (Giberto et al. 2005, Culha et al. 2009).

Tolerable range of salinity

12-32 ppt (larvae) (Mann & Harding 2003)

Invasion history

Rapana venosa was introduced into the Black Sea via shipping in the 1940s and, over the following decade, it spread along the Caucasian and Crimean coasts and to the Sea of Azov. Since then its range has extended quickly into the northwest Black Sea to the coasts of Romania, Bulgaria and Turkey since 1947. This species has become established in the northern Adriatic Sea since 1973 and Aegean Sea since 1990 and has also invaded and become established in Chesapeake Bay on the Atlantic coast of the United States since 1998. Isolated adults and egg masses have been reported from the Brittany coast of France and in the Rio del Plata between Uruguay and Argentina since 1999 (Mann & Harding 2003, Global-Invasive-Species-Database 2006, Savini & Occhipinti-Ambrogi 2006, USGS 2009).

Two full grown *Rapana venosa* were recorded in the North Sea (Netherlands and UK waters) for the first time in 2005 but the species has not been recorded there since (Harding & Mann 2005, Kerckhof et al. 2006a).

Pathway Information

Due to the long pelagic larval stage (up to 80 days (Kerckhof et al. 2006a), thousands of *R. venosa* larvae can travel long distances naturally via ship ballast water (Savini et al. 2004). Once a founder population is established in an area, range extension can occur quickly as a result of larval dispersal via tidal currents, migration of juvenile and adult whelks, or human mediated means such as ballast water, dredge spoils or transport of seed oysters. (Harding & Mann 2005)

Control

There are no proven methods currently available for control or eradication of *Rapana venosa* should it become established in a receptor environment (ICES 2004). Control efforts in Chesapeake Bay currently include offering a bounty for collected whelks and encouraging local restaurants to develop recipes incorporating this species. (Mann & Harding 2003).

Attempts to target a species for control or eradication must focus on the most susceptible lifecycle stage. Egg case mats, although visible and often concentrated, may be spread over vast areas, and, given the large numbers of developing embryos contained in each case, they represent considerable propagule pressure when present even in small numbers (ICES 2004). Pelagic larval forms are too dispersed to be considered possible targets, while identification and collection of post-settlement forms on hard substrates is difficult in complex community structures, due to the high probability of confusion with other gastropods. Although large epifaunal individuals are identified with comparative ease, collection by hand costs a considerable amount of diver time and collection through the use of commercial dredges targets only disparate populations and could cause unacceptable damage to the environment and populations of native species (ICES 2004).

The concept of natural controls has been briefly investigated. In Chesapeake Bay it was suggested that the blue crab, *Callinectes sapidus*, could be a control for *R. venosa* through predation (Harding & Mann 2003), but this crab (which is another exotic species in this estuary) has been shown to have a diet mainly based on the introduced golden mussel, *Limnoperna fortunei* (Giberto et al. 2005). Other possible natural controls are demersal fishes that prey on the infauna. The Whitemouth croaker, *Micropogonias furnieri*, is the dominant species in terms of biomass and sustains the coastal and artisanal fisheries in Argentina and Uruguay (Giberto et al. 2005).

Alternatively, the whelk may become a control mechanism for previously introduced species. Kerckhof et al. (2006) suggested that in the North Sea, *R. venosa* may find an abundant food source in the dense population of the introduced razor clam *Ensis directus*. As a result one invader may turn out to control another.

2. Rating elements for the PIES.COM model

Rate statements as L: Low, M: Medium, or H: High. Place specific biological information in descending order of risk with reference(s) under each element that relates to your estimation of probability or impact. Cite the literature (i.e. author, year) or use the reference codes of the biological statement (G: General knowledge, J: Judgment evaluation and E: Extrapolation) where appropriate and the uncertainty codes (VC: Very certain, RC: Reasonably certain, MC: Moderately certain, RU: Reasonably uncertain and VC: Very uncertain) after each element rating.

2.1 Probability of Establishment

Risk Element	Element Rating (L, M, H) L: Low, M: Medium, or H: High.	Uncertainty Code (VC, RC, MC, RU, VU)	Reference Codes (G, J, E))
Pathway risk	L The long pelagic larval stage allows larvae to travel long distances naturally via ship ballast water, and egg cases can be introduced via commercial shellfish transport. However, due to the current absence of the whelk in the Oosterschelde and the negligible ballast water uptake of ships travelling between the Oosterschelde and Wadden Sea, translocation is unlikely. A high risk of introduction will most likely be via natural means from the North Sea or via ballast water taken up from other areas.	RC	(Savini et al. 2004, Kerckhof et al. 2006a)
Introduction risk	H With high levels of global shipping and the whelk's ability to survive in ballast water, there is a high possibility of introduction.	RC	E, (Savini et al. 2004, Kerckhof et al. 2006a)
Establishment risk	H The whelk is fast growing, has a high fertility and a high tolerance to a range of temperatures and salinities, water pollution and oxygen	RC	(Zolotarev 1996, Kerckhof et al. 2006b, Saglam et al. 2009)

	deficiency. However, R. venosa has been found to deposit egg capsules only at temperatures >18 °C (18–23 °C) and larvae are suited to temperatures of 25°C to 29°C. Thus egg deposition and larval survival in the Wadden Sea is likely to occur primarily in the warm summer months.		
Spreading risk	H The species is highly fecund and disperses far and easily through pelagic larvae.	VC	(Zolotarev 1996, Kerckhof et al. 2006b)

2.2 Consequence of Establishment

Impact element	Element Rating (L, M, H)	Uncertainty Code (VC, RC, MC, RU, VU)	Reference Codes (G, J, E)
Ecological impact	H The whelk's active predation of epifaunal bivalves, and its proliferation is a serious threat to cultivated and natural oyster and mussel beds and the habitats they form.	VC	(Global-Invasive-Species-Database 2006).
Economic impact	H The introduction of *R. venosa* to the North Sea may threaten the industry on edible bivalves such as mussels *Mytilus edulis*, Pacific oysters *Crassostrea gigas* and cockles *Cerastoderma edule*.	MC	(Kerckhof et al. (2006b)
Perceived impact	M Unless significant changes to a habitat occurs, or if the species is present in large numbers, there is unlikely to be significant perceived impact as the whelk is relatively small and obscure.	RU	G

3. Risk Characterization

3.1 Probability of Establishment (PE)

Determination of a combined rating for the probability of establishment (PE) by taking the lowest rating among the four elements.

	Pathway	Introduction	Establishment	Spreading
Risk rating (L, M, H)	L	H	H	H
	PE Score = L			

3.2 Consequences of establishment (CE Score)

Determination of a combined rating for the probability of the consequence of establishment (CE Score) by matching one of the listed scenarios with the current study. **CE Score = H**

Scenario	Ecological	Economic	Percieved	CE Score
Impact Rating for this study (L, M, H)				
1	H	L, M, H	L, M, H	H
2	L, M, H	H	L, M, H	H
3	M	M	L, M, H	M
4	M	L	L, M, H	M
5	L	M	L, M, H	M
6	L	L	M, H	M
7	L	L	L	L

3.3 Organisms Risk Potential (ORP)

Determination of the final rating of organisms risk potential (ORP) by putting the values of PE and CE determined from 4.1 and 4.2 and matching with one of the listed cases with this study.
ORP Rating (L, M, H) = H

Case	Probability of Establishment	Consequence of Establishment	OPR Rating
Rating for this study (L, M, H)			
1	High	High	=High
2	Medium	High	=High
3	Low	High	=Medium
4	High	Medium	=High
5	Medium	Medium	=Medium
6	Low	Medium	=Medium
7	High	Low	=Medium
8	Medium	Low	=Medium
9	Low	Low	=Low

3.4 Pathway risk potential (PRP)

Determination of the pathway risk potential (PRP) based on the rating distribution of the seven elements used for deriving the organism risk potential (ORP), by matching one of the following listed scenarios.
PRP Rating (L, M, H) = H

Characteristics of the Rating Distribution of the Seven Elements for Deriving ORP	PRP Rating
1 or more scored with High rating(s) out of the seven	High
5* or more scored with Medium rating(s) out of the seven	High
1–5* scored with Medium rating(s) out of the seven	Medium
All scored with Low ratings	Low

*Note: The number, 5 used in this table is arbitrary. The selection of value 4 or 5 is possible when the number of Medium risk organisms reaches a level at which the total risk of the pathway becomes high.

4. Recommendations

Recommendations on the proposed introduction and mitigation measures based on the definition given below.

Low	Acceptable risk: organism(s) of little concern	• Introduction may be permitted • No mitigation is required
Medium	Unacceptable: organism(s) of moderate concern	• Introduction should be banned or should be controlled via risk management • Mitigation is justified
High	Unacceptable: organism(s) of high concern	• Introduction should be banned • Prevention rather than mitigation is mandated, and control measures should be considered.

Recommendations:

- Introduction should be banned
- Prevention rather than mitigation is mandated, and control measures should be considered.

5. Specific Management Questions:

At this moment it is not likely that *Rapana venosa* has been established in the North Sea. Two full grown individuals have been recorded in 2005, but no recordings have been reported since then. It is of importance that new observations are recorded in order to gain more information on the presence and spread of this species.

Rapana venosa do not pose any risk of being introduced with SMC-seed transfer from the Oosterschelde to the Wadden Sea since they are not present yet in the Oosterschelde.

Appendix C. ISEISA assessments

(Belgium Forum on Invasive Species 2009)

In the following pages the Invasive Species Environmental Impact Assessment (ISEISA) have been completed for the three species under consideration:

1. Japanese oyster drill *Ocinebrellus inornatus*
2. American oyster drill *Urosalpinx cinerea*
3. Asian rapa whelk *Rapana venosa*

Japanese oyster drill - *Ocinebrellus inornatus*

1. Dispersion potential or invasiveness

Medium risk (2 points)

- Except when assisted by man, the species does not colonize remote places. Natural dispersal rarely exceeds more than 1 km per year. The species can however become locally invasive because of a strong reproduction potential.

The lack of pelagic larvae in its lifecycle greatly restricts the natural spread of *Ocinebrellus inornatus* to the immediate local area (Buhle and Ruesink, 2009). Translocation of either eggs, juveniles or adults to new environments is generally facilitated by humans (Martel et al. 2004, Faasse & Ligthart 2009b). Two laying peaks (spring and autumn) and a laying effort of 27.000 eggs/female result in high fecundity (Martel et al. 2004, Faasse & Ligthart 2009b).

2. Colonisation of high conservation value habitats

High risk (3 points)

- The non-native species often colonizes high conservation value habitats and makes therefore a potential threat for red-listed species.

In the Wadden Sea both natural and man-made mussel and oyster beds exist in relative close proximity. The similarity of these natural and man-made environments and the abundant prey available would allow *Ocinebrellus inornatus* to easily colonize both.

Populations of *Ocinebrellus inornatus* in natural mussel beds may be more successful than those in man-made mussel beds. Populations in man-made mussel beds may be less successful than natural beds due to the regular disturbance of the environment during harvest and the long period of time before sexual maturity is reached. If the food supply and habitat are severely disturbed before juveniles can reach maturity and spawn (1.5-2 years; (Buhle et al. 2004, Martel et al. 2004, Eissinger 2009, McCoy 2009), population growth will be restricted compared to natural environments lacking such regular disturbances. Although there is little information on whether *O. inornatus* preys on infaunal bivalves buried in the sediment, it is unlikely that this occurs.

3. Adverse impacts on native species

Medium risk (2 points)

- The non-native species is known to cause local changes (<80 %) in population abundance, growth or distribution of one or several native species, especially among common and ruderal species. This effect is usually considered as reversible.

Where it is introduced *Ocinebrellus inornatus* can have negative impacts on native bivalve populations. In Netarts Bay, Oregon a major component of the diet of *O. inornatus* is the native clam *Macoma balthica* and the native cockle *Clinocardium nuttalli* (Carlton 1979). Williams and McDonald (2008) report anecdotal evidence that *O. inornatus* has replaced the native dogwhelk *Nucella lamellosa* in Willapa Bay.

The major impact of *Ocinebrellus inornatus* is economical, as it can decimate stocked shellfish populations (Cole 1942). In British Columbia and Washington, where *O. inornatus* was introduced in cases of oyster seed from Japan, it began attacking the farmed oysters as well as the Manila clam (*Venerupis philippinarum*). The drill caused about 25 % mortality in oyster stocks. Productions costs increased by about 20 % and profits decreased by about 55 % (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-Database 2007, Buhle & Ruesink 2009a). In Netarts Bay, Oregon the Japanese clam (*Venerupis philippinarum*) was introduced for aquaculture purposes, but due to predation by *O. inornatus*, it only became established after an intensive planting programme (Carlton 1992). Williams and McDonald (2008) reported that in Puget Sound *O.*

inornatus consumed mussels (*Mytilus edulis*) at a rate of almost one mussel per drill per day, almost double that of the native drill *Nucella Lamellosa*.

4. Alteration of ecosystem functions

Medium risk (2 points)

- The impact on ecosystem processes and structures is moderate and considered as easily reversible.

If the prey of *O. inornatus* is fundamental to the local ecosystem, providing habitats and food for other native species, the predation of *O. inornatus* may alter the local environment (Williams & McDonald 2008). Additionally, if *O. inornatus* outcompetes and replaces native species, it may indirectly cause a trophic cascade that ultimately alter the community structure and biomass of the coastal ecosystem (Williams & McDonald 2008). In the Wadden Sea mussel beds are a habitat forming species. The effect of *O. inornatus* may be substantial on some littoral mussel beds in the Wadden Sea which can last for over ten years. On the relatively stable and long standing oyster beds in England *O. inornatus* inflicted 25 % mortality on oyster spat in British Columbia and Washington (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-Database 2007, Buhle & Ruesink 2009a). However, the instability and often transient nature of shorter lived mussel beds in the Wadden Sea, may cause *O. inornatus* to have less effect on community structure.

5. Global environmental risk

	Low Risk	Medium Risk	High Risk
Dispersion potential or invasiveness		2	
Colonization of high conservation value habitats			3
Adverse impacts on native species		2	
Alteration of ecosystem functions		2	
Global environmental risk		9	

The ISEIA score is 9, therefore the species falls within the B (watch list) category.
The species is an 'alert list species'.

American oyster drill - *Urosalpinx cinerea*

1. Dispersion potential or invasiveness

Medium risk (2 points)
- Except when assisted by man, the species does not colonize remote places. Natural dispersal rarely exceeds more than 1 km per year. The species can however become locally invasive because of a strong reproduction potential.

The lack of pelagic larvae in its lifecycle greatly restricts the natural spread of *Urosalpinx cinerea* to the immediate local area. Translocation of either eggs, juveniles or adults to new environments is generally facilitated by humans (Faasse & Ligthart 2007, Global-Invasive-Species-Database 2008, Buhle & Ruesink 2009a, Locke & Hanson 2009).

Fecundity is not as high as many species with pelagic larvae, but juveniles are likely to have higher survival rates. When the young emerge they are well developed and ready to eat, foregoing a vulnerable pelagic, larval stage, allowing the species is able to populate new areas quickly and efficiently (Cole 1966). Females deposit 20-40 translucent capsules, containing 5-12 eggs each, on a suitable substrate, several times per spawning season (Cole 1942). After approximately 6-8 weeks the well developed but tiny young emerge from the eggs and begin feeding on various shellfish species and occasionally diversify to include encrusting ectoprocta. This diverse diet of juveniles reduces intra-specific competition for food (Franz 1971). Sexual maturity is reached after two years and individuals can live for up to eight years (Williams 2002, Cohen 2005).

2. Colonisation of high conservation value habitats

High risk (3 points)
- The non-native species often colonizes high conservation value habitats and makes therefore a potential threat for red-listed species.

In the Wadden Sea both natural and man-made mussel and oyster beds exist in relative close proximity. The similarity of these natural and man-made environments and the abundant prey available would allow *Urosalpinx cinerea* to easily colonize both.

Populations of *Urosalpinx cinerea* in natural mussel beds may be more successful than those in man-made mussel beds. Populations in man-made mussel beds may be less successful than natural beds due to the regular disturbance of the environment during harvest and the long period of time before sexual maturity is reached. If the food supply and habitat are severely disturbed before juveniles can reach maturity and spawn (two years; (Williams 2002, Cohen 2005), population growth will be restricted compared to natural environments lacking such regular disturbances. Although there is little information on whether *U. cinerea* preys on infaunal bivalves buried in the sediment, it is unlikely that this occurs.

3. Adverse impacts on native species

Medium risk (2 points)
- The non-native species is known to cause local changes (<80 %) in population abundance, growth or distribution of one or several native species, especially among common and ruderal species. This effect is usually considered as reversible.

Where *Urosalpinx cinerea* is introduced and has no natural predators or parasites, it can have a competitive advantage over the native species and affect the structure of local communities (Global-Invasive-Species-Database 2008). The invasion of *Urosalpinx cinerea* and its intense competition for food has adversely affected native molluscs such as the dog whelk (*Nucella lapillus*) in the Netherlands and the California marine snail (*Acanthinucella spirata*) in California. (Hancock, 1954; Faasse, 2007; Buhle, 2003; Alford, 1975; Eno, 1996).

Urosalpinx cinerea is a common and important pest to the commercial oyster industry. The species is a major threat to native oysters wherever they occur as they have been found to inflict over 60 % mortality of the annual seed crop (Williams 2002, Global-Invasive-Species-Database 2008). In England, for example, *U. cinerea* has been reported to feed on the native oyster (*Ostrea edulis*), with each snail estimated to consume about 40 spat per year (Eno et al. 1997, Cohen 2005). During its lifetime (at least six years (Cole 1966)), a single individual is capable of consuming 240 young oysters.

4. Alteration of ecosystem functions

Medium risk (2 points)

- The impact on ecosystem processes and structures is moderate and considered as easily reversible.

The intense predation of *Urosalpinx cinerea* on habitat forming bivalves such as mussels and oysters has the potential to alter habitats and therefore community structures in new environments. The effect of *U. cinerea* may be substantial on some littoral mussel beds in the Wadden Sea which can last for over ten years. On the stable and long standing oyster beds in England *U. cinerea* was reported to inflict 50 % mortality on oyster spat (Eno et al. 1997, Cohen 2005). However, the instability and often transient nature of the shorter lived mussel beds in the Wadden Sea, may cause *U. cinerea* to have less effect on community structure.

5. Global environmental risk

	Low Risk	Medium Risk	High Risk
Dispersion potential or invasiveness		2	
Colonization of high conservation value habitats			3
Adverse impacts on native species		2	
Alteration of ecosystem functions		2	
Global environmental risk	9		

The ISEIA score is 9, therefore the species falls within the B (watch list) category.
The species is an 'alert list species'.

Asian Rapa Whelk - *Rapana venosa*

1. Dispersion potential or invasiveness

High risk (3 points)
- The species is highly fecund, can easily disperse through active or passive means over distances >1 km/year and initiate new populations.

Rapana venosa has many characteristics of a successful invader. It is fast growing, has a high fertility and adults have a high tolerance to a range of temperatures, salinities, water pollution and oxygen deficiency (Zolotarev 1996, Kerckhof et al. 2006b). However, Mizzan (1993) (in Saglam et al. (2009)) reported that *R. venosa* would deposit egg capsules only during summer at temperatures >18 °C (18–23 °C) in the Venice lagoon, Italy. During culture experiements, Harding (2006) found that optimal temperatures to keep pelagic larvae in the laboratory were 25°C to 29°C. Thus egg deposition and larval survival in the Wadden Sea is likely to occur primarily in the warm summer months.

This species is highly fecund; each female can lay between 50-500 egg capsules, each containing 200-1000 eggs, multiple times per season, providing temperatures are appropriately warm (ICES 2004, Global-Invasive-Species-Database 2006). The accidental translocation of egg cases and undetected juveniles through the commercial transport of shellfish is therefore a possibility. Due to the long pelagic larval stage (up to 80 days (Kerckhof et al. 2006b)), *R. venosa* also has the potential to spread long distances naturally and via ship ballast water (Savini *et al.* 2004).

2. Colonisation of high conservation value habitats

High risk (3 points)

- The species often colonizes high conservation value habitats and makes therefore a potential threat for red listed species.

Rapana venosa can easily colonize habitats with a high conservation value if a source population is established nearby. The pelagic larvae of this species allow for fast and easy population spread and colonization of new environments. *Rapana venosa* favours compact sandy bottoms in which it can almost completely bury itself, but can also be found on artificial and natural rocky bottoms where there is an abundance of bivalve prey available (Savini *et al.* 2004).

3. Adverse impacts on native species

High risk (3 points)

- The development of the species often causes local severe (> 80 %) population declines and a reduction in species richness.

Rapana venosa is known to cause severe population declines in native bivalve populations. The whelk's active predation of epifaunal bivalves, and its proliferation is a serious threat to cultivated and natural populations of oysters and mussels (Global-Invasive-Species-Database 2006). *R. venosa* is considered responsible for the decline (by almost half) of the native, edible bivalve fauna in the Black Sea (Zolotarev 1996). The species has caused significant changes in the ecology of benthic organisms and is blamed for the near extinction of the Gudaut oyster (Harding & Mann 2003). Although scientists are still studying the impacts of *R. venosa*, there is grave concern about its potential damage to native species. (Global-Invasive-Species-Database 2006)

4. Alteration of ecosystem functions

High risk (3 points)

- The impact on ecosystem processes and structures (such as food web sections) is strong and difficult to reverse.

Due to its predatory nature *R. venosa* is considered as one of the most unwelcome invaders worldwide (ICES 2004). The whelk's intense predation on (potentially habitat forming) bivalve species can disrupt natural food webs leading to ecosystem imbalance and to habitat modification. The species has been reported to impact populations of shellfish such as *Mya arenaria*, *Ensis directus* and *Cyrtopleura costata* as well as a range of commercially valuable and habitat forming shellfish species such as mussels and oysters (Global-Invasive-Species-Database 2006). In the Chesapeake Bay region, USA, adult *R. venosa* are also less susceptible to predation by seasonally migrating turtles due to their thick broad shells when compared to large native gastropods such as *Busycon carica* and *Busycotypus canaliculatum* (Global-Invasive-Species-Database 2006). Once grown to a predator refuge size, *R. venosa* may remain in the area an unchallenged predator and competitor (Global-Invasive-Species-Database 2006, USGS 2009, Richerson 2010).

5. Global environmental risk

	Low Risk	Medium Risk	High Risk
Dispersion potential or invasiveness			3
Colonisation of high conservation value habitats			3
Adverse impacts on native species			3
Alteration of ecosystem functions			3
Global environmental risk	12		

The ISEIA score is 12, therefore the species falls within Category A (black list).
The species is an 'alert list species'.

Appendix D. Risico beoordeling – toetsing aan Habitatrichtlijn

In 2009 werd de Waddenzee aangewezen als speciale beschermingszone in de zin van artikel 4, vierde lid, van Richtlijn 92/43/EEG van de Raad van 21 mei 1992 inzake de instandhouding van de natuurlijke habitats en de wilde flora en fauna (PbEG L 206). Met dit besluit valt het gebied Waddenzee onder de Habitatrichtlijn en zijn instandhoudingdoelstellingen vastgesteld.

Introductie van uitheemse soorten kan een impact hebben op de instandhoudingdoelstellingen van het Natura 2000-gebied Waddenzee. In deze analyse wordt de mogelijke impact van de introductie van drie uitheemse invasieve roofslakken (Japanse oesterboorder, Amerikaanse oesterboorder en geaderde stekelhoorn) op de instandhoudingdoelstellingen onder de Habitatrichtlijn beoordeeld. Voor een volledige analyse van mogelijke effecten op het Natura 2000-gebied Waddenzee zou naast een analyse van de Habitatrichtlijn, ook een analyse van de Vogelrichtlijn moeten plaatsvinden. De introductie van invasive roofslakken kan namelijk indirect ook een impact hebben op Vogelrichtlijnsoorten die in dit gebied zijn aangewezen. Voor vogels geldt dat wanneer schelpdierbestanden op een zodanige wijze worden beïnvloed dat dit effecten heeft op foerageermogelijkheden en voedselopname van schelpdieretende vogels er zich ook negatieve effecten voor deze soorten kunnen voordoen. Dit kan gevolgen hebben voor de staat van Instandhouding van deze soorten. Hiervoor zou een doorvertaling van de gesignaleerde effecten moeten worden gemaakt naar vogelsoorten waar mogelijk effecten kunnen optreden. Het betreft alleen soorten die in het Gebiedendocument worden genoemd en die ook schelpdieren eten, zoal Eider, Topper, Brilduiker, Scholekster en mogelijk ook Kanoet. Onderliggende beoordeling richt zich volgens opdracht echter alleen op de Habitatrichtlijn.

1.1 Relevantie habitattypen en habitatrichtlijnsoorten

Het Natura 2000-gebied Waddenzee bestaat uit een complex van diepe geulen en ondiep water met zand- en slibbanken waarvan grote delen bij eb droog vallen. Deze banken worden doorsneden door een fijn vertakt stelsel van geulen. Langs het vasteland en de eilanden liggen verspreid kweldergebieden, die door grote verschillen in vocht- en zoutgehalte bijdragen aan een zeer diverse flora en vegetatie. Er is een nagenoeg ongestoorde hydrodynamiek en geomorfologie aanwezig, waarin natuurlijke processen zorgen voor instandhouding en ontwikkeling van karakteristieke ecotopen en habitats en de grenzen van land en water voortdurend wijzigen.

In dit Natura 2000-gebied (Aanwijzingsbesluit Waddenzee, 2009) zijn acht habitattypen en vijf habitatrichtlijnsoorten aangewezen. Dit zijn:

Habitattypen	
H1110	Permanent overstroomde zandbanken
H1140	Slik- en zandplaten
H1310	Zilte pionierbegroeiingen
H1320	Slijkgraslanden
H1330	Schorren en zilte graslanden
H2110	Embryonale duinen
H2120	Witte duinen
H2130	Grijze duinen
H2160	Duindoornstruwelen
H2190	Vochtige duinvalleien

Habitatrichtlijnsoorten	
H1014	Nauwe korfslak (*Vertigo angustior*)
H1095	Zeeprik
H1099	Rivierprik
H1103	Fint
H1364	Grijze zeehond
H1365	Gewone zeehond

Daarnaast zijn er zeven kernopgaven geformuleerd;

1.03 **Overstroomde zandbanken & biogene structuren:** Verbetering kwaliteit permanent overstroomde zandbanken (*getijdengebied*) H1110_A o.a. met biogene structuren met mossels. Tevens van belang als leefgebied voor eider A063 en zwarte zee-eend A065 en als kraamkamer voor vis.

1.07 **Zoet-zout overgangen Waddengebied:** Herstel zoet-zout overgangen (bijvoorbeeld via spuiregime en vistrappen) i.h.b. visintrek Afsluitdijk, Westerwoldse Aa en Lauwersmeer/Reitdiep in relatie tot Drentse Aa (rivierprik H1099).

1.09 **Achterland fint:** Behoud van verbinding met Schelde en Eems ten behoeve van paaifunctie voor fint H1103 in België en Duitsland.

1.10 **Diversiteit getijdenplaten:** Verbetering kwaliteit slik- en zandplaten *(getijdengebied)* H1140_A ten behoeve van vergroting biodiversiteit.

1.11 **Rust- en foerageergebieden:** Behoud slikken en platen voor rustende en foeragerende niet-broedvogels zoals voor bonte strandloper A149, rosse grutto A157, scholekster A130, kanoet A143, steenloper A169 en eider A063 en rustgebieden voor gewone zeehond H1365 en grijze zeehond H1364.

1.13 **Voortplantingshabitat:** Behoud ongestoorde rustplaatsen en optimaal voortplantingshabitat (waaronder embryonale duinen H2110) voor bontbekplevier A137, strandplevier A138, kluut A132, grote stern A191 en dwergstern A195, visdief A193 en grijze zeehond H1364.

1.16 **Diversiteit schorren en kwelders:** Behoud (Waddenzee) en herstel (Delta) van schorren en ziltegraslanden *(buitendijks)* H1330_A met alle successiestadia, zoet-zout overgangen, verscheidenheid in substraat en getijregime en mede als hoogwatervluchtplaats.

Niet al deze habitatypen, habitatrichtlijnsoorten en kernopgaven zijn relevant in relatie tot de impact van introductie van roofslakken. Roofslakken zijn mariene organismen. Deze organismen vinden daarom alleen een geschikt leefgebied in habtitattype 1110 en habitattype 1140. De kernopgaven 1.07 (Zoet-zout overgangen in Waddengebied), 1.11 (Rust- en foerageergebieden), 1.13 (Voortplantingshabitat) en 1.14 (Diversiteit schorren en kwelders) verliezen hierdoor hun relevantie. Ook kan er door de mariene aard van de roofslakken geen impact zijn op de nauwe korfslak (H1014).

De drie invasive roofslakken zijn allen carnivoor en eten voornamelijk weekdieren. De roofslak predeert niet op vissen en zeezoogdieren. Daarnaast heeft de roofslak geen directe invloed op de voedselvoorziening van de relevante habitatrichtlijnsoorten. Fint (H1103) eet voornamelijk dierlijk plankton en kleine vis, zeeprik (H1095) en rivierprik (H1099) parasiteren op vissen en zoogdieren. Grijze (H1364) en gewone zeehonden (H1365) eten voornamelijk vis. Hiermee vervalt de relevantie van de voor Natura 2000-gebied Waddenzee aangewezen habitatrichtlijnsoorten en kernopgave 1.09 (Achterland fint).

Voor een beoordeling van de risico's van introductie van de roofslakken in het Natura2000-gebied Waddenzee zijn hiermee alleen habitattype 1110 en habitattype 1140 en kernopgaven 1.03 (Overstroomde zandbanken & biogene structuren) en 1.10 (Diversiteit getijdenplaten) relevant. De beoordeling van de impact van introductie van de roofslakken zal zich daarom alleen op deze habitattypen en kernopgavenrichten.

1.2 Instandhoudingdoelstellingen Natura 2000–gebied Waddenzee en relevante habitattypen

Het ecologisch netwerk Natura 2000 moet de betrokken natuurlijke habitats en leefgebieden van soorten in hun natuurlijke verspreidingsgebied in een gunstige staat van instandhouding behouden of in voorkomend geval herstellen. Deze instandhoudingdoelstellingen zijn vastgelegd in de aanwijzingsbesluiten voor de gebieden, zoals die door de minister van LNV in februari 2009 zijn vastgesteld. Voor het Natura 2000-gebied Waddenzee zijn vier algemene instandhoudingsdoelen geformuleerd:

Instandhoudingdoelstellingen Natura 2000–gebied Waddenzee
Behoud en indien van toepassing herstel van: 1. de bijdrage van het Natura 2000-gebied aan de ecologische samenhang van Natura 2000 zowel binnen Nederland als binnen de Europese Unie; 2. de bijdrage van het Natura 2000-gebied aan de biologische diversiteit en aan de gunstige staat van instandhouding van natuurlijke habitats en soorten binnen de Europese Unie, die zijn opgenomen in bijlage I of bijlage II van de Habitatrichtlijn. Dit behelst de benodigde bijdrage van het gebied aan het streven naar een op landelijke niveau gunstige staat van instandhouding voor de habitattypen en de soorten waarvoor het gebied is aangewezen; 3. de natuurlijke kenmerken van het Natura 2000-gebied, inclusief de samenhang van de structuur en functies van de habitattypen en van de soorten waarvoor het gebied is aangewezen; 4. de op het gebied van toepassing zijnde ecologische vereisten van de habitattypen en soorten waarvoor het gebied is aangewezen.

Naast de algemene instandhoudingsdoelen voor het Natura 2000-gebied Waddenzee, zijn er ook instandhoudingdoelstellingen geformuleerd voor de relevante habitattypen binnen het Natura 2000-gebied;

H1110 Permanent met zeewater van geringe diepte overstroomde zandbanken *getijdengebied* (subtype A)	
Doel	Behoud oppervlakte en verbetering kwaliteit permanent overstroomde zandbanken,
Toelichting	Het habitattype permanent overstroomde zandbanken, *getijdengebied* (subtype A), dat momenteel landelijk een matig ongunstige staat van instandhouding kent, is nagenoeg beperkt tot de Waddenzee. Het habitattype betreft hier de ondiepe delen tussen platen (waarvan de platen zelf onderdeel uitmaken van habitattype H1140 slik- en zandplaten) en diepe geulen met hoge stroomsnelheden. Kwaliteitsverbetering is vooral mogelijk door een deel van de mosselbanken betere ontwikkelingskansen te bieden (diverse stadia van ontwikkeling aanwezig) en door het herstel van de omvang en samenstelling van de visstand. Kenmerkend voor het systeem is de functionele samenhang van verschillende deelsystemen zoals eb- en vloedgeulen en droogvallende platen (H1140). Herstel van zoet-zout gradiënten is tevens van belang voor verbetering van de kwaliteit van dit habitattype.

H1140 Bij eb droogvallende slikwadden en zandplaten *getijdengebied* (subtype A)	
Doel	Behoud oppervlakte en verbetering kwaliteit slik- en zandplaten,
Toelichting	De Waddenzee is het belangrijkste gebied voor het habitattype slik- en zandplaten, *getijdengebied* (subtype A). De oppervlakte van de platen is hier nagenoeg natuurlijk. Wat de kwaliteit betreft is enerzijds behoud van de morfologische variatie van belang: de afwisseling tussen platen met een verschillende hoogteligging, mate van dynamiek en sedimentsamenstelling, anderzijds de overgangen daartussen en de overgangen naar diepere geulen en naar habitattypen permanent

	overstroomde zandbanken (H1110) en zilte pionierbegroeiingen (H1310). Kansen voor verbetering van de kwaliteit liggen met name bij herstel van droogvallende mosselbanken (en de daarbij behorende levensgemeenschappen) en bodemfauna en bij uitbreiding van zeegras- en ruppia-velden. Onder meer herstel van geleidelijke zoet-zoutovergangen is hiervoor van belang. Voor de mosselbanken op de droogvallende platen wordt gestreefd naar een toename van de oppervlakte. Het betreft een zeer dynamisch habitattype waarvan de exacte locatie en de oppervlakte jaarlijks sterk kunnen wisselen ten gevolge van erosie- en sedimentatieprocessen.

De landelijke staat van instandhouding voor het habitattype permanent overstroomde zandbanken, *getijdengebied* (H1110 subtype A) is op het aspect kwaliteit beoordeeld als “matig ongunstig”. De landelijke staat van instandhouding voor het habitattype slik- en zandplaten, *getijdengebied* (H1140 subtype A) is op kwaliteit beoordeeld als “matig ongunstig”.

Samenvatting staat van instandhouding en doelstellingen						
Habitattype	Staat van instandhouding				Doelstellingen	
	Verspreiding	Oppervlakte	Kwaliteit	Toekomst	Oppervlakte	Kwaliteit
H1110	Gunstig	Gunstig	Matig ongunstig	Matig ongunstig	Behoud	Verbetering
H1140	Gunstig	Gunstig	Matig ongunstig	Matig ongunstig	Behoud	Verbetering

Aangezien de invasive roofslakken carnivoor zijn is het mogelijk dat deze soorten een impact hebben op het voorkomen en de verspreiding van weekdieren, met inbegrip van biobouwers zoals mosselen en Japanse oesters, in het gebied. Het is daardoor mogelijk dat zij een impact hebben op de kwaliteit van de habitattypen. Het is niet waarschijnlijk dat de introductie van invasive roofslakken invloed heeft op de verspreiding en het oppervlakte van de habitattypen op zich.

De impact van mogelijke introductie van invasive roofslakken in het Natura 2000 – gebied Waddenzee zal daarom worden beoordeeld aan de hand van deze instandhoudingdoelstellingen in het licht van de staat van instandhouding van de <u>kwaliteit</u> van de relevante habitattypen.

1.3 Beoordeling

In de Nederlandse mariene gebieden zijn drie invasive roofslakken vastgesteld (Japanse oesterboorder *Ocinebrellus inornatus*, Amerikaanse oesterboorder *Urosalpinx cinerea* en de geaderde stekelhoorn *Rapana venosa*), waarvan de twee oesterboorders zich onlangs gevestigd hebben in delen van de de Oosterschelde. De geaderde stekelhoorn is waargenomen in de Noordzee, voor de kust van Scheveningen. Op dit moment is geen van deze soorten in het Natura 2000-gebied Waddenzee vastgesteld.

Van de twee oesterboorders is bekend dat de belangrijkste verspreidingsvector wordt gevormd door commerciële schelpdiertransporten (zie rapport, hoofdstuk 5.1). Zowel volwassen exemplaren als eiclusters kunnen door verplaatsing van schelpdieren worden ingevoerd in nieuwe gebieden. De geaderde stekelhoorn kan in nieuwe gebieden terecht komen door natuurlijk transport via het pelagische larvale stadium, transport via het larvale stadium in ballastwater, of door het transport van eiclusters of volwassen dieren in schelpdiertransporten of bevestigd aan scheepshuiden. Transport van larven (geaderde stekelhoorn) via ballastwater of op scheepshuiden is op dit moment mogelijk. Schepen uit andere gebieden kunnen zonder wettelijke beperkingen de Waddenzee bevaren, in Waddenhavens aanleggen of ballastwater in het Natura 2000-gebied lozen. Op dit moment zijn directe schelpdiertransporten van de Oosterschelde naar de Waddenzee (de zogenaamde zuid-noord transporten) niet toegestaan zonder Natuurbeschermingswet (NB-wet)-vergunning. Er zijn op dit moment geen NB-wet vergunningen afgegeven voor zuid-noord transporten. Mosseltransport van de Deense en Duitse Waddenzee naar de Nederlandse Waddenzee is zonder vergunning wel toegestaan. Daarnaast was het lange tijd onduidelijk of mosselen getransporteerd mochten worden van de Oosterschelde naar de Deense en Duitse Waddenzee, deze transporten hebben dan ook plaatsgevonden. Recentelijk is vanuit Duitsland aangegeven dat deze transporten zonder vergunning niet mogelijk zijn. Enige tijd was er dus via het Deense en Duitse wad een indirecte transportroute ontstaat, die nu afgelsoten is. De drie roofslakken zijn niet waargenomen in de Deense en de Duitse Waddenzee.

De roofslakken zullen bij introductie in de Waddenzee geen nadeel ondervinden van de heersende abiotische factoren (zie rapport, hoofdstuk 5.2). Ook zijn voldoende prooien te vinden in het gebied, zoals mosselen en oesters. Aangezien de Japanse en Amerikaanse oesterboorder geen pelagische fase kennen in hun levenscyclus, zal de verspreiding binnen het gebied beperkt zijn en grotendeels afhankelijk van schelpdiertransporten binnen het gebied. Verspreiding van deze soorten zal in eerste instantie voornamelijk plaatsvinden naar locaties met mosselpercelen en de directe omgeving. Dit betekent dat deze oesterboorders zich dan in eerste instantie voornamelijk in het westelijke deel van de Waddenzee (tot aan Terschelling) zullen verspreiden. Natuurlijke verspreiding naar het oostelijke deel van de Waddenzee zal langzamer gaan. De geaderde stekelhoorn kent wel een pelagische fase. Verspreiding van deze soort binnen het Natura 2000 gebied Waddenzee via natuurlijke weg zal daarom sneller en vollediger gaan dan bij de twee oesterboorders. Bij een introductie op één van de mosselpercelen in de Waddenzee zal de soort zich ook snel naar de oostelijke helft van de Waddenzee kunnen verplaatsen.

In deze beoordeling zal een toetsing aan de habitatrichtlijn worden uitgevoerd op de introductie van één of meerdere van deze roofslakken in het Natura2000-gebied Waddenzee. Hierbij wordt gericht op de kernwaarden, de algemene instandhoudingdoelstellingen en de instandhoudingdoelstellingen van de relevante habitattypen (H1110 en H1140) in het licht van de staat van instandhouding van de kwaliteit van het gebied. De mogelijke effecten op de kwaliteit van de habitattypen worden beoordeeld aan de hand van structuur en functie (de in het profielendocument beschreven abiotische randvoorwaarden en overige kenmerken van een goede structuur en functie) en de typische soorten.

Mogelijke impact op de kwaliteit van H1110

9.1.1.1 Abiotische randvoorwaarden

Abiotische randvoorwaarden
Subtypen H1110 A en H1110 B vereisen een goede waterkwaliteit. Slecht afbreekbare stoffen hebben risico's door de opeenhoping in de voedselketen. In het verleden hebben bestrijdingsmiddelen (zoals drins), polychloorbifenylen (PCB's) en anti-aangroeimiddelen als tributyltin (TBT) negatieve effecten gehad. De laatste jaren zijn de concentraties van deze stoffen in het vet van dieren afgenomen. Het water is matig voedselrijk tot voedselrijk. De helderheid van het water is van dien aard dat fotosynthese door algen mogelijk is. Het zoutgehalte varieert van licht brak nabij de Haringvlietsluizen tot vrijwel zout meer zeewaarts en langs de Noordzeekustzone. Nabij de sluizen van het Haringvliet en de Afsluitdijk kan bij een sterke rivierafvoer het water sterk verzoeten, wat tot sterfte van bepaalde daarvoor gevoelige soorten, zoals schelpdieren, kan leiden. Gezien de van nature aanwezige dynamiek zijn beide subtypen bestand tegen enige mate van bodemverstoring vanwege het natuurlijke herstelvermogen. De voortdurende afwisseling van eb- en vloedstromen is een belangrijke sturende factor in dit habitat. De hiermee samenhangende factoren als fluctuaties in zoet - zout, hydrodynamiek, dynamiek in temperatuur (zomer – winter) en helderheid van het water, zijn bepalend voor de biodiversiteit van H1110.

Het is niet aannemelijk dat introductie van de roofslakken een directe invloed zal hebben op de waterkwaliteit, het zoutgehalte, de afwisseling van eb- en vloedstromen of dynamiek.
Omdat de roofslakken prederen op schelpdieren, zoals oester(broed) en mossel(broed), en ze in andere gekoloniseerde gebieden hebben gezorgd voor een negatief effect op inheemse schelpdiersoorten (zie tabel 1), is het mogelijk dat er indirecte lokale effecten optreden op abiotische randvoorwaarden door introductie van deze soorten. Sublitorale mosselbanken en oesterriffen vangen slibdeeltjes in, waardoor een stevige sliblaag ontstaat onder de structuren. De ondergrond onder de structuren en in de directe omgeving van de structuren is daarom ook veel slikkiger dan de zandplaat waar de structuur op is ontstaan. Door het filteren van het water is het water in de directe omgeving van deze structuren helderder en beïnvloedden ze de waterkwaliteit. Hierdoor kunnen lokaal effecten optreden in bodemsamenstelling en waterkwaliteit.

Tabel 1 Informatie uit de literatuur met betrekking tot effecten op mossel- en oestervoorkomens:
Amerikaanse oesterboorder
- In een experimentele opzet, bij temperaturen tussen 15-20 graden Celsius, verorberde een individuele Amerikaanse oesterboorder 0.5-1 mossel (*Mytilus edulis*) per week (Hanks, 1957) - In Willapa Bay, USA, prefereerden Amerikaanse oesterboorders de Japanse oester (*Crassostrea gigas*) boven de inheemse Olympia oester (*Ostrea lurida*) (Buhle & Reusink, 2009) - In Groot Brittannië veroorzaakte de Amerikaanse oesterboorder lokaal gemiddeld 50% sterfte in het jaarlijkse commerciële oesterbroed (*Ostrea edulis* en *Crassostrea virginica*) op besmette percelen. (Hancock 1954) - In Noord-Amerika veroorzaakte de Amerikaanse oesterboorder in sommige gebieden 60-70% sterfte in het commerciële oesterbroed (*Crassostrea virginica*) (Alford, 1975)
Japanse oesterboorder
- De Japanse oesterboorder hinderde de herintroductie van de inheemse Olympia oester (*Ostreola conchaphila*) in British Columbia en Washington (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004) - De Japanse oesterboorder veroorzaakte 25% sterfte in lokale oesterbestanden (*Crassostrea virginica, Crassostrea gigas en Ostreola conchaphila)* (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-database 2007, Elston 1997). - In Puget Sound, USA, verorberde de Japanse oesterboorder 1 mossel (*Mytilus edulis*) per dag, bijna twee keer zoveel als de inheemse boorder *Nucella Lamellosa* (Williams & McDonald 2008).
Geaderde stekelhoorn
- De geaderde stekelhoorn wordt verantwoordelijk gehouden voor de afname in de mossel *Mytilus galloprovincialis* in de Zwarte zee (Rubinshtein & Hiznjak, 1988 in ICES, 2004). - Ciuhcin (1984) in ICES (2004) schrijft de bijna gehele verdwijning van de inheemse oester *Ostrea edulis* en mossel *M. galloprovincialis* in Gudauta, Zwarte Zee toe aan predatie door de geaderde stekelhoorn. - In de Noord Adratische Zee verorbert de geaderde stekelhoorn 5±4 mossels (*Mytilus galloprovincialis*) in 44 dagen (Savini & Occipinti-Ambrogi 2006).

Er zijn geen redenen, abiotisch noch ecologisch, om aan te nemen dat deze invasive roofslakken in de Waddenzee een ander effect zullen hebben. Ze kunnen de in het Natura2000-gebied Waddenzee voorkomende mosselpercelen en wilde mossel- en oesterbanken aantasten.

Hoewel er geen directe effecten worden verwacht van introductie van de Japanse oesterboorder op abiotische factoren, zijn indirecte, lokale effecten op de bodemsamenstelling en waterkwaliteit niet uit te sluiten. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en de effecten van de roofslakken op wilde inheemse populaties en is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze lokale indirecte effecten.

9.1.1.2 Overige kenmerken van een goede structuur en functie

Dit onderdeel geeft een beschrijving van typerende abiotische en biotische structuren en functies. Het habitattype heeft een goede kwaliteit als het in belangrijke mate voldoet aan deze kenmerken.

Overige kenmerken van een goede structuur en functie
De hydromorfologische dynamiek die binnen H1110 aanwezig is wordt bepaald door een groot aantal factoren. Een belangrijke factor zijn de getijdenstromen, die fluctueren in richting en snelheid gedurende een getij maar ook tussen dood- en springtij. Daarnaast is er de golfwerking waarvan de intensiteit samenhangt met bijvoorbeeld de kracht van de wind [….] [….] Dit heeft zijn effect op de samenstelling van de aanwezige levensgemeenschappen [….] [….] Een goed functionerend habitattype H1110 is te herkennen aan de samenstelling en leeftijdsopbouw van de aanwezige levensgemeenschap [….] Het kustgebied is een productief systeem gebaseerd op vorming van

organische stof door (ééncellige) algen (fytoplankton) die óf direct als voedsel dienen (via zoöplankton, bodemdieren en vissen) of waarvan de afbraakproducten dienen als voedsel.
Specifiek in relatie tot subtype H1110 A
Zachte structuren, zoals de velden van Groot Zeegras, vormden in het verleden een kenmerkend onderdeel van subtype H1110_A (zie hiervoor). Plaatselijk voorkomende harde structuren - zoals mosselbanken, mosselpercelen, schelpenbanken, stenen en grind – zijn onderdeel van dit subtype [….] [….] Biogene structuren in de vorm van mosselbanken in diverse stadia van ontwikkeling zijn een kenmerkend onderdeel van dit subtype [….]

Naar alle waarschijnlijkheid zal de introductie van de invasive roofslakken geen direct effect hebben op de hydromorfologische dynamiek. Omdat de roofslakken prederen op schelpdieren en in andere gekoloniseerde gebieden negatieve effecten hebben op inheemse soorten (tabel 1 en 2), kunnen de roofslakken wel een impact hebben op de samenstelling van de leefgemeenschap. Niet alleen door directe effecten als predatie, maar ook door indirecte effecten als competitie met inheemse predatoren en effecten op met structuurvormende schelpdieren geassocieerde soorten. Effecten op mosselbanken en oesterkweek en mosselpercelen zijn bekend uit andere gekoloniseerde gebieden (tabel 1 en 2). Doordat de invasive roofslakken een voorkeur hebben voor juvenile oesters (*Crassostrea gigas*) (Buhle et al, 2004; Cohen 2005, Alford 1975) kan de introductie van deze roofslak ook een effect hebben op de leeftijdopbouw van de aanwezige Japanse oesterlevensgemeenschap.

Aan de hand van de informatie over het dieet van de roofslakken en de gevolgen in andere gebieden waar de soorten zijn geïntroduceerd, kan niet worden uitgesloten dat de introductie van één of meerdere invasive roofslaksoorten een negatief effect kan hebben op de samenstelling van de aanwezige leefgemeenschap, de leeftijdsopbouw van Japanse oesters en het voorkomen van harde structuren zoals mosselbanken en oesterriffen. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en de effecten van de roofslakken op de kenmerken van een goede structuur en functie is echter niet voldoende om een inschatting te kunnen maken van de grootte van dit effect.

9.1.1.3 Huidige situatie structuur en functie H1110

9.1.1.3.1 Huidige situatie structuur en functie H1110
In structuur en functie van het systeem van subtype 1110_A is opvallend dat, mogelijk door afnemend nutriëntenniveau en/of veranderd lichtklimaat, de totale biomassa (productie) van vis sterk is verminderd. Mosselbanken in diverse stadia van ontwikkeling zijn kenmerkend voor subtype A en hebben binnen het subtype belangrijke ecologische functies. De mosselbanken van de oudere stadia komen relatief het minste voor. In geulen in het oostelijk deel van de Waddenzee (Eems en Zoutkamperlaag) als ook nabij de Afsluitdijk en in het Molenrak, komen nog enkele oude banken voor. Dat oudere stadia nu minder voorkomen dan in de referentieperiode kan niet met zekerheid worden gezegd, maar een zekere toename op termijn van het aandeel van oude mosselbanken lijkt gezien hun ecologische waarde aangewezen.

Van de drie roofslakken is bekend dat zij mosselen eten (Eno et al 1997; Cohen 2005, Williams & McDonald 2008, Zolotarev 1996). In de Zwarte Zee is de geaderde stekelhoorn verantwoordelijk voor het bijna uitserven van mosselbanken (*Mytillus galloprovincialis*) en oesterriffen (*Crassostrea gigas en Ostrea edulis*) (Zolotarev 1996, Savini & Occhipinti-Ambrogi 2006). De Japanse oesterboorder consumeert in Puget Sound (USA) twee keer zoveel mosselen als de inheemse roofslak (gemiddeld een mossel per dag). In de getijdegebieden van de midden Atlantische regio zijn de zeepok (*Balanus balanoides*) en de mossel (*Mytilus edulis*) de belangrijkste voedselbron van de Amerikaanse oesterboorder (Franz, 1971). Er kan hierdoor niet worden uitgesloten dat introductie van één of meerdere invasive roofslaksoorten in het Natura2000-gebied Waddenzee een negatief effect zal hebben op het voorkomen van mosselbanken. Hierdoor kan de huidige situatie in de structuur en functie worden verslechterd. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en effecten van de roofslakken op het voorkomen van wilde mosselbanken en is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze verslechtering.

9.1.1.4 Typische soorten

Conform de Habitatrichtlijn worden voor alle habitattypen zogenaamde 'typische soorten' geselecteerd, die gezamenlijk een goede kwaliteitsindicator vormen voor de (compleetheid van de) levensgemeenschap van het habitattype. De set van typische soorten is een indicator voor de kwaliteit (en daarmee de staat van instandhouding) van het habitattype op landelijk niveau.

Typische soorten			
H1110-A is intern gestructureerd uit meerdere componenten en de daarmee geassocieerde soorten. De onderstaande lijst van typische soorten bevat dus soorten die typisch zijn voor het zachte substraat van de dynamischer zandbanken van het getijdengebied, van de waterkolom daarboven en soorten die typisch zijn voor harde substraten zoals de mosselbanken.			
Nederlandse naam	Wetenschappelijke naam	Soortgroep	Relevantie
Zeeanjelier	*Metridium senile*	Bloemdieren	indirect
Slibanemoon	*Sagartia troglodytes*	Bloemdieren	indirect
Zandzager	*Nephtys hombergii*	Borstelwormen	n.v.t.
Groene zeeduizendpoot	*Nereis virens*	Borstelwormen	n.v.t.
	Spio martinensis	Borstelwormen	n.v.t.
Gladde zeepok	*Balanus crenatus*	Kreeftachtigen	direct
Strandkrab	*Carcinus maenas*	Kreeftachtigen	indirect
Gewone zwemkrab	*Liocarcinus holsatus*	Kreeftachtigen	indirect
Haring	*Clupea harengus*	Vissen	n.v.t.
Slakdolf	*Liparis liparis*	Vissen	n.v.t.
Zeedonderpad	*Myoxocephalus scorpius*	Vissen	n.v.t.
Spiering	*Osmerus eperlanus*	Vissen	n.v.t.
Botervis	*Pholis gunnellus*	Vissen	n.v.t.
Bot	*Platichthys flesus*	Vissen	n.v.t.
Schol	*Pleuronectes platessa*	Vissen	n.v.t.
Dikkopje	*Pomatoschistus minutus*	Vissen	n.v.t.
Gote zeenaald	*Syngnathus acus*	Vissen	n.v.t.
Kleine zeenaald	*Syngnathus rostellatus*	Vissen	n.v.t.
Puitaal	*Zoarces viviparus*	Vissen	n.v.t.
Gewone zeester	*Asterias rubens*	Stekelhuidigen	indirect
Nonnetje	*Macoma balthica*	Weekdieren	direct
Strandgaper	*Mya arenaria*	Weekdieren	direct
Mossel	*Mytilus edulis*	Weekdieren	direct

De roofslakken eten voornamelijk schelpdieren, zoals jonge oesters, mosselen, maar ook zeepokken en andere slakken (tabel 3).
Uit andere gebieden waar de soorten zijn geïntroduceerd is bekend dat de roofslakken negatieve effecten kunnen hebben op inheemse epibenthische schelpdierpopulaties (zie tabel 2).

Tabel 2 Informatie uit de literatuur met betrekking tot effecten op schelpdiervoorkomens:
Amerikaanse oesterboorder
- In een experimentele opzet, bij temperaturen tussen 15-20 graden Celsius, verorberde een individuele Amerikaanse oesterboorder 0.5-1 mossel (*Mytilus edulis*) per week (Hanks, 1957) - In Groot Brittannië veroorzaakte de Amerikaanse oesterboorder lokaal gemiddeld 50% sterfte in het jaarlijkse commerciële oesterbroed (Ostrea edulis en *Crassostrea virginica*) van besmette percelen (Hancock 1954). - In Noord Amerika veroorzaakte de Amerikaanse oesterboorder in sommige gebieden 60-70% sterfte in het commerciële oesterbroed (*Crassostrea virginica*) (Alford, 1975).
Japanse oesterboorder
- De Japanse oesterboorder hinderde de herintroductie van de inheemse Olympia oester (*Ostreola conchaphila*) in British Columbia en Washington (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004) - De Japanse oesterboorder veroorzaakte 25% sterfte in oesterbestanden van besmette gebieden (*Crassostrea virginica, Crassostrea gigas en Ostreola conchaphila)* (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-database 2007, Elston 1997) - In Puget Sound, USA, verorberde de Japanse oesterboorder 1 mossel (*Mytilus edulis*) per dag, bijna twee keer zoveel als de inheemse boorder *Nucella Lamellosa* (Williams & McDonald 2008). - In Netarts Bay, Oregon, USA hinderde de Japanse oesterboorder het opstarten van het kweken van de venusschelp *Venerupis philippinarum* (Carlton 1992). - In Netarts Bay, Oregon zijn de inheemse *Macoma balthica* en de inheemse kokkel *Clinocardium nuttalli* een belangrijke voedselbron voor de Japanse oesterboorder (Carlton 1979).
Geaderde stekelhoorn
- Predatie door de geaderde stekelhoorn wordt verantwoordelijk gehouden voor de afname in de mossel *Mytilus galloprovincialis* in de Zwarte zee (Rubinshtein & Hiznjak, 1988 in ICES, 2004). - Ciuhcin (1984) in ICES (2004) schrijft de bijna gehele verdwijning van de inheemse oester *Ostrea edulis* en mossel *M. galloprovincialis* in Gudauta, Zwarte Zee () toe aan predatie door de Geaderde stekelhoorn. - In de Noord Adratische Zee verorbert de geaderde stekelhoorn 5±4 mossels (*Mytilus galloprovincialis*) in 44 dagen (Savini & Occipinti-Ambrogi 2006). - De geaderde stekelhoorn wordt in de Zwarte Zee verantwoordelijk gehouden voor de afname (van bijna 50%) van de inheemse eetbare schelpdieren (Zolotarev 1996). - De geaderde stekelhoorn heeft in de Chesapeake Bay, USA effect op schelpdieren als de strandgaper (*Mya arenaria*), Amerikaanse zwaardschede (*Ensis directus*) en de boormossel *Cyrtopleara costata* (Global-Invasive-Species-Database 2006).

Er zijn geen redenen, abiotisch noch ecologisch, om aan te nemen dat deze invasive roofslakken in de Waddenzee een ander effect zullen hebben dan die hierboven beschreven. Ze kunnen de in het Natura2000-gebied Waddenzee voorkomende mosselpercelen en wilde mossel- en oesterbanken aantasten. Hierdoor kunnen de roofslakken ook een negatief indirect effect hebben op soorten die zich hechten aan biotische structuren, zoals bloemdieren.

Vooral de geaderde stekelhoorn predeert naast op de bodemlevende schelpdieren als mossel en oester, ook op schelpdiersoorten die zich in de bodem ingraven, zoals de strandgaper (*Mya arenaria*) en de Amerikaanse zwaardschede (*Ensis directus*) (Global-Invasive-Species-Database, 2006 #127). Hiermee kunnen de roofslakken ook een potentieel gevaar vormen voor populaties van ingegraven schelpdiersoorten.

Door concurrentie met inheemse soorten die schelpdieren eten kan de introductie van de roofslakken ook een negatief indirect effect hebben op typische soorten, zoals krabben en zeesterren.

Aan de hand van de informatie over het dieet van de roofslak en de gevolgen in andere gebieden waar de soort is geïntroduceerd kan niet worden uitgesloten dat, bij introductie van een of meerder roofslakken in het Ntura2000-

gebied Waddenzee, de omstandigheden voor enkele typische soorten zodanig negatief worden beïnvloed dat er sprake kan zijn van een (sterke) achteruitgang van deze soorten. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en effecten van de roofslakken op typische soorten is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze achteruitgang.

9.1.1.5 Huidige situatie typische soorten habitattype 1110

Huidige situatie typische soorten habitattype 1110
Voor een gunstige staat van instandhouding is het wenselijk dat de geselecteerde typische soorten van het habitattype op landelijk niveau op (middel)lange termijn stabiele populaties hebben, gerelateerd aan het oppervlak van het habitattype. Voor de typische soorten bepalen de trend en het huidig voorkomen samen of een typische soort op de (middel)lange termijn stabiel is of zal uitsterven (dat is het criterium voor de beoordeling). Of een soort een reëel risico loopt op uitsterven, kan worden bepaald aan de hand van de Rode Lijst(en) of door de actuele populatieomvang te vergelijken met het minimum voor een stabiele populatie (FRV). Er wordt uitgegaan van de stelregel dat een habitattype zeer ongunstig (rood) scoort als minimaal 25% van de typische soorten ernstig bedreigd (of reeds verdwenen) is. Een habitattype scoort matig ongunstig (oranje) als minimaal één typische soort zeer zeldzaam is. In alle andere gevallen scoort het habitattype gunstig (groen). Het aantal typische soorten in subtype 1110_A is sinds de referentieperiode niet afgenomen maar stabiel gebleven. Dit geldt zowel voor soorten van het open water als bodembewoners. Wel is de abundantie van de soorten veranderd, zoals die van de puitaal en het nonnetje (een belangrijke voedselsoort voor jonge vis). Daardoor zijn/gaan mogelijk verschuivingen in verhoudingen tussen functionele groepen op(ge)treden. Het merendeel van de typische soorten voor subtype H1110_A komt vrij algemeen tot zeer algemeen voor. De beoordeling van de staat van instandhouding is om die reden dus gunstig.

Het is mogelijk dat introductie van één of meerdere invasive roofslakkensoorten een negatief effect zal hebben op de mossel- en oesterpopulatie in het gebied. In andere gebieden in de wereld waar de roofslakken zijn geïntroduceerd en zich invasief hebben ontwikkeld hadden ze een significant effect op inheemse epibenthische schelpdierpopulaties en/of commerciële oesterkweek en mosselpercelen (zie tabel 1 en 2). Er zijn geen abiotische of ecologische kenmerken van de Waddenzee, waarom deze roofslakken in dit gebied niet dezelfde effecten zullen kunnen hebben. Door de mogelijk grote impact op mosselen en oesters kunnen ook indirecte effecten ontstaan op soorten die zich hechten aan deze soorten, zoals bloemdieren, of op soorten die ook op mosselen of oesters prederen, zoals krabben en zeesterren. Naast schelpdieren die op de bodem leven, kunnen de roofslakken ook een negatief effect hebben op soorten die ingegraven in de bodem leven (tabel 1 en 2). Vooral van de geaderde stekelhoorn is bekend dat de soort een negatief effect heeft op populaties van de strandgaper (*Mya arenaria*) en de Amerikaanse zwaardschede (*Ensis directus*) (Global-Invasive-Species-Databse 2006). Beide schelpdiersoorten komen ook in de Waddenzee voor.

Door deze mogelijke directe en indirecte effecten van introductie van één of meerdere invasive roofslakken in het Natura 2000-gebied Waddenzee op deze typische soorten van habitattype 1110 kan niet worden uitgesloten dat er een verslechtering optreedt van de huidige situatie. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en de effecten van de roofslakken op de huidige situatie van de typische soorten is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze mogelijke verslechtering.

9.1.1.6 Mogelijke impact op doelstelling H1110 en kernwaarde 1.03

De introductie van één of meerdere invasive roofslakkensoorten in habitattype 1110 van het Natura2000-gebied Waddenzee kan een indirect en lokaal negatief effect hebben op de abiotische randvoorwaarden, een direct of indirect negatief effect op enkele typische soorten en een direct negatief effect op enkele kenmerken van een goede structuur en functie. Dit houdt in dat niet kan worden uitgesloten dat de kwaliteit van habitatype 1110 ingeval van introductie van één of meerdere invasive roofslaksoorten negatief wordt beïnvloed. Daarnaast zal de introductie de ontwikkelingskansen van wilde mosselbanken niet verbeteren. Hiermee zou een deel van de doelstelling voor dit Natura2000-gebied (verbetering van kwaliteit) en de bijbehorende kernwaarde (1.03

Overstroomde zandbanken en biogene structuren) in ernstig in gevaar kunnen komen. De huidige kennis met betrekking tot effecten van de roofslakken op de typische soorten en de mate van kolonisatie in de Waddenzee is echter niet voldoende om een inschatting te kunnen maken van de grootte van dit gevaar.

Mogelijke impact op de kwaliteit van H1140

9.1.1.7 Abiotische randvoorwaarden

Abiotische randvoorwaarden
Het habitattype H1140 'Slik- en zandplaten' komt voor in kustgebieden. De voortdurende afwisseling van eb en vloed is een belangrijke sturende factor in dit habitat. De hiermee samenhangende sturende factoren als afwisseling van afslijting (erosie) en afzetting (sedimentatie) van bodemmateriaal, fluctuaties in zoet - zout, hydrodynamiek (en daarmee samenhangend larventransport), dynamiek in temperatuur (zomer – winter) en helderheid van het water, getijamplitude en overstromingsduur, slibgehalte, stroming, golfwerking en wind zijn bepalend voor de biodiversiteit van H1140. Voor veel typische soorten is de duur en frequentie van het droogvallen van de zandplaten van belang, evenals de bodemsamenstelling, het gehalte aan voedingsstoffen en de waterkwaliteit. De platen die 25 tot 60 % van de tijd droogvallen, zijn het rijkst aan bodemleven. In de rustige delen en in de omgeving van grote concentraties bodemdieren bezinkt fijn slib en organisch materiaal. De daar optredende zuurstofloze condities zijn belangrijk bij de afbraak van organisch materiaal en de daarop volgende levering van nutriënten voor de lokale primaire productie. Het habitattype vereist een goede waterkwaliteit. Slecht afbreekbare stoffen, die zich dikwijls hechten aan fijn slib en organisch materiaal, hebben risico's door de opeenhoping in de voedselketen. In het verleden hebben bestrijdingsmiddelen (zoals drins), polychloorbifenylen (PCB's) en antiaangroeimiddelen als tributyltin (TBT) negatieve effecten gehad. De laatste jaren zijn de concentraties van deze stoffen in de bodem en in dieren afgenomen. Het water is matig voedselrijk tot voedselrijk. Het water is van nature troebel in de slikkige delen en relatief helder in de geulen (onderdeel van H1110) en boven zandige platen. Van het voedsel voor benthos wordt ongeveer de helft geïmporteerd uit de Noordzeekustzone en bestaat de andere helft uit lokale primaire productie, waarvan driekwart uit het pelagiaal en een kwart door diatomeeën op de droogvallende platen. Subtype H1140_A is zeer gevoelig voor chronische verstoring van de bodem. Voor soorten of ecotopen (bijvoorbeeld zeegrasvegetaties en mosselbanken) is sprake van chronische aantasting als er een onbalans is in frequentie van verstoring (bijvoorbeeld 1 maal per jaar) en de benodigde herstelperiode (bijvoorbeeld 2-3 jaar). In dat geval kan permanente afname van kwaliteit van het habitattype (zowel structuur en functie als typische soorten) optreden. Herstel treedt pas op na de volgende succesvolle broedval of zaadzetting en hervestiging. De broedval kan sterk variëren tussen jaren. Kokkels en Strandgapers (Mya sp.) hebben gemiddeld eens in de 5-7 jaar een goede broedval, mosselen om de 3 tot 4 jaar. Bij de meeste wormen is de broedval elk jaar redelijk tot goed. […]

Het is niet waarschijnlijk dat de invasive roofslakken een direct effect hebben op de dynamiek, waterkwaliteit, bodemsamenstelling of het gehalte aan voedingsstoffen. De soorten kunnen voorkomen op gravel, modder, zand en schelpenbodems en hebben een sterke voorkeur voor oesterriffen (Buhle et al, 2004). Het dieet van de invasive roofslakken bestaat uit benthische schelpdieren, vooral soorten die op de bodem leven, zoals oesters en mosselen (Eno et al 1997, Williams & McDonald 2008, Global-Invasive_Species_Database 2006). In andere gebieden waar de soorten zijn geïntroduceerd hadden zij grote effecten op (wilde) mossel- en/of oestervoorkomens (Cohen 2005, Buhle & Ruesink 2009, Zolotarev 1996) (tabel 3). Mosselen en oesters zijn biobouwers. Zij vormen driedemensionale structuren op de wadbodem, die hoog boven de omgeving kunnen uitsteken. Hierdoor kunnen, bijvoorbeeld, vogels bij vloed langer gebruik maken van de droogvallende platen om naar voedsel te zoeken. Wanneer de druk van de invasive roofslakken zo hoog word dat lokaal mossel- en oesterbanken verdwijnen zouden veranderingen op kunnen optreden in waterkwaliteit en bodemsamenstelling. Hierdoor kunnen wel degelijk lokale indirecte effecten optreden.

Hoewel het niet aannemelijk is dat introductie van de invasive roofslakken een direct effect zal hebben op de abiotische randvoorwaarden in het Natura2000-gebied Waddenzee, zijn lokale indirecte effecten niet uit te sluiten. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en effecten van de roofslakken op mosselbanken en oesterriffen is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze lokale indirecte effecten.

9.1.1.8 Overige kenmerken van een goede structuur en functie

Dit onderdeel geeft een beschrijving van typerende abiotische en biotische structuren en functies. Het habitattype heeft een goede kwaliteit als het in belangrijke mate voldoet aan deze kenmerken.

Overige kenmerken van een goede structuur en functie
[…] Gezonde droogvallende gebieden zijn herkenbaar aan de bodemfauna die past bij de lokale hydrografische en morfologische omstandigheden. […]Wat betreft de bodemfauna wordt hierbij aangetekend dat de totaalbiomassa van het soortenspectrum van de bodemdieren relatief stabiel kan zijn, maar dat de jaarlijkse fluctuaties van de afzonderlijke soorten van nature zeer groot kunnen zijn. Wanneer er geen duidelijke ingrepen plaatsvinden (of recentelijk hebben plaatsgevonden) die meetbare effecten hebben op populaties van de typische soorten of kenmerkende onderdelen en wanneer de milieukwaliteit voldoende is, functioneert dit habitat in principe naar behoren. De verschillende structurerende elementen van de getijdenplaten (zoals mosselbanken, velden van schelpkokerworm en zeegrasvelden) worden als kenmerkende onderdelen, en dus kwaliteitskenmerk, van de structuur en functie van het habitattype beschouwd. Dit stemt overeen met de werkwijze bij habitattypen H1110, H1130 en H1160. […]Bij laagwater foerageren vogels op een veelheid van bodemdieren. Sommige zoals Zilverplevier, Rosse Grutto, Kluut, Tureluur en Bonte strandloper zijn gespecialiseerd op wormen, andere op schelpdieren. Wormen komen voor op platen met verschillende sedimenttypen, maar ook binnen structuurrijke ecotopen zoals banken van mosselen of Japanse oesters. Binnen de op schelpdieren gespecialiseerde vogels is weer een onderscheid tussen soorten die op verschillende formaten foerageren. Zilvermeeuwen eten mosselbroed, Eiders en Scholeksters grote mosselen of kokkels en de Kanoetstrandloper heeft een voorkeur voor nonnetjes, maar eet ook kleine kokkels en kleine mosselen. […] […] De levensgemeenschappen omvatten zowel ingegraven als aan het oppervlak levende bodemdieren, zeegrasvelden en mosselbanken. Bodemdieren vormen een belangrijke schakel tussen de ecosystemen van het open water en de bodemzone daaronder. Bodemdieren filteren slib en organisch materiaal uit het water en leggen dat vast. Ze verrijken daarmee de wadplaten. Sommige van deze organismen komen in grote aantallen voor en de biomassa's zijn dan groot. Soms vormen ze zelfs biogene structuren (zoals mosselbanken) die in diverse stadia van ontwikkeling voorkomen. Zulke specifieke structuren zijn weer leefgebieden voor verschillende andere soorten die karakteristiek zijn voor de wadplaten. Herkenbare structuren worden ook gevormd door velden van schelpkokerworm (Lanice sp.) maar ook kokkelbanken. Dikwijls omdat daarop goed zichtbare macroalgen groeien die soms ook weer fungeren als aanhechting van mosselbroed. De belangrijkste (qua biomassa, structuur en ecologisch belang) structuurvormende elementen zijn de mosselbanken in diverse stadia van ontwikkeling. Mosselbroedval treedt onregelmatig op en in de eerste winter verdwijnt gemiddeld bijna de helft van de jonge banken. Daarna is de achteruitgang minder en in ongestoorde situaties resulteert dit in het voorkomen van mosselbanken van zeer verschillende leeftijden en verschillende stadia van ontwikkeling en afbraak, elk met specifieke eigenschappen en waarde voor biodiversiteit. De waarde van deze mosselbanken is dat zij een habitat

bieden voor de geassocieerde levensgemeenschappen, een voedselbron vormen voor garnalen, krabben en steltlopers (hetzij de mossel zelf, hetzij de geassocieerde soorten) en een functie hebben in de nutriëntencyclus van het ecosysteem (waterfiltering en verrijking van de bodem met hoog organisch slib). Deze range aan mosselbanken van verschillende leeftijden moet dan ook gezien worden als een belangrijk kwaliteitskenmerk. In de referentieperiode 1960-1990 kwam gemiddeld meer dan 4.000 ha mosselbanken voor.

Van de drie roofslakken is bekend dat zij in andere gebieden waar zij zijn geïntroduceerd een negatief effect hebben op de inheemse schelpdiersoorten (tabel 1, 2 en 3). Niet alleen door predatie, maar ook indirect door competitie met inheemse predatoren of door het veranderen van het leefgebied (structuurvormende schelpdieren) kunnen negatieve effecten ontstaan. Effecten op mosselbanken en oesterkweek en mosselpercelen zijn bekend uit andere gekoloniseerde gebieden (tabel 1). Doordat de invasive roofslakken een voorkeur hebben voor juvenile schelpdieren (Buhle et al, 2004; Cohen 2005, Alford 1975), kan de introductie van deze roofslak ook een effect hebben op de leeftijdopbouw schelpdiersoorten. Er zijn geen redenen om aan te nemen dat de invasive roofslakken in de Waddenzee andere effecten zullen hebben dan in andere gebieden waar de soorten zijn geïntroduceerd.

Aan de hand van de informatie over het dieet van de roofslakken en de gevolgen in andere gebieden waar de soorten zijn geïntroduceerd, kan niet worden uitgesloten dat de introductie van één of meerdere invasive roofslaksoorten een negatief effect heeft op de samenstelling van de aanwezige bodemdieren, de leeftijdsopbouw van schelpdieren of het voorkomen van harde structuren zoals mosselbanken en oesterriffen. Wanneer hierdoor meetbare effecten optreden in de populaties van typische soorten of kenmerkende onderdelen van het habitat, zoals het voorkomen van mosselbanken, dan wordt de structuur en functie van het gebied aangetast. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en effecten van de roofslakken op de (typische) soorten en is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze aantasting.

9.1.1.9 Huidige situatie structuur en functie

Huidige situatie structuur en functie
In het Waddengebied is de sedimentsamenstelling van subtype A lokaal veranderd, waarbij het slibgehalte in de platen is afgenomen. Mogelijk is dit een gevolg van (tijdelijke) afname van het bestand aan filtrerende organismen (kokkel, mossel), zandsuppleties langs de Noordzeestranden, klimaateffecten (stormen) en bodemberoering. Biogene structuren zoals mosselbanken zijn nog niet hersteld van de afname in de jaren '80 van de vorige eeuw. De daarmee samenhangende soorten van hard substraat zijn daarmee ook nog niet in en gunstige staat. Zeegrasvelden vertonen zeer langzaam herstel, maar de oppervlakken zijn nog veel minder dan in de referentieperiode en in vergelijkbare gebieden in de Duitse Wadden die wat dit betreft als referentie aangehouden zouden kunnen worden.

De drie invasive roofslakken eten voornamelijk schelpdieren (Cohen 2005, Buhle & Ruesink 2009, Global-Invasive_Species_Database) (tabel 3). Introductie in het Natura2000-gebied Waddenzee zou kunnen resulteren in een lokale afname van het bestand aan filtrerende organismen (o.a. mossel), waarbij lokaal effecten in het slibgehalte kunnen optreden. Ook kunnen locale effecten op biogene structuren optreden (tabel 3). Hiermee kan niet worden uitgesloten dat introductie van één of meerdere invasive roofslakken in het Natura2000-gebied Waddenzee een verslechterend effect zou kunnen hebben op de huidige situatie van structuur en functie.

9.1.1.10 Typische soorten

Conform de Habitatrichtlijn worden voor alle habitattypen zogenaamde 'typische soorten' geselecteerd, die gezamenlijk een goede kwaliteitsindicator vormen voor de (compleetheid van de) levensgemeenschap van het habitattype. De set van typische soorten is een indicator voor de kwaliteit (en daarmee de staat van instandhouding) van het habitattype op landelijk niveau.

Typische soorten			
H1140_A is intern gestructureerd uit meerdere componenten en de daarmee geassocieerde soorten. De onderstaande lijst van typische soorten bevat dus soorten typisch voor het zachte substraat van de slik- en zandbanken van het getijdengebied, van de (bij vloed aanwezige) waterkolom daarboven en soorten die typisch zijn voor harde substraten zoals de mosselbanken.			
Nederlandse naam	Wetenschappelijke naam	Soortgroep	Relevantie
Schelpkokerworm	*Lanice conchilega*	Borstelwormen	n.v.t.
Wadpier	*Arenicola marina*	Borstelwormen	n.v.t.
Zager	*Nereis virens*	Borstelwormen	n.v.t.
Zandzager	*Nephtys hombergii*	Borstelwormen	n.v.t.
Zeeduizendpoot	*Nereis diversicolor*	Borstelwormen	n.v.t.
Gewone strandkrab	*Carcinus maenas*	Kreeftachtigen	indirect
Garnaal	*Crangon crangon*	Kreeftachtigen	n.v.t.
Groot zeegras	*Zostera marina*	Vaatplanten	n.v.t
Klein zeegras	*Zostera noltii*	Vaatplanten	n.v.t.
Kokkel	*Cerastoderma edule*	Weekdieren	direct
Mossel	*Mytilus edulis*	Weekdieren	direct
Nonnetje	*Macoma balthica*	Weekdieren	direct
Platte slijkgaper	*Scrobicularia plana*	Weekdieren	direct
Strandgaper	*Mya arenaria*	Weekdieren	direct
Wulk	*Buccinium undatum*	Weekdieren	indirect/direct
Schol	*Pleronectes platessa*	Vissen	n.v.t.
Bot	*Platichtys flesus*	Vissen	n.v.t.
Diklipharder	*Mugil labrosus*	Vissen	n.v.t

De invasive roofslakken eten voornamelijk jonge op de bodem levende schelpdieren, zoals mossel en oester (Cohen 2005, Buhle & Ruesink 2009, Global-Invasive_Species_Database) (tabel 3). Vooral van de geaderde stekelhoorn is bekend dat deze ook inheemse ingegraven schelpdieren eet (Global-Invasive_Species_Databse 2006). In Netarts Bay, Oregon zijn de inheemse *Macoma balthica* en de inheemse kokkel *Clinocardium nuttalli* een belangrijke voedselbron voor de Japanse oesterboorder (Carlton 1979) (tabel 3). Ingegraven soorten als kokkel, nonnetje en strandgaper kunnen bij een introductie van de roofslakken in de Waddenzee daarom ook negatief beïnvloed worden.

De uitheemse roofslakken kunnen concurreren om voedsel met inheemse roofslakken (tabel 3). In Tomales Bay concurreert de uitheemse Amerikaanse oesterboorder met de inheemse oesterboorder *Acanthinucella spirata* om voedsel (Travis, Global-Invasive-Species-Database). Uit anecdotische informatie uit Willapa Bay blijkt dat de Japanse oesterboorder mogelijk de inheemse slak *Nucella lamellosa* heeft vervangen (Williams & McDonald 2008). Daarom kan de introductie van de invasive roofslakken in het Natura2000-gebied Waddenzee ook indirect effect hebben op typische soorten die ook op schelpdieren prederen, zoals de strandkrab en de wulk.

Tabel 3 Informatie uit de literatuur met betrekking tot effecten op weekdieren en kreeftachtigen:
Amerikaanse oesterboorder
- In een experimentele opzet, bij temperaturen tussen 15-20 graden Celsius, verorberde een individuele Amerikaanse oesterboorder 0.5-1 mossel (*Mytilus edulis*) per week (Hanks, 1957) - In Groot Brittannië veroorzaakte de Amerikaanse oesterboorder lokaal gemiddeld 50% sterfte in het jaarlijkse commerciële oesterbroed (Ostrea edulis en *Crassostrea virginica*) van besmette percelen (Hancock 1954) - In Noord Amerika veroorzaakte de Amerikaanse oesterboorder in sommige gebieden 60-70% sterfte in het commerciële oesterbroed (*Crassostrea virginica*) van besmette percelen (Alford, 1975) - In de getijdegebieden van de midden Atlantische region zijn de zeepok (*Balanus balanoides*) en de mossel (*Mytilus edulis*) de belangrijkste voedselbron van de Amerikaanse oesterboorder (Franz, 1971) - In Tomales Bay concurreert de uitheemse Amerikaanse oesterboorder met de inheemse oesterboorder *Acanthinucella spirata* om voedsel (Travis, Global-Invasive-Species-Database). - Uit anekdotische informatie uit Willapa Bay blijkt dat de Japanse oesterboorder mogelijk de inheemse slak *Nucella lamellosa* heeft vervangen (Williams & McDonald 2008).
Japanse oesterboorder
- De Japanse oesterboorder hinderde de herintroductie van de inheemse Olympia oester (*Ostreola conchaphila*) in British Columbia en Washington (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004) - De Japanse oesterboorder veroorzaakte 25% sterfte in oesterbestanden (*Crassostrea virginica, Crassostrea gigas en Ostreola conchaphila)* op besmette percelen (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-database 2007, Elston 1997) - In Puget Sound, USA, verorberde de Japanse oesterboorder 1 mossel (*Mytilus edulis*) per dag, bijna twee keer zoveel als de inheemse boorder *Nucella Lamellosa* (Williams & McDonald 2008). - In Netarts Bay, Oregon, USA hinderde de Japanse oesterboorder het opstarten van het kweken van de venusschelp *Venerupis philippinarum* (Carlton 1992). - In Netarts Bay, Oregon zijn de inheemse *Macoma balthica* en de inheemse kokkel *Clinocardium nuttalli* een belangrijke voedselbron voor de Japanse oesterboorder (Carlton 1979)
Geaderde stekelhoorn
- Predatie door de geaderde stekelhoorn wordt verantwoordelijk gehouden voor de afname in de mossel *Mytilus galloprovincialis* in de Zwarte zee (Rubinshtein & Hiznjak, 1988 in ICES, 2004). - Ciuhcin (1984) in ICES (2004) schrijft de bijna gehele verdwijning van de inheemse oester *Ostrea edulis* en mossel *M. galloprovincialis* in Gudauta, Zwarte Zee () toe aan predatie door de Geaderde stekelhoorn. - In de Noord Adratische Zee verorbert de geaderde stekelhoorn 5±4 mossels (*Mytilus galloprovincialis*) in 44 dagen (Savini & Occipinti-Ambrogi 2006). - De Geaderde stekelhoorn wordt in de Zwarte Zee verantwoordelijk gehouden voor de afname (van bijna 50%) van de inheemse eetbare schelpdieren (Zolotarev 1996). - De geaderde stekelhoorn heeft in de Chesapeake Bay, USA effect op schelpdieren als de strandgaper (*Mya arenaria*), Amerikaanse zwaardschede (*Ensis directus*) en de boormossel *Cyrtopleara costata* (Global-Invasive-Species-Database 2006). - In Chesapeake Bay heeft de geaderde stekelhoorn in negatief effect op de inheemse boorder *Urosalphinx cinerea* (Global-Invasive-Species-Databse 2006)

Er zijn geen redenen, abiotisch noch ecologisch, om aan te nemen dat deze invasive roofslakken in de Waddenzee niet eenzelfde effect zullen kunnen hebben.

Aan de hand van de informatie over het dieet van de roofslakken en de gevolgen in andere gebieden waar de soorten zijn geïntroduceerd kan niet worden uitgesloten dat, bij introductie van een of meerdere van deze invasive roofslakken in het Natura2000-gebied Waddenzee, de omstandigheden voor enkele typische soorten zodanig negatief zullen worden beïnvloed dat er sprake kan zijn van een sterke achteruitgang van deze soorten. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en de effecten van de roofslakken op de typische soorten en is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze achteruitgang.

9.1.1.11 Huidige situatie typische soorten

Voor een gunstige staat van instandhouding is het wenselijk dat de geselecteerde typische soorten van het habitattype op landelijk niveau op (middel)lange termijn stabiele populaties hebben gerelateerd aan het oppervlak van het habitattype. Voor de typische soorten bepalen de trend en het huidig voorkomen samen of een typische soort op de (middel)lange termijn stabiel is of zal uitsterven (dat is het criterium voor de beoordeling). Of een soort een reëel risico loopt op uitsterven, kan worden bepaald aan de hand van de Rode Lijst(en) of door de actuele populatieomvang te vergelijken met het minimum voor een stabiele populatie (FRV). Er wordt uitgegaan van de stelregel dat een habitattype zeer ongunstig (rood) scoort als minimaal 25% van de typische soorten ernstig bedreigd (of reeds verdwenen) is. Een habitattype scoort matig ongunstig (oranje) als minimaal één typische soort zeer zeldzaam is. In alle andere gevallen scoort het habitattype gunstig (groen).

Huidige situatie typische soorten
Het aantal typische soorten is sinds de referentie periode niet afgenomen maar stabiel gebleven. Het merendeel van de typische soorten voor subtype A komt vrij algemeen tot zeer algemeen voor, maar de abundantie van de soorten is wel veranderd, zoals die van de platvissen en het nonnetje (een belangrijke voedselsoort voor jonge vis). Daardoor zijn/gaan mogelijk verschuivingen in verhoudingen tussen functionele groepen op(ge)treden (bijv. een toename van wormenetende vogels en een afname van schelpdieretende vogels). Mosselen vormen weer redelijk uitgestrekte banken in de oostelijke Waddenzee, maar in de Westelijke Waddenzee komen mosselbanken nauwelijks meer voor. De wulk is nu nagenoeg uitgestorven in de Nederlandse Waddenzee, maar hij lijkt weer bezig te zijn aan een opmars. In de Noord-Duitse Waddenzee komt de soort eierleggend voor op droogvallende mosselbanken. De soort is een heel geschikte indicator zowel voor verstoring als voor verontreiniging.

Van de drie roofslakken is bekend dat zij weekdieren eten (Eno et al 1997; Cohen 2005, Williams & McDonald 2008, Zolotarev 1996) (tabel 3), waardoor het voorkomen van schelpdieren beïnvloed kan worden. Daarnaast kunnen de uitheemse invasive roofslakken concurreren om voedsel met inheemse roofslakken (tabel 3). Introductie van de invasive roofslakken zou dus ook een negatief effect kunnen hebben op de opmars van de wulk.

Hierdoor kan niet uitgesloten worden dat introductie van één of meerdere van de invasive roofslakken een negatieve impact kan hebben op de huidige situatie van de typische soorten in het Natura2000-gebied Waddenzee. Wanneer de roofslakken een verslechtering veroorzaken van de huidige situatie kan niet worden uitgesloten dat de staat van instandhouding wordt aangetast. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en effecten van de roofslakken op de typische soorten en is echter niet voldoende om een inschatting te kunnen maken van de grootte van deze verslechtering.

9.1.1.12 Mogelijke impact op doelstellingen H1140 en kernwaarde 1.10

De introductie van één of meerdere invasive roofslakkensoorten in habitattype 1140 van het Natura2000-gebied Waddenzee kan een indirect en lokaal negatief effect hebben op de abiotische randvoorwaarden, een direct of indirect negatief effect op enkele typische soorten en een direct negatief effect op enkele kenmerken van een goede structuur en functie. Dit houdt in dat niet kan worden uitgesloten dat de kwaliteit van habitattype 1140 van het Natura2000-gebied Waddenzee en de bijbehorende kernwaarde (1.10 Diversiteit getijdenplaten) ingeval van introductie van één of meerdere invasive roofslaksoorten negatief wordt beïnvloed. Hiermee zou een deel van de doelstelling voor dit Natura2000-gebied (verbetering van kwaliteit) in gevaar kunnen komen. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en de (indirecte) effecten van de roofslakken op de abiotische randvoorwaarden, kenmerken van een goede structuur en functie en typische soorten, is echter niet voldoende om een inschatting te kunnen maken van de grootte van dit gevaar.

9.1.1.13 Mogelijke impact op algemene doelstellingen

De roofslakken prederen allen voornamelijk op epibenthische schelpdieren, zoals mosselen en oesters (tabel 3). Zij kunnen een groot effect hebben op de populaties van deze schelpdieren, zowel op de percelen als op de wilde banken (tabel 1, 2 en 3). Vooral de geaderde stekelhoorn eet ook ingegraven schelpdiersoorten. In andere gebieden waar deze soort is geïntroduceerd heeft deze een impact op populaties van de strandgaper (*Mya arenaria*) en de Amerikaanse zwaardschede (*Ensis directus*) (Global-Invasive_Species_Database, 2006 #127). Beide schelpdiersoorten leven ingegraven in het sediment. Daarnaast kan competitie met inheemse slakken als de purperslak en de wulk een negatief effect hebben op populaties van deze soorten in het Natura2000-gebied Waddenzee (Kerckhof et al, 2006; Faasse & Lighthart, 2007).
Van de drie roofslakken is bekend dat zij in andere gebieden waar zij zijn geïntroduceerd een effect hebben op de inheemse soorten. In sommige gevallen wordt gesproken over een effect waarbij schelpdierpopulaties ten gronde werden gericht en lokale omgeving significant werd aangetast door de introductie van de roofslakken (Global-Invasive_Species_Database; Calton, 1979; Williams & McDonald, 2008; Zolotarev, 1996; Harding, 2003). Er zijn geen indicaties, abiotisch noch ecologisch, waarom deze effecten niet ook zouden kunnen optreden bij introductie van de roofslakken in het Natura2000-gebied Waddenzee.

Aangezien de drie roofslakken zich naar alle waarschijnlijkheid kunnen handhaven en uitbreiden in (delen van) het Natura2000-gebied Waddenzee (zie rapport, hoofdstuk 5.2), ze grootschalige negatieve effecten kunnen hebben op inheemse schelpdiersoorten en kunnen concurreren met locale roofslakken zijn negatieve effecten op de biologische diversiteit en aan de gunstige staat van instandhouding van natuurlijke habitats en soorten waarvoor het gebied is aangewezen, de samenhang van de structuur en functies van de habitattypen en van de soorten waarvoor het gebied is aangewezen en de op het gebied van toepassing zijnde ecologische vereisten van de habitattypen en soorten waarvoor het gebied is aangewezen niet uit te sluiten. Dit betekent dat drie van de vier doelstellingen voor het Natura2000-gebied Waddenzee negatief kunnen worden beïnvloed bij introductie bij één of meerdere van deze invasive roofslakken.

1.4 Conclusie

In paragraaf 1.3 zijn de mogelijke negatieve effecten van de introductie van een of meerdere roofslakkensoorten op de natuurlijke kenmerken van de Natura2000-gebied Waddenzee, volgens de Habitatrichtlijn, beoordeeld. Hierbij is gericht op de kernwaarden, de algemene instandhoudingdoelstellingen en de instandhoudingdoelstellingen van de relevante habitattypen (H1110 en H1140) in het licht van de staat van instandhouding van de kwaliteit van het gebied. De mogelijke effecten op de kwaliteit van de habitattypen zijn beoordeeld aan de hand van structuur en functie (de in het profielendocument beschreven abiotische randvoorwaarden en overige kenmerken van een goede structuur en functie) en de typische soorten. Voor een volledige analyse van mogelijke effecten op het Natura 2000-gebied Waddenzee zou naast een analyse van de Habitatrichtlijn, ook een analyse van de Vogelrichtlijn moeten plaatsvinden. De introductie van invasive roofslakken kan namelijk indirect ook een impact hebben op Vogelrichtlijnsoorten die in dit gebied zijn aangewezen. Voor vogels geldt dat wanneer schelpdierbestanden op een zodanige wijze worden beïnvloed dat dit effecten heeft op foerageermogelijkheden en voedselopname van schelpdieretende vogels er zich ook negatieve effecten voor deze soorten kunnen voordoen. Dit kan gevolgen hebben voor de staat van Instandhouding van deze soorten. Hiervoor zou een doorvertaling van de gesignaleerde effecten moeten worden gemaakt naar vogelsoorten waar mogelijk effecten kunnen optreden. Het betreft alleen soorten die in het Gebiedendocument worden genoemd en die ook schelpdieren eten, zoals Eider, Topper, Brilduiker, Scholekster en mogelijk ook Kanoet. Onderliggende beoordeling richt zich volgens opdracht echter alleen op de Habitatrichtlijn.

Geconcludeerd kan worden dat niet kan worden uitgesloten dat bij de introductie van één of meerdere roofslakken in het Natura 2000-gebied Waddenzee, effecten optreden die significant zullen zijn in het licht van de instandhoudingdoelstellingen van de Habitatrichtlijn. Aan deze conclusie liggen de gepubliceerde impacts van invasies van deze roofslakken in andere gebieden ten grondslag in combinatie met het feit dat er geen abiotische of ecologische barrières zijn waarom deze roofslakken zich niet in dit gebied zouden kunnen handhaven en reproduceren. De huidige kennis met betrekking tot de mate van kolonisatie in de Waddenzee en de effecten van de roofslakken op de instandhoudingsdoelstellingen zijn echter niet voldoende om een inschatting te kunnen maken van de grootte van de optredende effecten.

Bij een mogelijke introductie van één of meerdere invasive roofslakken in het Natura2000-gebied Waddenzee kan niet worden uitgesloten dat significante aantasting van het habitattype 1110 en 1140 als wezenlijk kenmerk van het beschermde gebied optreedt.

Appendix E. Overview of case studies

Urosalpinx cinerea **American oyster drill**		***Ocinebrellus inornatus*** **Japanese oyster drill**		***Rapana venosa*** **Veined Rapa Whelk**	
Location	Effect	Location	Effect	Location	Effect
England (Eno et al. 1997, Cohen 2005).	*U. cinerea* has been reported to consume about 40 spat of the native oyster (*Ostrea edulis*) each per year.	Willapa Bay, USA (Williams & McDonald 2008)	Anecdotal evidence that *O. inornatus* has replaced the native dogwhelk *Nucella lamellosa*	The Black Sea (Zolotarev 1996, Harding & Mann 2003, Giberto et al. 2005, Savini & Occhipinti-Ambrogi 2006).	*R. venosa* is considered responsible for the decline (by almost half) of the native, edible bivalve fauna. The species has caused significant changes in the ecology of benthic organisms and is blamed for the near extinction of the Gudaut oyster. predation by *R. venosa* has been identified as the primary cause of the collapse of several mussel and oyster banks.
Experiment (Hanks 1957)	At temperatures ranging between 15-20 °C, *U. cinerea* consumed 0.5-1 mussel per individual, per week.	British Columbia and Washington (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004).	The drill was reported to hamper efforts to restore beds of native Olympia oysters (*Ostreola conchaphila*).	Chesapeake Bay in the Mid-Atlantic, United States (Global-Invasive-Species-Database 2006).	The whelk has been reported to impact populations of shellfish such as *Mya arenaria*, *Ensis directus* and *Cyrtopleura costata* as well as a range of commercially valuable shellfish species, the native *Urosalpinx cinerea*, the hermit crab *Clibanarius vittatus* and the native gastropods such as *Busycon carica* and *Busycotypus canaliculatum*
Britain (Hancock 1954)	*U. cinerea* has been found to inflict locally on average 50 % mortality of the annual commercial oyster seed crop in	British Columbia and Washington (Committee-on-Nonnative-Oysters-in-the-Chesapeake-Bay 2004, Global-Invasive-Species-Database 2007,	The drill caused about 25 % mortality in oyster stocks. Productions costs increased by about 20 % and profits decreased by about 55 %	Northern Adriatic Sea (Savini & Occhipinti-Ambrogi 2006).	The whelk has been shown to consume the mussel *Mytilus galloprovincialis* at a rate of 5±4 mussels in 44 days per individual. Previous experimental results with Rapa Although this appears a low rate,

	infested culture plots	Buhle & Ruesink 2009a)			Carranza et al. (2009) argue that even if per capita consumption rates are low, the unusually high abundances of the Rapa Whelk still poses a threat to mussel beds. Furthermore, impact will be higher in areas where mussels are the unique prey item for *R. venosa*. In the above mentioned study three species were offered to the whelks.
				Punta del Este, Maldonado Bay, Uruguay (Carranza *et al.* 2009)	Local fishermen reported a severe depletion of mussel beds covered in Punta del Chileno and Punta Ballena areas associated to high densities of the *Rapa whelk*.
North American Atlantic (Alford, 1975 In (Global-Invasive-Species-Database).	U. cinerea has been recorded as inflicting 60-70% mortality on oyster spat.	Netarts Bay, Oregon, USA (Carlton 1992)	Predation by *O. inornatus* severely hampered efforts to establish aquaculture of the Japanese clam (*Venerupis philippinarum*)	Bulgarian waters, the Kerch Strait and the Caucasian shelf (Savini & Occhipinti-Ambrogi 2006).	Predation by *R. venosa* is considered the main reason for the decline of *M. galloprovincialis .*
Tomales Bay USA (Travis, undated In (Global-Invasive-Species-Database).	Nonindigenous *U. cinerea* directly competes with native California marine snail (*Acanthinucella spirata*) for prey	Puget Sound, USA (Williams & McDonald 2008).	*O. inornatus* consumed mussels (*Mytilus edulis*) at a rate of almost one mussel per drill per day, almost double that of the native drill *Nucella Lamellosa*.	Cesenatico Emilia-Romagna, on the Adriatic coast (Savini *et al.* 2004).	Local fishermen observed an increase in numbers of by-catch of *R. venosa*. Squid fishermen were particularly disturbed by the presence of the whelk which utilises nets as spawning substratum crawling inside, occupying all the room available and adding extra weight to the draug