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Commissioned by: Common Wadden Sea Secretariat

29 June 2015
Report nr 15-126

Status:	Final report
Report nr.:	15-126
Date of publication:	29 June 2015
Title:	Alien species in the Dutch Wadden Sea: policies and management
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Photo credits cover page:	Pacific oyster *Crassostrea gigas*, mantle cavity with tentacles, Joost Bergsma / Bureau Waardenburg
Number of pages incl. appendices:	123
Project nr:	14-687
Project manager:	dr. T.M. van der Have
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Preface

The 12th Wadden Sea Conference (Tønder, 6 february 2014) has decided to further develop a trilateral strategic framework for dealing with alien species in the Wadden Sea as well as a trilateral alien species management and action plan for the international Wadden Sea (§ 35 of the Tønder Declaration). The Task Group Management of the Wadden Sea Board will coordinate this initiative in close cooperation with its Working Group Alien Species.

The Common Wadden Sea Secretariat, therefore, commissioned this project to Bureau Waardenburg to (1) prepare an inventory of the current situation and future intentions with regard to monitoring, policy and management of alien species in the Dutch Wadden Sea; (2) prepare an update of relevant regulations, directives and conventions within EU, OSPAR and IMO; (3) prepare an update of current management actions; (4) analyse the findings from the perspective of the requirements of Wadden Sea alien species monitoring and management, including a gap analysis; (5) to give recommendations for amendments to the strategic framework for alien species management in the Wadden Sea based upon the analysis.

This report was prepared in close cooperation with D. Poszig and C.J.M. Philippart of the WaLTER project (see also http://www.walterwaddenmonitor.org/themas/ for the thematic report). Folkert de Jong, Saa Henry Kabuta and Sander Smolders provided comments on previous versions of this manuscript. The authors thank everyone who has contributed to this report.

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Summary

The 12th Trilateral Governmental Wadden Sea Conference (Tønder, Denmark, 6 February 2014) discussed a draft Strategic Framework for Alien Species and took the first steps towards the development of a trilateral alien species management and action plan for the international Wadden Sea (§ 35 of the Tønder Declaration). The overall objective of the draft Strategic Framework is to address the threats to the Wadden Sea ecosystem and biodiversity through alien species. The efforts to address alien species in the Wadden Sea should focus on five main elements: (1) prevention; (2) early Detection/warning and rapid response; (3) eradication and control; (4) raising awareness; (5) implementation. The first three elements represent three lines of defence: preventing establishment, eradication after establishment and control after spread. Raising awareness enhances prevention and early detection and facilitates acceptance of management actions. For efficient implementation of the policy a coherent and coordinated IAS management and action plan needs to be developed.

The aim of this study is to assemble and update the information required for the management and action plan. The following elements of the draft Strategic Framework are addressed: (a) ecological risks and risk assessment, (b) compliance to international legislation and conventions, (c) the value of current monitoring programs for early detection and evaluation of prevention, (d) the status of management actions, (e) the level of awareness among stakeholders and (f) the requirements for implementation.

Ecological risks: species and pathways

- A wide variety of marine and terrestrial habitats is present, including man-made habitats where alien species are frequently introduced (also known as gateways or hubs) and recipient, natural habitats where alien species settle after secondary dispersal.
- Different vectors and pathways of alien species are present, the number of pathways and rate of new introductions of new invasive alien species are suspected to increase and more negative (and occasionally positive) impact on conservation goals is expected.
- A large number of risk assessments of alien species actually or potentially present in the Wadden Sea is already available. New pathways, including live bait and pets available through Internet, need more attention.

Compliance: international regulations and conventions

- 18 different and specific legal instruments from international regulations and conventions apply to the Wadden Sea region or are in the process of implementation, which, when taken together and fully implemented, are potentially sufficient to reduce new introductions, spread and impact of alien species; Points of attention are coordination, harmonization and prioritization of actions.

Early detection: monitoring efficiency

- At least 18 different monitoring programs are currently carried out, which actually and potentially detect alien species usually as a side effect at varying levels of coverage and frequency, but many programs do not label alien species as such.
- Not all species groups can be detected and in most cases it is unknown if detection is timely enough for rapid response, if considered necessary and feasible after risk assessment, or for the evaluation of prevention monitoring.
- None of the inventories or monitoring programs is yet fully suited for early detection and for uncovering the population dynamics of an alien species.

Management actions

- Few management actions have been carried out, including prevention measures in aquaculture (prevention monitoring of mussel transports), eradication of translocated native species and management of plant species on Wadden Sea islands.
- Closed hull fouling cleaning systems and a port-based ballast water treatment system are under development.
- No information is yet available on the efficiency of these management actions.

Awareness and implementation

- Different authorities can implement different legal instruments at different levels (ministries, councils, provinces) and at larger scales than the Wadden Sea, which may hamper efficient management actions; too few management actions have been carried out for feasible evaluation.
- Different levels of awareness of both alien species and management options are present among stakeholder groups, which may limit the necessary information and support for management actions.
- Broad dissemination of alien species information is considered a priority as it will enhance public awareness, facilitate early detection, generate support for management actions and provide a “level playing field” for all stakeholders.

1 Introduction

1.1 Background

In 2010, the Ministerial Council of the Netherlands, Germany and Denmark adopted the revised Wadden Sea Plan, which constitutes the common framework for the protection and sustainable management of the Wadden Sea as an ecological entity (Common Wadden Sea Secretariat 2010). One of the objectives of the Trilateral Cooperation laid out in the Wadden Sea Plan is to achieve "a natural ecosystem, its functions and characteristic biodiversity". This conservation target is challenged by the introduction of alien species, in particular when they become invasive.

Biological invasions can affect biodiversity negatively, e.g. by means of interspecific competition, alteration of habitat, effects on food-web properties, hybridization and the transfer of diseases (e.g. Molnar *et al*. 2008, Savini *et al.* 2010, Rabitsch *et al.* 2013, Katsanevakis *et al.* 2014). Alien species can also have positive impacts though, e.g. by affecting species of high conservation value in a positive way, but generally positive impacts seem to be underestimated yet (Katsanevakis *et al.* 2014). Aside from effects on biological diversity, alien species can also have adverse as well as favorable effects for society or specific economic sectors, e.g. fisheries or shipping (Molnar *et al*. 2008, Vilà *et al*. 2010, Rabitsch *et al.* 2013, Katsanevakis *et al.* 2014).

The 12th Trilateral Governmental Wadden Sea Conference (Tønder, Denmark, 6 february 2014) discussed a draft Strategic Framework for Alien Species and took the first steps towards the development of a trilateral alien species management and action plan for the international Wadden Sea (§ 35 of the Tønder Declaration). The Task Group Management of the Wadden Sea Board will coordinate this initiative in close cooperation with its Working Group Alien Species.

1.2 Draft Strategic Framework for Alien Species in the trilateral Wadden Sea

The overall objective of the Strategic Framework is to address the threats to the Wadden Sea ecosystem and biodiversity through alien species. This will be done by:

- Preventing alien species from entering the Wadden Sea Area;
- Early detection and rapid response;
- Eradicating, if feasible, alien species that have become established in the Wadden Sea Area and are assessed as (potentially) invasive. If eradication is not feasible anymore, minimizing further spread of invasive alien species once they have been detected in the Wadden Sea Area;

Several approaches provide recommendations for management of alien species in the Wadden Sea (e.g. national strategies and/or action plans and various publications, amongst them the QSR 2009 (Nehring *et al*., 2009)).

There is general agreement that the efforts to address alien species in the Wadden Sea should focus on five main elements:
(1) Prevention;
(2) Early Detection/warning and rapid response;
(3) Eradication and control;
(4) Raising awareness;
(5) Implementation.

The first three elements represent three lines of defence: preventing establishment, eradication after establishment and control after spread. Raising awareness enhances prevention and early detection and facilitates acceptance of management actions. For efficient implementation of the policy a coherent and coordinated IAS management and action plan needs to be developed (Figure 1).

Figure 1 *The management cycle with components of an IAS management and action plan with conservation actions (early detection, risk analysis and mitigation including prevention, eradication or control) in blue and governmental actions (decision making, evaluation) in green.*

1.3 Aim / Outline

The aim of this study is to assemble and update the information needed to identify the requirements of this management and action plan to prevent the threats of alien species to the Wadden Sea ecosystem.

This report will generally follow the structure of the draft Strategic Framework in the first three chapters. The background section of the draft Strategic Framework briefly summarizes the policy aims of the Sylt declaration (chapter 1, this report) with a clear set of definitions (chapter 1), the general problem of alien species, their pathways and impact in the Wadden Sea region for both marine and terrestrial habitats (chapter 2) and the available legal instruments (chapter 3) with relevance to alien species in the Wadden Sea region. The aim is to include as much as possible the legal instruments and policies which are linked to specific monitoring programs including alien species and management actions relevant for invasive alien species.

The main text of the Strategic Framework includes the abovementioned objective and the five elements and points out the management options for each element for marine and terrestrial habitats separately or combined (chapter 3). This chapter provides an update and overview of information needs, monitoring programs, an analysis of current and future monitoring and recommendations for the trilateral Strategic Framework (section 3.2). An overview of current management actions is presented in section 3.3. Chapter 4 will analyse all information included in chapters 2 and 3 in the light of the pathways present, available and future legal instruments, management actions and possible gaps therein. Chapter 5 provides recommendations for the elements of the draft trilateral Strategic Framework with respect to the national implementation of legal instruments and legal obligations, based on the information and gap analysis in the previous chapters. In addition, recommendations will be made for the integrated and coordinated approach of the draft Strategic Framework for Alien Species in the trilateral Wadden Sea.

Box 1. Definitions

(Based on Definitions of CBD VI/23)

Native species
”Native species" refers to a species, subspecies or genetically distinct populations, occurring within its natural range (past and present).

Alien species[1]
”Alien species" refers to a species, subspecies or genetically distinct populations, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.

Invasive alien species[2]
"Invasive alien species" (IAS) means an alien species whose introduction and/or spread threaten biological diversity.

Problem or nuisance species
A species for which it can be assumed that based on the best available scientific data it will have a (significant) negative impact on the conservation goals of a Natura 2000 area.

Introduction
"Introduction" refers to the movement by human agency, indirect or direct, of an alien species outside of its natural range (past or present). This movement can be either within a country or between countries or areas beyond national jurisdiction.

Intentional introduction
“Intentional introduction" refers to the deliberate movement and/or release by humans of an alien species outside its natural range.

Unintentional introduction
"Unintentional introduction" refers to all other introductions, which are not intentional.

Establishment
"Establishment" refers to the process of an alien species in a new habitat successfully producing viable offspring with the likelihood of continued survival.

[1]Species occurring naturally in neighbouring countries of the Wadden Sea and entering independently, due to for instance climate change (climate shifters), do not fall under this definition.
[2] For the purposes of the present guiding principles, the term "invasive alien species" shall be deemed the same as "alien invasive species" in decision V/8 of the Conference of the Parties to the Convention on Biological Diversity.

Box 1. Continued.

Risk analysis
"Risk analysis" refers to: (1) the assessment of the consequences of the introduction and of the likelihood of establishment of an alien species using science-based information (i.e., risk assessment), and (2) to the identification of measures that can be implemented to reduce or manage these risks (i.e., risk management), taking into account socio-economic and cultural considerations.

Pathway
A pathway is the route along which alien species are introduced outside their normal geographical range.

Vector
Vectors are constructions, devices or forms of transport by which alien species are actively or passively introduced outside their normal geographical range.

Risk
Risk = probability X impact.

Risk assessment
Science-based assessment of the likelihood of introduction, establishment and spreading, including identification of origin and pathway of an alien species and assessing the consequences of the actual and potential introduction for biodiversity, human and animal health, safety and economy. Risk assessments are usually carried out with standardized and internationally accepted protocols.

Risk management
Policy-based measures to reduce the risk of introduction, establishment, spread and impact of an invasive alien species, risk analysis and risk communication. Management options are prevention, eradication, management or acceptance.

2 Current status alien species in Wadden Sea region and their pathways

2.1 Introduction

Alien species are organisms that are introduced actively or passively by human activities in new areas often far outside their original distribution (Richardson *et al.*, 2000). A substantial number of these alien species has become invasive after establishing in these introduction areas and spreading further and subsequently can pose a threat to biodiversity (e.g., Mack *et al*., 2000). Invasive Alien Species (IAS) are now recognised as an important factor for the loss of habitat and biodiversity (Clavero and Garcia, 2005, McKinney & Lockwood, 1999). Recent data from the Wadden Sea region, which includes several Natura 2000 areas, already show substantial changes in abundance of marine and terrestrial alien species and consequently ecological impact (Buschbaum *et al*., 2012, Nehring *et al*., 2009).

Introductions occur through recreational and commercial shipping and aquaculture in marine ecosystems, horticulture and keeping of pets in terrestrial ecosystems. In addition, dispersal from other areas of introduction, in particular harbours and marinas or gardens in towns just outside or close to the Natura 2000 areas, is another important pathway. The Wadden Sea is especially vulnerable as it borders one of the most intensive shipping areas and economically most exploited marine regions, the North Sea. The Wadden Sea islands are vulnerable because of the large number of human visitors throughout the year.

In the marine environment there are, in general, four important vectors for the introduction of Invasive Alien Species by human activities:

1. Ships ballast water (mainly commercial ships);
2. Ship hull fouling, both commercial and recreational vessels;
3. Aquaculture, in particular shellfish transports;
4. Dispersal from other areas of introduction (also in terrestrial habitats).

On the islands in the Wadden Sea other vectors may be present, such as:

5. Horticulture (in towns);
6. Pet trade (in towns, e-commerce);
7. Transport (cars, ferries).

Each vector requires specific conservation action to reduce their risks, such as prevention or eradication. Prevention is generally the best management option as for vectors like shellfish transport or ballast water. However, the openness of the marine Wadden Sea ecosystem with a high pressure from human activities constrains the effectiveness of prevention. An integrated management approach is therefore needed. The Wadden Sea islands, on the other hand, are isolated from the large and

open mainland and this isolation might provide good opportunities to prevent new introductions, detect new species early and, if deemed necessary, carry out successful eradication.

Thus, early detection of alien species has a twofold function: (1) in marine habitats it is an essential element to evaluate the effectiveness of prevention (Bailey *et al*., 2011; Campbell *et al*., 2007; Costello *et al*., 2007; Crooks, 2005) and, (2) if considered feasible, implement a rapid response to eradicate invasive alien species in an early invasion stage, in particular in terrestrial ecosystems. The best strategy is to target high-risk vectors and related high-risk sites (introduction sites or hot spots, Campbell *et al*., 2007; Hoffman *et al*., 2011; Trebitz *et al*., 2009), detect initial colonization, evaluate the effectiveness of prevention (Costello *et al*., 2007) and prepare management responses such as eradication.

2.2 Biological invasions and pathways

2.2.1 Unified framework biologial invasions

In policy-making and research on non-native species and invasion processes, various concepts and terminology are being used. Blackburn *et al.* (2011) proposed a unified framework that is useful to describe the stages of the invasion process (Figure 2). The invasion stages comprise different barriers for a species to overcome that necessitate different types of management interventions. In this report, the term alien species will be used for introduced non-native species from the point in time of their introduction, while the term invasive alien species (IAS) is only used for alien species after their establishment and dispersal, thus at the stage of spreading according to Blackburn *et al*. (2011). The use of “invasive” in combination with “alien species” will prevent any confusion with other invasive species such as climate shifters (species invading new areas as a result of climate change) and expanding species (e.g., Collared dove *Streptopelia decaocto*). A full list of definitions is included in Box 1 (p. 14-15).

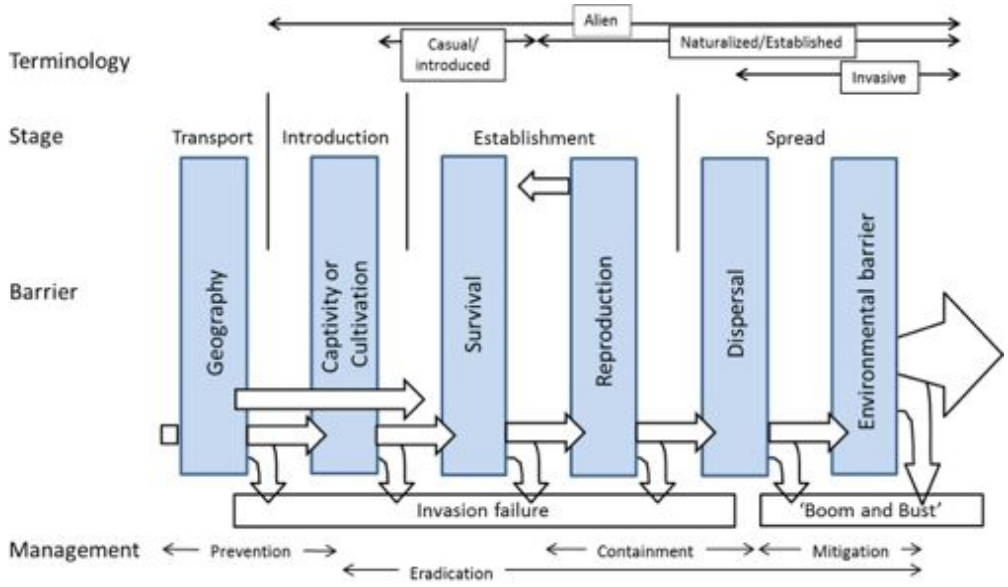

Figure 2 *The proposed unified framework for biological invasions presented by Blackburn et al. (2011). The block arrows describe the species' movement along the invasion process with respect to the barriers that the species need to overcome, with standardized terminology (above) and different types of management related to different invasion stages (below).*

2.2.2 Pathways in marine habitats

Through human activities, alien species are introduced on a regular basis in the international Wadden Sea. A substantial number of these alien species have been identified over the last decades (Gittenberger & Rensing, 2012). Only a small amount of them is considered invasive (Gittenberger *et al*., 2012). They are considered invasive if they can propagate and directly affect indigenous species (predators, pathogens, toxins) or indirectly affect endogenous species by occupying the niche of or overgrowing the indigenous species.

In the marine environment there are four important pathways for the introduction of invasive alien species:

1. Ships ballast water (mainly commercial ships);
2. Ship hull fouling (including sea chests; both commercial and recreational vessels);
3. Aquaculture;
4. Migration or passive spreading via water currents (secondary dispersal) from other areas of introduction.

These pathways include vectors like ships, vessels and shellfish transports which each require their own specific conservation actions.

Ships ballast water

Organisms that survive the ballast water tanks of the ship can thrive when released in a new environment (e.g., Briski *et al*., 2012). Many of these organisms are free-

swimming aquatic organisms as algae or jellyfish. But also larvae of species that grow on solid surfaces can be found in ballast water (e.g., Gollasch *et al*., 2009.

Free-living aquatic species cannot easily be eradicated when they are released in the environment. In this, the IMO Ballast Water Management Convention will aid to reduce the risk of introduction of invasive species. This Convention will seriously reduce the number of organisms released in the environment by commercial ships. However, due to the associated costs and lack of equipment, facilities and capacities to install ballast water management systems on board of ships, it will take some time after the Convention comes into force to be effective.

Ship hull fouling

For the commercial shipping industry reduction of hull fouling is of economic importance as it affects energy consumption and reduces the speed of vessels. Therefore, owners of commercial ships try to prevent hull fouling and biofouling as much as possible. Despite this, commercial ships significantly contribute to the number of introductions of new species in areas like the Wadden Sea (Briski *et al*., 2012; Gollasch, 2002; Gollasch *et al*., 2009; Zabin *et al*., 2014).

Antifouling paint is not sufficient to prevent the introduction of alien species and, therefore, several states and international organisations have made additional measures mainly for commercial but also recreational shipping (see references in Zabin *et al*., 2014). These additional measures include vessel inspections, hull cleaning (in water and/or dry docks) and awareness programs. The IMO has adopted guidelines for survey and certification of anti-fouling systems on ships (e.g., IMO 2002, 2003). Member states, which signed the convention, agree to these guidelines and implemented these in national and/or regional regulations.

For recreational vessels there has only been limited attention on this matter, although they also form an important vector. It has been shown in preliminary studies that recreational vessels contribute to the introduction of new species significantly (Gittenberger *et al*., 2009, 2011).

Elimination of invasive species from the ship hull is technically challenging, especially as species tend to colonize cavities in the hull, such as water inlets and outlets, heat exchangers, anchor holes, anchor chains, sea chests etc. Traditional anti-fouling paints using TBT (tributyltin) have been banned worldwide, because of their toxic and polluting effect on the environment and have been replaced by paints with other toxic substances (e.g., copper).

Reduction of hull borne invaders can be achieved, but elimination is technically not possible yet. Species that attach to ship hulls will spread rapidly because they do not need extra stepping-stones during secondary dispersal to colonise a new habitat and the harbours where they become established will function also as stepping stones.

Thus, early warning and rapid eradication (sanitation) may provide an effective conservation method.

Aquaculture
Fishery is one of the important economic activities in the Wadden Sea. Efforts are made to make commercial fishery as sustainable as possible. One of the main fishery and aquaculture activities in the Wadden Sea are shellfish cultures, e.g. blue mussels. The Wadden Sea is rich in nutrients and provides an ideal growing environment for these shellfish. Shellfish transports are a major source of alien species (e.g., Gollasch *et al*., 2009; Hewitt *et al*., 2006; Jensen & Mikkelsen, 2011; Kools *et al*., 2011).

Because the exploitation of subtidal mussel seed stocks has to be replaced completely by mussel seed collected from mussel seed collectors by 2020, Dutch authorities have decided to allow transports of blue mussels gathered from mussel seed collectors in the Oosterschelde for mussel culture plots in the Wadden Sea. To this aim they have set up a transport and monitoring protocol to avoid the introduction of invasive alien species from the Oosterschelde into the Wadden Sea (Gittenberger, 2010; Ministry of EZ, 2012). The protocol does not include the surveillance of parasites and pathogens. Demonstration of the effectiveness of this protocol may enable the expansion to other aquaculture activities and to other EU countries.

Dispersal from other areas of introduction
Species introduced to the Southern North Sea coast can easily migrate to the Wadden Sea. Also the Kiel Canal allows species to migrate between the Baltic Sea and the Wadden Sea. For example, the Chinese mitten crab *Eriocheir sinensis*, is known to have migrated via this route (Bouma & Soes, 2010). To date, no conservation actions have been developed to mitigate these effects.

2.2.3 Pathways in terrestrial habitats

Horticulture
Alien plant species have been introduced for ornamental purposes in gardens and parks and for agriculture in the Netherlands for centuries. Many species have spread to natural areas. Insects are frequent stowaways in pot plants. Commercial pot plants are submitted to regular inspections. The exchange of pot plants between botanical gardens is another source of insects, in particular if these plants have been collected in the wild. The invasive garden ant *Lasius neglectus* has been introduced to the Netherlands through this pathway., This invasive alien species of unknown origin became established in several cities, where it locally occurs in such high densitites that it can exclude other ant species (van Loon, 2009). By the same pathway it would be able to colonize the Wadden Sea islands.

Pet trade
The pet trade is an important source of alien species and includes mainly vertebrate species groups like ornamental fish, amphibians, reptiles, birds and mammals, in

particular reptiles and birds, which are most abundant in the pet trade (Bush *et al*., 2014; Carrete & Tella, 2008). Pets are sold in shops and through e-commerce (Derraik & Phillips, 2010) or barted for other species. Many pet species or ornamental birds have recently been recorded and reproducing in the wild (e.g., Sacred Ibis *Threskiornis aethiopicus* (Smits *et al*., 2010), Russian rat snake *Elaphe schrenckii* (van de Koppel *et al*., 2012), opossums (van Vliet & Lensink, 2012), raccoon *Procyon lotor* (Lammertsma, *et al*., 2008), striped skunk *Mephitis mephitis* (van Belle & Schut, 2011), several species of squirrel (Dijkstra & Dekker, 2008) or became locally established and have spread in the Netherlands (Pallas's squirrel *Callosciurus erythraeus* near Weert). Individuals of these species may have escaped (most likely in squirrels) or deliberately released. Many of these species originate from similar climate zones and are therefore able to colonize Wadden Sea islands after introduction. Pathogens, like *Batrachochytrium dendrobatidis* and *B. salamandrivorans*, have been spread around the globe by trade in amphibians and have resulted locally in serious declines in amphibians (e.g., Spitzen & Zollinger, 2010).

Transport
Alien species are frequently stowaways in transports of goods by cars, trains and airplanes. These include insects with wood boring larvae (e.g., Asian long-horned beetle, *Anoplophora glabripennis* and Large elm beetle *Scolytus scolytus*, which both can have considerable impact on native trees) respectively in pellets or logs, spiders in imported American cars (Black widow spider *Latrodectus mactans,* Noordijk *et al*., 2013), and Indian House crows *Corvus splendens* (Slaterus *et al*., 2009) and Brown rats (*Rattus norvegicus*) on ships.

Secondary dispersal
Many alien species have established populations on the mainland and may colonize the islands through natural dispersal. This is most likely for plants with wind dispersed seeds, flying insects (e.g. Asiatic ladybird) and birds, e.g., Egyptian goose and Greater Canada goose.

2.2.4 Introduction and recipient habitats

Alien species are usually not introduced directly into natural areas, but in or near harbours, towns and rural areas. The habitats present in these areas and connecting these with natural areas can be considered as introduction habitats (or hubs as in the hub and spoke model which describes the dispersal of alien species from introduction sites (hubs) and with specific vectors such as small vessels (spokes) to the wider surrounding area, (Carlton, 1996; Inglis *et al*., 2006; Richardson *et al*., 2011). These include artificial hard substrate in ports and marinas (jetties, buoys), mussel culture plots in subtidal areas, the tidemark with debris on beaches and along dykes. Parks and road verges in and around towns and regional movements of small ships often connect respectively towns and harbours with natural areas (cf. the spokes in the abovementioned hub and spoke model).

In natural areas, recipient habitats differ in their resistance to invasion. Brackish zones and disturbed habitats are generally invaded more easily (e.g., Simberloff & von Holle 1999; Wolff, 1999), which is generally explained by the lower species richness of these recipient habitats and resulting lower biotic resistance. This also applies to islands, which always have less species compared to mainland areas due to their isolation and small surface area, and lower resistance to biotic invasions. In particular ground-breeding birds are vulnerable for mammalian predators (e.g., Blackburn *et al*., 2004)

Soft sediments dominate the tidal and intertidal areas in the Wadden Sea, the North Sea coastal zone and North Sea (Quality Status Report, Marencic & de Vlas, 2009). The majority of marine alien species are adapted to natural hard substrates (see section 2.3 and Table 1; Nehring *et al*., 2009; Buschbaum *et al*., 2012) and usually introduced by attachment to artificial hard substrates (ship hulls, shells). It is expected that soft sediment areas with high species richness are more resistant to alien species, except perhaps for soft sediment areas close to introduction habitats like mussel culture plots and harbours.

2.3 Marine alien species in the Dutch Wadden Sea

The total number of marine alien species recorded in the Dutch part of the Wadden Sea is now over 60 (Table 1, Gittenberger & Rensing, 2012) and new species are still being found. Most alien species have been found in the western part of the Wadden Sea (Gittenberger *et al*., 2009), where several important pathways are present: a large port (naval harbour of Den Helder), many smaller marinas and mussel culture plots with mussel imports from the Eastern Scheldt. The continuous input of (potentially reproducing) individuals of new alien species along these pathways determines to a large extent the success of invaders, which is also known as “propagule pressure” (Wilson *et al*., 2009) and the availability of suitable habitats close to the introduction sites.

Secondary dispersal or introductions from nearby areas can also occur. In the Dutch coastal areas and the Dutch part of the North Sea nearly 200 species of marine alien and cryptogenic species have been recorded (database Werkgroep Exoten with references to original publications). A substantial number (over 120 species, Gittenberger, 2009; Gittenberger & Rensing, 2012; Wijsman & De Mesel, 2008; 2009)) of alien species has been found in the Eastern Scheldt estuary in the southwest of the Netherlands, which is high compared to other areas around the North Sea (Gollasch *et al*., 2009). This is most likely related to the number of pathways present in that area, including large ports (Vlissingen), numerous marinas, extensive areas with aquaculture and regular mussel and oyster imports, and a wide variety of habitats ranging from fresh to marine and from soft sediments to hard substrates.

All these species survived after introduction, most of these species have become established, but only a few species have spread substantially and can be considered invasive.

The highest number of alien species as well as the proportion of alien species relative to the total number of native species is present in mesohaline or brackish areas of rivers and estuaries (Wolff, 1999). This seems to be related to the presence of relatively unsaturated ecological niches (including the increase in abundant artificial hard substrate) together with intensive international shipping (Wolff, 1999; Nehring *et al*., 2009). The most abundant species in this zone are *Ficopomatus enigmaticus, Marenzelleria viridis, Eriocheir sinensis and Sinelobus vanhaareni*.

Introduction and recipient habitats

Many marine alien species have arrived here by attachment to ships and/or shellfish, which form a suitable hard substrate. Therefore, the majority of marine alien species detected in the Wadden Sea can be found on natural or artificial hard substrates (Table 1), such as jetties, floating pontoons, in harbours, buoys and dykes inside and outside harbours (also known as "gateways for alien species", Nehring *et al.*, 2009, or "hubs", Carlton, 1996). Typical species are seaweeds (*Gracilaria vermiculophylla*), barnacles *Austrominius modestus* and *Amphibalanus improvisus* and sea squirts *Didemnum vexillum* (only in and near the harbour of Terschelling), *Molgula mahattensis*, *Botrylloides violaceus* and *Styela clava*. The large kelp species Wakame *Undaria pinnatifida* has only been found in the harbour of Terschelling. Under the rocks of dykes *Hemigrapsus sanguineus* and *H. takanoi* have become very common (Gittenberger *et al*., 2009, 2012, 2014).

Areas where shellfish have been imported in the past (flat oysters from North America, where they were introduced, and transported back to Europe, Pacific oysters from the N.W. Pacific) and are imported currently (mussel culture plots in the Western Wadden Sea) could be other introduction areas of alien species. The inspections of mussel transports to the Dutch part of the Wadden Sea according to the mussel import protocal may prevent this (Gittenberger, 2010, Ministry of EZ, 2012).

Soft sediments form the majority of the natural habitats of the Wadden Sea (QSR, Marencic & de Vlas, 2009) and for which these areas are designated under the Birds and Habitat Directives. For alien species they can be considered recipient habitats. Because most alien species need hard substrate they are therefore expected to settle and spread using natural and man-ade hard substrates in the soft sediments. Within these habitats three hotspots are recognised: around the high tide level salt marshes are dominated by Spartina swards, around the low tide level where Pacific oyster beds have become dominant and provide a natural hard substrate for other alien species like Japanse seaweed *Sargassum muticum*, and subtidal mussel culture plots (Nehring *et al*., 2009). Higher in the intertidal zone typical soft sediment species are *Alitta virens*, *Monocorophium sextonae*, Clam *Mya areanaria*, and American slipper limpet *Crepidula fornicata*.

American razor clam *Ensis directus* has now become very abundant (and perhaps still increasing) in the sublitoral of the western Wadden Sea and now forms 80% of the total macrobenthic biomass in the western Wadden Sea (Drent & Dekker, 2013). Another abundant alien species in the soft sediment sublitoral is the false angel wing *Petricolaria pholadiformis*.

Table 1 *List of 57 marine alien species in the Dutch part of the Wadden Sea with taxonomy, year of first record in the Netherlands and habitat (adapted from Buschbaum* et al*., 2012).*

Species	Phylum	Class	First record NL	Salinity	Substrate
Antithamnionella spirographidis	Rhodophyta	Florideophyceae	1974	estuarine to marine	hard
Antithamnionella ternifolia	Rhodophyta	Florideophyceae	1951	estuarine to marine	hard
Ceramium cimbricum	Rhodophyta	Florideophyceae	2009	estuarine to marine	hard
Neosiphonia harveyi	Rhodophyta	Florideophyceae	1960	estuarine to marine	hard
Gracilaria vermiculophylla	Rhodophyta	Florideophyceae	1999	estuarine to marine	hard
Acrochaetium densum	Rhodophyta	Florideophyceae		estuarine to marine	hard
Codium fragile atlanticum	Chlorophyta	Bryopsidophyceae		estuarine to marine	hard
Codium fragile fragile	Chlorophyta	Bryopsidophyceae		estuarine to marine	hard
Botrytella sp.	Ochrophyta	Phaeophyceae	1919	estuarine to marine	hard
Sargassum muticum	Ochrophyta	Phaeophyceae	1977	estuarine to marine	hard
Undaria pinnatifida	Ochrophyta	Phaeophyceae	1999	estuarine to marine	hard
Colpomenia peregrina	Ochrophyta	Phaeophyceae	1921	estuarine to marine	hard
Ulva pertusa	Chlorophyta	Ulvophyceae	1993	estuarine to marine	hard
Spartina anglica	Tracheophyta	Spermatopsida	1924	estuarine to marine	hard
Haliclona xena	Porifera	Demospongiae	1977	estuarine	hard
Diadumene cincta	Cnidaria	Anthozoa	1925	estuarine to marine	hard
Diadumene lineata	Cnidaria	Anthozoa	1912	estuarine to marine	hard
Nemopsis bachei	Cnidaria	Hydrozoa	1905	estuarine to marine	hard
Cordylophora caspia	Cnidaria	Hydrozoa	≤1874	fresh to brackish	hard
Anguillicoloides crassus	Nematoda	Chromadorea	1985	parasite	parasite
Ensis directus	Mollusca	Bivalvia	1981	estuarine to marine	soft
Mya arenaria	Mollusca	Bivalvia	1250	estuarine	soft
Teredo navalis	Mollusca	Bivalvia	1660	estuarine to marine	in wood
Crassostrea gigas	Mollusca	Bivalvia	1928	estuarine to marine	soft/hard
Mytilopsis leucophaeata	Mollusca	Bivalvia	1895	brackish	soft
Petricolaria pholadiformis	Mollusca	Bivalvia	1905	marine	soft
Crepidula fornicata	Mollusca	Gastropoda	1929	estuarine to marine	hard
Corambe obscura	Mollusca	Gastropoda	1879	brackish	hard

Table 1 Continued.

Species	Phylum	Class	First record NL	Salinity	Substrate
Microphthalmus similis	Annelida	Polychaeta	1962	estuarine to marine	soft
Alitta virens	Annelida	Polychaeta	1903	estuarine	soft
Ficopomatus enigmaticus	Annelida	Polychaeta	1968	brackish	hard
Neodexiospira brasiliensis	Annelida	Polychaeta	1982	estuarine to marine	hard
Boccardiella ligerica	Annelida	Polychaeta	1919	brackish	hard
Marenzelleria neglecta	Annelida	Polychaeta	2002	brackish	soft
Marenzelleria viridis	Annelida	Polychaeta	1983	estuarine	soft
Aphelochaeta marioni	Annelida	Polychaeta	1940	estuarine to marine	soft
Tharyx killariensis	Annelida	Polychaeta	1998	estuarine to marine	soft
Caprella mutica	Arthropoda	Malacostraca	1993	marine	hard
Monocorophium sextonae	Arthropoda	Malacostraca	1952	estuarine to marine	hard
Gammarus tigrinus	Arthropoda	Malacostraca	1960	fresh to brackish	soft/hard
Jassa marmorata	Arthropoda	Malacostraca	2009	marine	hard
Platorchestia platensis	Arthropoda	Malacostraca	1950	estuarine to marine	hard
Rhithropanopeus harrisii	Arthropoda	Malacostraca	1874	brackish	soft/hard
Eriocheir sinensis	Arthropoda	Malacostraca	1930	fresh to brackish	soft/hard
Hemigrapsus sanguineus	Arthropoda	Malacostraca	1999	estuarine	soft/hard
Hemigrapsus takanoi	Arthropoda	Malacostraca	2000	estuarine	soft/hard
Sinelobus vanhaareni	Arthropoda	Malacostraca	2006	brackish	soft
Mytilicola intestinalis	Arthropoda	Maxillopoda	1949	parasite	parasite
Austrominius modestus	Arthropoda	Maxillopoda	1946	marine	hard
Amphibalanus improvisus	Arthropoda	Maxillopoda	1827	marine	hard
Telmatogeton japonicus	Arthropoda	Insecta	2005	brackish to marine	hard
Bugula stolonifera	Bryozoa	Gymnolaemata	1993	estuarine to marine	hard
Didemnum vexillum	Chordata	Ascidiacea	1991	estuarine	hard
Aplidium glabrum	Chordata	Ascidiacea	1977	estuarine	hard
Molgula manhattensis	Chordata	Ascidiacea	1762	estuarine	hard
Botrylloides violaceus	Chordata	Ascidiacea	2009	estuarine	hard
Styela clava	Chordata	Ascidiacea	1974	estuarine	hard

Species on the horizon

For early detection several invasive alien species are important, which have not yet been found in the Wadden Sea but are present in the Delta area, France or the UK. These include Pacific eelgrass *Zostera japonica* (spreading in North America), American horseshoe crab *Limulus polyphemus*, Pacific Whelk *Rapana venosa* (Kerckhof *et al*., 2006), other oyster species *Crassostrea sp*., American and Japanese oyster drill (resp., *Urosalpinx cinerea* and *Ocinebrellus inornatus*, Fey *et al*., 2010) and Manila clam *Ruditapes philippinarum.*

2.4 Alien species on the Dutch Wadden Sea islands

The northern edge of the Wadden Sea is protected by a series of barrier islands. These are, from west to east: Texel, Vlieland, Terschelling, Ameland, Schiermonnikoog, Rottumeroog and Rottumerplaat. The last two islands are not

inhabited anymore. Another uninhabited island, Griend, is situated in the middle of the Wadden Sea. In addition, several sand banks are situated between most islands, which are infrequently flooded at extreme high tides: Noorderhaaks, Richel, Engelsmanplaat, 't Rif and Simonszand. The distribution of most taxonomic groups (e.g., higher plants, insects, amphibian, fish, reptiles, birds and mammals) on the Wadden Sea islands is known reasonably well to very well and the occurrence and distribution of alien species has been recently assembled for the first time (Lensink *et al.*, in prep.). In this section an overview is given of the alien species found in the major terrestrial ecosystems and is based on this review.

Four groups of terrestrial ecosystems are present on the islands:

- Dunes, sandy areas with natural grasslands, shrubs and forests and locally (stagnant) fresh water above ground level in the lower parts;
- Salt marshes, sandy to clay sediments, which are regularly (lower parts) to infrequently (higher parts) flooded by sea water;
- Polders, embanked areas behind sea dykes, which are used for agriculture (grassland and arable land) intersected by fresh water and brackish ditches;
- Urban areas, which are found in and around villages and holiday resorts, with buildings and gardens.

The sand banks usually are covered with bare sand and sparsely vegetated primary dunes. Most dune areas and salt marshes are protected as Natura 2000 areas and managed as nature reserves. On Texel a part of the polder or embanked area is included in the Natura 2000 area.

Pathways

Three groups of introduced species can be found on the Wadden Sea islands: alien species (non-native species actively or passively introduced by human activities outside their natural range), translocated native species (species, which are native to the Netherlands but are naturally absent on and deliberately moved to the Wadden Sea islands) and feral species (house cat, feral goose, feral duck and feral dove).

The sea forms a natural barrier for many terrestrial species and isolates the Wadden Sea islands from the mainland. Several human activities are important vectors for alien species to cross this barrier. Plant trade, garden centres or natural dispersal (by wind, water or birds), are the main vectors for the introduction of higher plants to the islands. Seed dispersal from gardens and in garden waste deposited in roadsides are successive stages of the invasion of the islands. A few plant species became established after transport containers were washed ashore on the beach, like the cranberry *Vaccinium macrocarpon* in 1845 on Terschelling.

Occasionally species are introduced actively. European roe deer *Capreolus capreolus* have been introduced to Ameland and Terschelling for hunting purposes. A male roe deer arrived on Ameland over the former dam and hunters introduced several females subsequently. On Terschelling roe deer was introduced in the early nineties for

hunting purposes. In 2008 an inhabitant of Terschelling introduced several red deer *Cervus elaphus* illegally to Terschelling and was subsequently fined and convicted to pay the costs of eradication. In 2009 unknown persons introduced at least two foxes, a male and a female, illegally to Vlieland. These foxes killed hundreds of young cormorants and spoonbills in spring 2009 (also known as surplus killing).

Introduction habitats
Gardens, public gardens and parks are the introduction habitats where alien plant species survive and reproduce and subsequently can spread to surrounding natural areas. Road verges are also habitats in which alien species can spread further. Alien species, which are tolerant for salt spray in combination with humid sea wind, have been planted on a large scale in all forest areas on the larger Wadden Sea islands. These include Sitka spruce *Picea sitchensis*, Black pine *Pinus nigra*, Maritime pine *Pinus pinaster* and Silver poplar *Populus alba*.

Vertebrate species are usually introduced in natural or semi-natural habitats: fish in ponds and small lakes, snakes in shrubs, squirrels in forest. After introduction they disperse to similar habitats in agricultural areas or natural habitats (for example Canada geese and feral geese). From these sites other suitable areas are colonised.

Alien water plants often become established after disposal of plants from aquaria and garden ponds bought in garden centres.

Wooden pellets used in general trade and pot plants from garden centres are well known vectors of insects. Again, garden parks and road verges can function as suitable steps to natural areas.

Recipient habitats
Dunes and salt marshes can be considered as recipient habitats where alien species can become established after dispersal from the introduction habitats and have a negative impact on native species if they become invasive. More alien species are found in dune areas compared to salt marshes. This is probably related to the low salt tolerance of many alien species, in particular plants and invertebrates. Many alien plant species originate from gardens and agriculture, which are essentially based on the presence of fresh water. Virtually all trade includes species, which are not salt tolerant.

Older succession stages in the dune areas, such as forest, shrubs and grassland valleys, also have more alien species than the first stages, including primary dunes and the first dune ridge next to the beach. This difference may also be caused by lower salt tolerance of many terrestrial alien species.

In agricultural areas alien species are present mainly in road verges and waterways and less in the intensively managed arable fields (except for the crops themselves).

Alien species

Over 300 alien species of higher plants have been recorded on the Dutch Wadden Sea islands. The majority occurs only at one or two locations. A few species are more common and are present on the five larger islands and occasionally on the three smaller ones and sand banks. Twenty invasive alien species have become established several decennia ago and are still increasing in numbers and spreading (Table 2). The nature reserve managers often regarded them as nuisance species because they can have a negative impact on conservation goals. Without management these species would dominate the tree and shrub layers in the forests. In addition, a few shrub species are able to colonize more dune areas. In the salt marshes only one alien species occurs, *Spartina anglica*, which has invaded the lower parts of all salt marshes and even the highest parts of the intertidal areas bordering the salt marshes. In brackish area only a few alien species occur, for example, golden buttons (Goudknopje, *Cotula coronopifolia*). Six species of invasive water plants have become established on several larger islands (Table 3).

Only a few vertebrate alien species occur on the Wadden Sea islands (Table 4). These include a few highly visible bird species such as Egyptian goose *Alopochen aegyptiacus* (in fact more related to shelducks) and the Greater Canada goose *Branta canadensis* and fish species like Pumpkinseed sunfish (*Lepomis gibbosus*). Mammal predators are absent on the Wadden Sea islands due to their natural isolation. A few alien mammal predatory species are present on the larger five islands, including Brown rat *Rattus norvegicus* and feral cat *Felis catus*. These invasive mammals form a substantial threat for ground breeding birds and other ground dwelling organisms.

Translocated native species

Many native species are absent on the Wadden Sea islands due to the natural barrier of the sea. Ungulates, such as European roe deer, red deer and fallow deer, are naturally absent. As mentioned above, roe deer has been introduced to Ameland and Terschelling and still occurs in small numbers. Red deer has been introduced and eradicated on Terschelling. Larger predators, like red fox, are also absent. As a result, extensive colonies of ground breeding seabirds occur on most islands. This situation is managed by governmental law enforcement, as can be shown by several recent introductions, including red deer on Terschelling (2008) and red fox on Vlieland (2009). These translocated native species are a potential threat to the conservation goals of the Natura 2000 areas on the Wadden Sea islands, similar to the potential impact of translocated non-native or alien species.

Table 2 *Invasive alien plants and mosses which occur on one or more Dutch Wadden Sea islands, with presumed negative impact on biodiversity, with the number of islands on which the species occurs and the total number of 5x5 km squares in which the species is recorded. Without management these IAS will become dominant in one or more vegetation types and can potentially displace native species.*

Scientific	**English**	**Dutch**	**# islands**	**# squares**	**measures**	**habitat(s)**
Acer platanoides	Norway maple	Noorse esdoorn	5	10		forest
Acer pseudoplatanus	Sycamore	Gewone esdoorn	6	29		forest
Amelanchier lamarckii	Juneberry	Amerikaans krentenboompje	5	20	yes	forest, dunes
Crassula helmsii	Australian swamp stonecrop	Watercrassula	2	2		fresh water
Elodea nuttallii	Western waterweed	Smalle waterpest	3	9		fresh water
Fallopia japonica	Japanese knotweed	Japanse duizendknoop	4	11	yes	fields, forest
Heracleum mantegazzianum	Giant hogweed	Reuzenberenklauw	5	20	yes	fields
Ligustrum ovalifolium	Oval-leaved privet	Haagliguster	4	13		dunes
Pinus sylvestris	Scots pine	Grove den	5	19		forest
Populus alba	Silver poplar	Witte abeel	6	28		forest, dunes
Populus x canescens	Grey poplar	Grauwe abeel	5	25		forest, dunes
Prunus serotina	Black cherry	Amerikaanse vogelkers	5	28	yes	forest, dunes
Quercus rubra	Red oak	Amerikaanse eik	5	11		forest
Robinia pseudoacacia	Robinia	Robinia	3	8		forest, dunes
Rosa rugosa	Rugose rose	Rimpelroos	8	43	yes	dunes
Senecio inaequidens	Narrow-leaved ragwort	Bezemkruiskruid	6	18		dunes
Spartina anglica	Common cord-grass	Engels slijkgras	9	35		lower salt marsh
Symphoricarpos albus	Snowberry	Sneeuwbes	4	13		forest, dunes
Vaccinium macrocarpon	Cranberry	Cranberry	5	16	partly	dune valleys
Mosses						
Campylopus introflexus		Grijs kronkelsteeltje	7	31	yes	dunes

Table 3 *Invasive fresh water plant, included in the Covenant Water Plants, which occur on one or more Wadden Sea islands with presumed negative impact on biodiversity, with number of islands where the species is recorded and the total number of 5x5 km squares where the species, is recorded.*

Scientific	English	Dutch	# islands	# squares	habitat(s)
Azolla filiculoides	Waterfern	Grote kroosvaren	2	7	fresh water
Cabomba caroliniana	Green cabomba	Waterwaaier	0	0	fresh water
Crassula helmsii	Australian swamp stonecrop	Watercrassula	2	2	fresh water
Egeria densa	Egeria	Egeria	1	1	fresh water
Eichhornia crassipes	Water hyacinth	Waterhyacinth	0	0	fresh water
Hydrocotyle ranunculoides	Floating pennywort	Grote waternavel	1	1	fresh water
Hydrilla verticillata	Hydrilla	Hydrilla	0	0	fresh water
Ludwigia grandiflora	Water-primrose	Waterteunisbloem	0	0	fresh water
Ludwigia peploides	Floating primrose-willow	Kleine waterteunisbloem	0	0	fresh water
Myriophyllum aquaticum	Parrot's feather	Parelvederkruid	2	2	fresh water
Myriophyllum heterophyllum	Watermilfoil	Ongelijkbladig vederkruid	0	0	fresh water
Pistia stratiotes	Water cabbage	Watersla	1	1	fresh water
Salvinia molesta	Kariba weed	Grote vlotvaren	0	0	fresh water

Table 4 *Vertebrate invasive alien species, which occur on one or more Wadden Sea islands with presumed negative impact on biodiversity, with # of islands where the species is recorded and the total # of 5x5 km squares where the species, is recorded.*

Scientific	English	Dutch	# islands	# squares	measures	habitat(s)
Mammals						
Oryctolagus cuniculus	*Rabbit*	Konijn	6	39	yes	dunes, forest,
Rattus norvegicus	*Brown rat*	Bruine rat	5	20		dunes, forest, salt marsh
Mustela furo	*Ferret*	Fret	1	1		dunes, forest,
Birds						
Alopochen aegyptiaca	*Egyptian goose*	Nijlgans	5	29	yes	dunes, forest, salt marsh, arable fields
Branta canadensis	*Greater Canada goose*	Grote Canadese gans	4	15	yes	dunes, salt marsh, arable fields
Feral mammals						
Felis catus	*Feral cat*	Huiskat	5	38	yes	dunes, forest, salt marsh, arable fields
Fish						
Cyprinus carpio	*Common carp*	Karper	3	7		fresh water
Lepomis gibbosus	*Pumpkin sunfish*	Zonnebaars	2	2		fresh water
Sander lucioperca	*Pikeperch*	Snoekbaars	1	4		fresh water
Carassius auratus	*Goldfish*	Goudvis	3	4		fresh water

Feral species

Four feral species are known to occur on the Dutch Wadden Sea islands: feral cat (Table 4), feral goose, feral duck and feral dove. Feral cats are a threat to ground nesting birds and ground dwelling mammals. They are managed on several islands by fauna management units, supported by the governmental authorities. On other islands the cooperation between authorities and fauna management units is less effective, in some cases also limited by legal procedures. Feral ducks and feral geese are increasing in numbers (Lensink *et al*., 2013a,b) and hybridize with wild mallards and greylag geese. In addition, feral geese mix with flocks of wild greylag geese, which locally overgraze and enrich vulnerable, nutrient-low wet grasslands in dune valleys. For this reason, local breeding populations of greylag goose, including feral geese, are actively managed on Texel. Feral doves occur only in very small numbers and no negative impact on biodiversity if known.

Future developments

The number of invasive alien species, which potentially can become established on Wadden Sea islands, is large. Many alien species occur on the mainland, which can become established and spread by natural dispersal from the mainland (plants dispersed by wind and birds, birds and other groups). New illegal introductions of both native and alien species may occur, as well as accidental escapes of vertebrates kept as pets (e.g., raccoon, various opossum species, striped skunk among others).

3 Inventory and current status of management actions

3.1 Legal instruments, conventions and guidelines

Currently, at least 18 different legal instruments apply to the management of IAS within the trilateral region (Table 3.1). These include national legislation derived from EU directives (Habitat and Bird Directives, Marine Strategy Framework Directive, Water Framework Directive) and from EU regulations (Prevention and management of IAS 1143/2014, 708/2007 on IAS in aquaculture, 338/97 IAS in trade). Other legislation is derived from international conventions (IMO Ballast Water Convention), CITES (trade in endangered species) and IPPC (plant health). In addition to these legal obligations a substantial number of global and regional conventions include articles and guidelines on management of invasive alien species and have in various ways been implemented in national IAS policies and management plans. An overview of relevant EU Directives and regulations, as well as international conventions and guidelines, together with articles dealing with alien species is given in Appendix 1 (source: Nobanis). These legal instruments differ in general scope, type of human activity involved, focal habitat and targeted species (Bouma *et al.,* 2011, Table 1), but overlap to some extent. The requirements for monitoring and management are summarised in section 3.2 (Table 8) and section 3.3 (Table 9), respectively. The legal instruments will be discussed first as they provide an important obligatory framework for both monitoring and management. The scope of these legal instruments varies and is in different stages of national implementation.

EU Regulations are addressed to all EU member states and have to be implemented in full. They are directly applicable and do not need specific national legislation. EU Directives are addressed to all EU member states and require an objective to be achieved by a given date. National authorities must draw up specific legislation in order to conform to the Directive within a certain time period (the date of implementation is known as the date of transposition).

Until recently, no coherent legislation was available in Europe for management actions directed at IAS and the related pathway or vector, because the prevailing directives and conventions focus on other issues, like global or regional biodiversity in all or specific environments. Therefore, depending on scope and outreach each legal instrument separately has its strength and weakness with respect to managing IAS in general and the Wadden Sea area, in particular. The new EU Regulation on the Prevention and Management of the introduction and spread of Invasive Alien Species aims to close this gap. The EU directives and regulations, conventions and guidelines relevant for the Wadden Sea area are further discussed in this section and commented on in italics with respect to the situation in the Dutch part of the Wadden Sea and Dutch Wadden Sea islands.

Table 5 Overview of (18) EU legislation, conventions, guidelines and four codes of conduct relevant for management of IAS in the Wadden Sea (see Appendix 4 and text for details).

EU Directive or Regulation	**Acronym**	**year**	**Subject**	**Management focus**	**scope /habitat**	**scope/ species**
Council Regulation Management IAS 1143/2014	EU IAS	2014	Management IAS	1. pathway / vector related 2. IAS	1. location specific 2. species/area specific	all IAS
Bird Directive 79/409/EEC	N2000	1979	conservation birds	project / activity related	all habitats	all AS
Habitat Directive 92/43/EEC	N2000	1992	conservation habitats	project / activity related	all habitats	all AS
Marine Strategy Framework Directive 2008/56/EC	MSFD	2008	conservation marine habitats	general policy	all marine habitats	all species/ all AS
Council regulation 708/2007 aquaculture	EU aqua	2007	IAS in aquaculture	activity related	location specific	activity related AS
Council Regulation 338/97 trade	EU trade	1997	IAS in trade	trade related	not relevant	specific trade species
Water Framework Directive 2000/60/EC	WFD	2000	conservation fresh water habitats	general policy	all fresh water habitats	all AS
Global conventions						
Biological Diversity	CBD	1992	biodiversity	not specified	all habitats	all AS
Bonn Convention	Bonn	1979	Migratory animals	not specified	all habitats	all AS
Convention on International Trade of Endangered Species	CITES	1973	endangered species	border control	trade	listed IAS
International Maritime Organisation	IMO	2004	marine environment	ballast water	ports	all marine AS
Internation Plant Protection Committee	IPPC/EPPO	1951	plant health	border control	trade	all plant AS
Ramsar Convention	Ramsar	1971	wetland conservation	wetland birds	wetlands	waterbird AS
United Nations Convention of the Law of the Sea	UNCLOS	1982	marine environment	not specified	marine environment	all marine AS
Regional conventions						
African-Eurasian Waterbirds Agreement	AEWA	1995	African-Eurasian waterbirds	waterbirds	wetlands	all waterbirds/ AS
Bern Convention	Bern	1979	European biodiversity	project/ species related	project/ species related	project/ species related
Helsinki Commission, Baltic Sea	HELCOM	1992	Marine environment,	ballast water	ports	all AS
Oslo and Paris Commissions, Northeast Atlantic	OSPAR	1992	Marine environment, North East Atlantic	ballast water	ports	all AS
Guidelines/Code of conduct						
Food and Agricultural Organization of the United Nations	FAO	1995	agriculture	code of conduct	agricultureal habitats	terrestrial AS
International Union for Nature Conservation	IUCN	2000	biodiversity	general guidelines	all habitats	all AS
IMO fouling guidelines	IMO hull fouling	2012	marine environment	guidelines hull fouling	shipping	marine AS
International Council for Exploration of the Sea	ICES	2003	marine environment	code of practice	marine environment	marine AS

3.2.1 EU regulations and directives

EU Regulation No 1143/2014 on the Prevention and Management of the introduction and spread of Invasive Alien Species (EU IAS regulation).

This regulation on the prevention and management of the introduction and spread of invasive alien species has been adopted by 22 October 2014 (EU 2014). Its aim is to coordinate the efforts of the EU Member States to diminish the threats of Invasive Alien Species (IAS). The European Commission is of the opinion that this legislation will protect indigenous biodiversity as well as managing other risks of IAS, such as health, economy and safety. The Regulation focuses on a list of IAS of the greatest concern within the EU. This list is now under review and is likely to include more species.

The IAS on the final list will be controlled by three key management actions:

- Prevention of introduction into the area of Member States;
- Early warning and rapid response after detection of IAS populations;
- Management of established IAS populations to limit ecological impact and damage.

Prevention includes measures to ban the import and transport of IAS. Exemption licenses or permits may be provided for research and conservation. If a non-listed IAS becomes an acute threat in one of the Member States then the Regulation allows emergency measures to be taken. This approach is similar to emergency actions in sanitary, veterinary and phytosanitary issues. Appropriate measures controlling transports and imports of IAS must be implemented within a year after the regulation has come into force.

Early warning systems will require each Member State to set up a monitoring strategy and report IAS data at the EU level. Member States have 18 months after the enactment of the regulation to establish an adequate monitoring program.

Management of established IAS will require Member States to develop a surveillance program to follow established populations and evaluate the success of eradication programs. Member States also have to take measures to eradicate newly established IAS populations within three months after their detection. These management actions have to be implemented within 12 months after the enactment of the regulation.

The list of IAS of EU concern, which should be managed by the regulation, is currently under review by expert consultation in each Member State. A standardised risk assessment framework has been developed for the candidate IAS for the final list. The distribution across Member States was assessed for each IAS.

With this regulation the EU aims to effectively control the ecological and economic impact of IAS by a unified approach and concerted action. This is particularly necessary because IAS have no consideration for geopolitical borders and cause damage worth at least 15 billion euros per year in control/eradication, sanitary and

veterinary risks, damage to infrastructure and loss of agricultural production (Shine *et al.*, 2010).

This regulation is directly related to the existing EU targets on biodiversity and the current 2020 Biodiversity Strategy. This strategy includes specific measures to control or eradicate key IAS and further introduction of IAS by 2020.

Marine IAS substantially compliant with criteria of EU concern

Several marine IAS are substantially compliant with the criteria of the list of species of EU concern (Roy *et al.*, 2013) (Table 6). This is based on the available risk assessments carried out in the EU member states. For the Netherlands the list of species is now under expert review to be proposed to the EU in 2015. Tables in §3.1.1 mainly includes actual or potential IAS which are not yet present in the Wadden Sea and this information could be used to evaluate and adapt the current and proposed early detection, prevention and management actions in the trilateral Wadden Sea.

Table 6 *Marine invasive alien species which are substantially compliant with the EU criteria for "EU concern" (Roy et al., 2013) actually or potentially occurring in the Netherlands, with status established (1), high risk species after risk assessment (Appendix 4) (2) or potential invasive alien species in horizon scanning assessment (Matthews et al., 2013)(3), actual and potential presence in the Wadden Sea.*

Species	English name	status	Wadden Sea actual	Wadden Sea potential
Asterias amurensis	"Asian seastar"	3	no	?
Crassostrea gigas	Pacific oyster	1	yes	
Didemnum vexillum	Sea squirt	2	yes	
Homarus americanus	American lobster	3	no	yes
Morone americana	American seabass	3	no	yes
Ocinebrellus inornatus	Japanese oyster drill	2	no	yes
Paralithodes camtschaticus	Red king crab	3	no	?
Pileolaria berkeleyana	"Asian worm"	3	no	yes
Rapana venosa	Asian rapa whelk	3	no	yes
Urosalpinx cinerea	American oyster drill	2	no	yes
Venerupis philippinarum	Manila clam	2	no	yes
Watersipora subtorquata	Asian encrusting bryozoan	3	no	?
Undaria pinnatifida	Wakame	2	yes	
Caprella mutica	Japanese skeleton shrimp	1	yes	
Crepidula fornicata	Slipper limpet	1	yes	
Sargassum muticum	Japanese seaweed	1	yes	

1 established
2 high risk species after risk assessment
3 potential alien species in horizon scanning project

EU Natura 2000 network (Habitat Directive 92/43/EECand Birds Directive 79/409/EEC)

The Birds Directive provides a framework for the conservation and management of wild birds in Europe. It sets a broad objective regarding non-native birds, but leaves to the discretion of each Member State how compliance with these objectives is achieved. The Habitat Directive aims to promote the maintenance of biodiversity in the Member States by defining a common framework for the conservation of wild flora and fauna and habitats of Community interest. The Directive establishes a European ecological network known as the Natura 2000 network. The Habitat Directive is a part implementation of the CBD Convention at European level.

Although both directives include articles dealing specifically with invasive alien species, the general framework of the conservation goals of Natura 2000 areas provide a legal framework to manage the impact of invasive alien species within or close to these areas. Within Natura 2000 areas any new activity or project leading to introduction of new IAS, which might negatively impact the conservation goals has to be submitted to an environmental impact assessment procedure. If the negative impact cannot be mitigated, the new activity might be prohibited if the activity or project is not of substantial societal importance. The impact of established IAS is sometimes managed by measures taken in the context of the Natura 2000 management plan.

Many existing pathways and vectors already present in or just outside the Wadden Sea Natura 2000 areas for quite some time, however, are outside the scope of these directives, despite the specific articles dealing with IAS (Appendix 1). Monitoring or management of invasive alien species is not included in the Natura 2000 Management Plan of the Wadden Sea.

Marine Strategy Framework Directive 2008/56/EC (MSFD)

The EU Marine Strategy Framework Directive establishes a framework for the conservation of the marine environment. The objective of the MSFD is to achieve or maintain a “good environmental status” (GES) in the marine environment by 2020 at the latest (Article 1). Marine strategies will be developed and implemented “in order to protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been negatively affected”. For descriptor 2 of the MSFD, non-indigenous (synonym: alien) species, the GES shall be met if “non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem” (Annex I). The GES is determined at the level of marine (sub)regions. The Wadden Sea falls under the OSPAR-region “North-east Atlantic Ocean”, but Member States may implement the MSFD by reference to subdivisions in order to take into account the specificities of a particular area (Article 4(2)).

Marine strategies are developed by the Member States and implemented with the aim of achieving or maintaining good environmental status in the marine environment by the year 2020. The MSFD has several clear objectives to reduce the introduction,

establishment and impact of IAS in marine and coastal habitats (Appendix 1 in Directive).

Eleven generic qualitative descriptors are to be considered when determining the environmental status of waters. Alien species are specifically addressed in Descriptor 2: “Non-indigenous species introduced by human activities are at levels that do not adversely alter the environment”. Criteria and indicators for determining if this qualitative descriptor is achieved are currently being developed by each Member State. The proposed criteria that are under consideration are:

- *Prevention of new AS introductions*. Indicators for this are accounts of vectors associated with new introductions and changes in pathways and vectors
- *Prevention of establishment and spread of AS*. Indicators are Inventories of newly arrived AS and areas of their origin, trends in introduction of alien species and accounts of newly colonised localities.
- *Change in Species composition*. The indicator is the ratio between non-indigenous species and native species.
- *Prevention of spread of IAS*. Indicators are a target list on potentially harmful species and the abundance and distribution range of IAS.
- *The absence or minimal level of IAS impact*, which disturb environmental quality.

The trend in the arrival of new alien species has proposed as an indicator of the efficacy of policy instruments aimed at reducing the introduction of alien species (Costello *et al*., 2007). Olenin *et al*. (2007) developed the Biopollution level index as an additional indicator. Increasing biopollution indicates additional stress for the ecosystem. It is a signal of failed management concerning introductions of alien species. The index includes abundance, distribution range and impacts on native communities; habitats and ecosystem functioning are assessed. The EU MSFD good environmental status task group 2 on non-indigenous species has reviewed this indicator and considered it as a straightforward and practical way of assessing impacts of the NIS and their potential to become invasive. The Netherlands Marine Strategy only monitors the number of invasive alien species, the number of new invasive alien species and the ratio between density of invasive alien species and density of native species (Ministerie van I&M, 2014).

The MSFD requires Member States, which share a marine region to cooperate to ensure that the Directive’s objectives are achieved and to coordinate their actions using the structures of the regional sea conventions. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) is the relavant convention for the North Sea, the coastal zone and Wadden Sea region (see also below, section 3.1.3).

The initial assessment for alien species should be done by 2012 and include:

- An analysis of the current environmental status of waters which include an inventory of the temporal occurrence, abundance and spatial distribution of non-

indigenous, exotic species or where, relevant, genetically distinct form of native species, which are present in the region/sub-region;
- An analysis of the predominant pressures and impacts for introduction of non-indigenous species and translocations.

The Draft Marine Strategy for the Netherlands has been published in 6 March 2014 and after formal consultation the final Marine Strategy was published on 18 September 2014.

The MSFD objectives have specific monitoring requirements, which are to some extent implemented in current monitoring programs, which detect alien species as a side effect and also include the Wadden Sea. The management obligations, however, are too general for focused prevention or rapid reaction if a new IAS is detected.

Water Framework Directive 2000/60/EC (WFD)
The aim of the Water Framework Directive is to achieve Good Ecological and Good Chemical Status by establishing a framework for the protection of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and groundwater. It will ensure that all aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands meet 'good status' by 2015. The Dutch part of the Wadden Sea (between islands and coast) is designated under the WFD and the North Sea coastal zone of the Wadden Sea is designated under the MSFD.

The WFD requires Member States to set up river basin districts and for each a corresponding river basin management plan. The Directive envisages a cyclical process where river basin management plans are prepared, implemented and reviewed every six years. Although the text of the Water Framework Directive does not explicitly mention alien species, the European Commission have come to accept that alien species are a pressure on water bodies and invited the Member States to adress the alien species problem when implementing the Directive (e.g. IMPRESS 2002). The Wadden Sea Management Plan is part of the Rijn delta management plan and the Eems management plan.

Although IAS are considered as a major pressure in many aquatic ecosystems, few Member States (including the Netherlands) have included IAS in the assessment or monitoring of the ecological status of aquatic ecosystems (Vandekerkhove et al., 2013). The impact of alien species in the Wadden Sea on the food web with subsequent changes in species composition is acknowledged (e.g., Pacific oyster, RWS, 2012) and the national Policy Framework on Invasive Alien Species (see below, section 3.1.5). The consequences of the introduction of new alien species, however, are difficult to predict and have not led to any management actions.

Council Regulation (EC) no 708/2007 concerning use of alien and locally absent species in aquaculture
This regulation aims to optimise benefits associated with introductions and translocations of alien and locally absent species used in aquaculture, but to prevent

alterations in ecosystems and negative biological interaction including genetic change with indigenous populations and restricting the spread of non-target species and detrimental impacts on natural habitats. The main focus is on risk assessments of alien species before allowing introduction or translocation. Ten alien species are exempted from the regulations, including Pacific oyster C. g*igas* and Manila clam *Ruditapes philippinarum*.

The latter species is established in the Eastern Scheldt probably after active introduction (Wijnhoven & Hummel, 2009) and has not been found in the Wadden Sea.

Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora by regulating trade therein

One of the articles states that the Commission may establish restrictions relating to certain countries of origin, on the introduction into the Community of live specimens of species for which it has been established that their introduction into the natural environment of the Community presents an ecological threat to wild species of fauna and flora indigenous to the Community. In the annexes to the new directive a few invasive alien species that have become threats in importing EU-countries have been included: *Oxyura jamaicensis, Trachemys scripta, Rana catesbeiana*. The appendices are regularly updated.

The alien species regulated through CITES are only the intentional introductions since it is based on an approval system. Furthermore, it only relates to trade to the EU and not within the EU.

3.1.2 Global conventions

International Convention for the Control and Management of Ships' Ballast water and Sediments (Ballast water management and control, BWMC)

Parties must prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments. The parties may take more stringent measures with respect to these management actions, consistent with international law.

National legislation has been prepared, but will only be implemented if a certain number of countries have ratified the convention and a minimum amount of tonnage in ships has been reached.

The strength of this legislation is that it will be globally implemented (level playing field, but is clearly aimed only at one pathway and not yet in function. A wide variety of purification systems and compliance methods have been developed.

International Plant Protection Convention (IPPC)

The International Plant Protection Convention is an international treaty relating to plant health. While the Convention applies mainly to quarantine pests involved with

international trade it extends to the protection of natural flora and plant products. It also includes both direct and indirect damage by pests, thus including weeds. The provisions extend to cover conveyances, containers, storage places, soil and other objects or material capable of harbouring plant pests.

The International Plant Protection Committee aims primarily at international plant trade to prevent introductions of insects and weeds, which threaten agricultural crops. However, regulations also apply to insects harmful for native plants in natural habitats, such as the Asiatic longhorn beetle, which can cause much damage to natural forests. If this species is detected a rapid response is obligatory and all trees have to cut within a radius of several hundreds of meters from the point of detection.

This regulation also applies to the Wadden Sea islands. Its strength is global and standardised implementation, but the focus is mainly limited to agricultural plants.

Convention on Biological Diversity (CBD)
The Convention on Biological Diversity is an agreement to take action on specific points relating to biodiversity including the threats posed by alien species. Each party has to report its actions and how effective this is in meeting the objectives of the Convention. More than 180 states are now parties to the CBD. The CBD addresses the introduction of alien species globally. The Convention also works through legally binding agreements such as the COP decisions mentioned above. The CBD covers both unintentional and intentional introductions.

This convention has been very important for developing legal instruments to preserve biodiversity, such as the Habitats Directive, and was crucial for the development of national and EU policy plans focusing on IAS.

Convention on the Conservation of Migratory Species of Wild Animals *(Bonn Convention)*
The Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention) aims to preserve terrestrial, marine and avian migratory species throughout their range globally. Migratory species that need or would significantly benefit from international co-operation are listed in Appendix II of the Convention. Invasive alien species, which threaten migratory species listed in Appendix II may be subjected to management (e.g., Ruddy duck).

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
CITES is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. The convention works by subjecting international trade of selected species to certain controls. The species covered by CITES are threatened species which are listed in three appendices according to the degree of protection they need in the exporting countries. A provision states that the Convention does not limit the right of

Parties to adopt domestic measures restricting or prohibiting trade, taking, possession or transport of species not included in the appendices of the convention.

The provision has been used in Europe to address specific alien species (see EU regulation 338/97).

The Convention on Wetlands (Ramsar Convention)
The Convention's mission is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world. The Ramsar Convention has identified invasive species as one of the threats to wetlands.

United Nations Convention on the Law of the Sea (UNCLOS)
The Law of the Sea Convention or UNCLOS is concerned with the global marine environment and defines the responsibilities and rights of nations with respect to their use and the management of marine natural resources of the oceans worldwide, by establishing environmental guidelines for both businesses and governments. Member states (including those of the European Union) oblige to protect and preserve the marine environment from a "significant and harmful change" from the pollution by the intentional or unintentional introduction of alien species. Article 196 (1) of the Convention states that: "States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto."

3.1.3 Regional conventions

African Eurasian Waterbird Agreement
The AEWA-Agreement covers 235 bird species that depend on wetlands for at least part of their annual cycle. Geographically the area covers 117 countries from Europe, parts of Asia and Canada, the Middle East and Africa. Throughout the migration systems of waterbirds the states aim to ensure a coordinated approach as well as a wide range of conservation actions (defined in the Action Plan). The Action Plan addresses species and habitat conservation, management of human activities, research and monitoring, education and information, and implementation. Another activity of the AEWA-Agreement is a regular review of the status of each migratory water- bird population within the Agreement area. The agreement has several articles dealing with invasive species. There is special attention to the eradication of the Ruddy duck *Oxyura jamaicensis* as part of action plan for conservation of the globally threatened White-headed duck *O. leucocephala*.

Ruddy ducks can potentially occur in shallow fresh water areas with abundant submerged vegetation on Wadden Sea islands.

Bern Convention

The Bern Convention is a binding international legal instrument in the field of nature conservation and its aim to preserve wild flora and fauna, their natural habitats and to promote European co-operation in that field. Several recommendations under the convention have dealt with alien species, including one which recommends the eradication of: *Mustela vison* (American mink), *Ondatra zibethicus* (Muskrat), *Myocastor coypus* (Coypu), *Sciurus carolinensis* (Grey squirrel), *Oxyura jamaicensis* (Ruddy duck), *Cervus nippon* (Sika deer), *Procyon lotor* (Raccoon), *Nyctereutes procyonoides* (Raccoon dog), *Castor canadensis* (Canadian beaver), *Trachemys scripta* (Red eared slider or terrapin), *Rana catesbeiana* (American bull frog). Most of these species can potentially be introduced to Wadden Sea islands.

If Ruddy ducks would be observed on a Wadden Sea island, then eradication would be an appropriate rapid response according to the AEWA White-headed duck action plan and would also fulfill the obligations of the Bern Convention.

Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)

The OSPAR Convention is the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. The OSPAR Commission manages the work under the convention and is made up of governmental representatives of the Contracting Parties (including the trilateral Wadden Sea countries) and the European Commission, representing the European Union. The Convention uses a definition of pollution, that enables the OSPAR to also deal with alien species (or biopollution): "Pollution" means the introduction by man, directly or indirectly, of substances or energy into the maritime area which results, or is likely to result, in hazards to human health, harm to living resources and marine ecosystems, damage to amenities or interference with other legitimate uses of the sea." In 2008 the OSPAR countries have started preparations on a collective approach on the regional aspects of the implementation of the MSFD. They have developed a road map, which includes the issues for cooperation and coordination, the requirements of the MSFD and the necessary steps to be implemented with a timetable up to 2012 (OSPAR, 2010).

3.1.4 International guidelines / Code of Conduct

HELCOM/OSPAR Guidelines on the granting of exemptions under the International Convention for the Control and Management of Ships' Ballast Water and Sediments, Regulation A-4 (Helcom Baltic Marine Environment Protection Commission 2013):

These voluntary guidelines assist applicants and national authorities with the realization of inventories of (invasive) alien species in ports as part of a risk assessment undertaken in the application process for an exemption under the Ballast Water Management Convention.

IUCN Guidelines for the prevention of Biodiversity Loss Caused by Alien Invasive Species, 2000

The guidelines are intended to assist governments and management agencies in their implementation of article 8h of the Convention on Biological Diversity. The overall aim is to reduce the negative effects of alien invasive species. The guidelines were prepared by the SSC Invasive Species Specialist Group.

ICES code of practice on the Introduction and transfer of Marine Organisms, 2003

The ICES Code of Practice recommends procedures and practices to reduce the risks of the intentional introduction and transfer of marine (including brackish water) organisms. See also report from the working group on introduction and transfer of marine organisms (2003).

IMO Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species

The IMO adopted a guideline for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species by international shipping (adopted by MEPC 15 July 2011). These voluntary guidelines provide a full management strategy to manage hull fouling and the possible invasive alien species risks involved. Specific requirements to minimize the transfer of invasive aquatic species through biofouling are as follows:

- Each ship should imply hull husbandry, that is, to hold a biofouling management plan and a biofouling record book;
- Each ship should have and maintain an anti-fouling system (i.e. biofouling preventions systems and / or biofouling resistant materials);
- Ships should regularly undergo in-water inspections, cleaning and maintenance by accredited biofouling inspection divers or other means;
- Ships' masters and crews should be trained in biofouling management and treatment procedures;
- Biofouling prevention should be considered in the design and construction of new ships;
- States should maintain and exchange relevant information related to the management of biofouling.

IMO Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (Hull Fouling) for Recreational Craft.

The IMO developed biofouling management guidelines especially for recreational shipping (adopted by the IMO 12 november 2012). It has been recognised that recreational shipping can be a major vector for species introductions in some areas. The guidelines for managing hull fouling on recreational craft are as follows:

- Explanation in layman terms for what biofouling is, how it occurs and why the spread of alien species is a problem;
- Explanation that all boats and trailers can be affected;

- Explanation that specific anti-fouling systems should be used for specific applications;
- Explanation of 'niche' areas and biofouling control in those areas ('niche areas' are specific areas susceptible to biofouling such as propulsion units, rope guards, outlets, sea chests etc.);
- Detailed explanation of in-water and out-water cleaning procedures and legislation;
- Recommendations for recording biofouling related activities.

It should further be addressed what to do with material scraped from vessel hulls. This should not re-enter the aquatic environment without treatment.

3.1.5 National IAS legal instruments and policy: the Netherlands

Flora and Fauna Act

The Flora and Fauna Act is the primary piece of legislation that deals with the protection of species. It is prohibited to release any animal or egg into the wild, including alien species. It is forbidden to introduce, buy, sell, transport etc. plants or animals that are listed in the governmental decree (Decision concerning appointment of animal and plant species under the Flora and Fauna Act and Decision concerning combating harmful organisms), and that pose a threat to the survival of protected indigenous species or cause a significant deterioration of conditions that are vital for the survival of those species. The Minister of the Department of Economic Affairs has the power to return animals/plants, which are brought within the territory of the Netherlands illegally, i.e. without the required permits. The owner/transporter/importer will pay for these costs.

The regulation for management and damage control of animals has been changed on 29 September 2008 (TRCJZ/2008/2630). Several IAS have been added and ecological damage to nature has been included to motivate management or eradication of IAS. Provincial fauna management units carry out the management or eradication of animals causing damage to agriculture, infrastructure, fisheries and nature.

The Flora and Fauna Act also applies, for example, to alien species used as pets, which are occasionally released on Wadden Sea islands. The IAS listed for management or eradication by fauna management units are presented in Table 7.

Table 7 *List of invasive alien species, which can be eradicated or managed in the Netherlands, including Wadden Sea islands according to the amendment of the Flora and Fauna Act in 2008 (see text).*

English name	Scientific name
Coypu	*Myocastor coypus*
Grey Squirrel	*Sciurus carollinensis*
Bar-headed goose	*Anser indicus*
Raccoon dog	*Nyctereutes procyonoides*
Mouflon	*Ovis orientalis*
Muntiac	*Muntiacus reevesi*
Musk rat	*Ondatra zibethicus*
Egyptian goose	*Alopochen aegyptiaca*
Ruddy duck	*Oxyura jamaicensis*
Siberian groundsquirrel	*Tamias sibericus*
Raccoon	*Procyon lotor*
Black swan	*Cygnus atratus*

Nature Conservation Act 1998

Art. 16 and 19 - It is prohibited to perform certain acts without a permit, which could harm animals or plants that live in a protected environment (art. 16) or a Natura2000 zone (art. 19d) or would have a significant detrimental effect on species that live in this protected environment. It is generally accepted that releasing IAS into the wild is an act prohibited in articles 16 and 19d. According to the Policy plan on Invasive species (see below), this could also apply to the introduction of IAS in a protected nature area, as the IAS could have significant negative impacts on the indigenous species that live in the area.

This act is currently the most prominent legal instrument to prevent introduction of IAS in Natura2000 areas where these species do not occur and could have a negative impact on the conservation goals of the Natura2000 area. This is, for example, implemented to the mussel transports from the Eastern Scheldt to the mussel culture plots in the Western Wadden Sea.

Policy Framework on Invasive Alien Species

The Policy Framework on IAS is described in this document. It was published in 2007 and is the most detailed action plan on IAS, but is non-binding.

As part of this policy plan the Invasive Alien Species Team (now part of the Netherlands Food and Consumer Product Authority, Ministry of Economic Affairs) was established in 2009, which signals and monitors alien species, carries out risk assessments and has initiated prevention, eradication and management actions for selected IAS.

Table 8 Monitoring requirements derived from EU legislation and conventions.

Legislation and conventions	acronym	monitoring requirements	scope/ habitat	scope/ species	frequency	monitoring
EU Directive or Regulation						
Council Regulation Management IAS 1143/2014	EU IAS	1. pathway / vector related 2. IAS	1. location specific 2. species/area specific	all IAS	continuous, annually	1. new introductions, 2. impact
Bird Directive	N2000	Project / activity related	all habitats	all AS	activity related	new introductions
Habitat Directive	N2000	Project / activity related	all habitats	all AS	activity related	new introductions
Marine Strategy Framework Directive	MSFD	continuous	all habitats	all species/ all AS	continuous, annually	new introductions, impact
Council regulation 708/2007 aquaculture	EU aqua	activity related	location specific	activity related AS	activity related	activity related
Council Regulation 338/97 trade	EU trade	trade related	not relevant	specific trade species	not relevant	not relevant
Global conventions						
Biological Diversity	CBD	not specified	-	-	-	-
Bonn Convention	Bonn	not specified	-	-	-	-
Convention on International Trade of Endangered Species	CITES	border control	trade	listed IAS	continuous	introductions
International Maritime Organisation	IMO	ballast water	ports	all marine AS	continuous	introductions
International Plant Protection Committee	IPPC/EPPO	border control	trade	all plant AS	continuous	introductions
Ramsar Convention	Ramsar	wetland birds	wetlands	waterbirds	annually	introductions, impact
United Nations Convention of the Law of the Sea	UNCLOS	not specified	-	-	-	-
Regional conventions						
African-Eurasian Waterbirds Agreement	AEWA	waterbirds	wetlands	all waterbirds /AS	annually	introductions, impact
Bern Convention	Bern	project/species related	project/species related	project/species related	projectwise	impact, evaluation
Helsinki Commission, Baltic Sea	HELCOM	ballast water	ports	all AS	annually	introductions, impact
Oslo and Paris Commissions, Northeast Atlantic	OSPAR	ballast water	ports	all AS	annually	introductions, impact

3.2 Monitoring marine alien species in the Dutch Wadden Sea

An overview of the monitoring requirements from EU directives, regulations and global and regional conventions is given in Table 8 (p. 45). An overview of the monitoring programs in the Dutch part of the North Sea and North Sea coastal zone which include the Wadden Sea or specifically for the Wadden Sea with subject, monitoring type program name, environment, focal species and relevant regulations is presented in Table 9 (p. 56). This table presents an overview of all relevant monitoring programs (including inspections), which can detect alien species, and follows the monitoring and survey types, which serve legislative requirements as identified by Lehtiniemi *et al*. (2015). The monitoring programs or inspections in Table 9 are ordered according to subject (pathway, species or general biodiversity) and information is included on focal habitat or inspection site, focal species or species group, relevant regulations and monitoring type as presented in Figure 3 and discussed below.

3.2.1 Information needs and monitoring questions

A comprehensive assessment of information and monitoring needs was carried out amongst stakeholders in the Wadden Sea region (Vugteveen *et al.* 2014). In this assessment, which included online surveys, the topic of alien species scored high. Respondents specifically had an interest in learning more about the (long-term) effects of alien species on the Wadden Sea ecosystem, e.g. the effects of alien species on food webs, which in turn might be impacting bird populations. Other information needs concerned the vectors and spread of alien species and more specifically, ballast water as one such vector. The need for an inventory of the occurrence and distribution of alien species in the Wadden Sea was stated, as well as the need to carry out long-term, regular surveillances of the effects of alien species on the Wadden Sea ecosystem. However, the current monitoring was considered inadequate for keeping track of introductions of new species (e.g. via mussel transports or shipping) as well as for finding out more about the effects of alien species on the Wadden Sea ecosystem. In summary, questions concerned the full scope of the invasion process, including questions about the origin and transfer of alien species, their dispersal, to their effects on the Wadden Sea ecosystem.

Regulation-driven information needs

In addition to research-driven questions, there are regulation-driven information needs resulting from various legal instruments, which apply to the management of alien species in the trilateral Wadden Sea region. In the following, an overview of these regulation-driven information needs is given.

Water Framework Directive (2000/60/EC):

As mentioned in section 3.2.1 the WFD aims to achieve Good Ecological and Good Chemical Status. The ICES Benthos Ecology Working Group described the key principles of the Water Framework Directive and Marine Strategy Framework Directive and suggested that the way forward is to focus on the effect of alien species (function,

niche) on the ecosystem, and to follow the precautionary principle by installing an early warning system (monitoring program) on a national level (Van Hoey *et al*. 2010).

Council Regulation concerning use of alien and locally absent species in aquaculture (EC No 708/2007 of 11 June 2007):
The regulation specifies that alien species shall be monitored after their release into open aquaculture facilities for a period of two years or a full generation cycle, whichever is longer. Questions that the monitoring needs to answer are:

- Have the impacts of the alien species in question been accurately predicted?
- Are there additional or different impacts?
- What is the level of spread or containment of the alien species?

The advisory committee, after the evaluation of the monitoring programme, may "require longer monitoring periods to assess any possible long-term ecosystem effects" (Article 18(2)).

Marine Strategy Framework Directive (2008/56/EC):
As mentioned in section 3.2.1 the objective of the MSFD is to achieve or maintain a "good environmental status" (GES) in the marine environment. In order to judge if the GES of alien species (descriptor 2), particularly invasive alien species, has been met, the following questions need to be answered:

- What are the trends in abundance of alien species in the Wadden Sea?
- What is the temporal occurrence of alien species in the Wadden Sea?
- What is the spatial distribution of alien species in the Wadden Sea?

These shall be investigated with special regard to risk areas, and in relation to the main vectors and pathways of the spreading of alien (invasive) species.
Furthermore, the environmental impact of invasive alien species was named as a criterion in the COM Decision (2010/477/EU). Indicators for this criterion are the "ratio between invasive non-indigenous species and native species in some well-studied taxonomic groups that may provide a measure of change in species composition" and "impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible".

Regulation of the European Parliament and of the Council on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (EU No 1143/2014):
This regulation addresses the problem of invasive alien species in terrestrial as well as aquatic environments (see also section 3.2.1). A preliminary list of invasive alien species of potential EU concern has been proposed by the Commission (included in the report of Roy *et al*., 2013) and currently contains only one marine species, *Sargassum muticum*, but a few more species would be fully compliant with the risk criteria (Table 6, Roy *et al*., 2013). Monitoring of alien species from the list of Union concern shall be done by making use of monitoring already established under Union legislation (European Commission 2014), e.g. via the assessments under the MSFD.
The effectiveness of management actions (eradication, population control or containment) in minimizing the impacts on biodiversity and ecosystem services shall

be surveyed, making use of the same monitoring programme set up for early detection of alien species on the list of Union concern.

Joint HELCOM/OSPAR Guidelines for ballast water management exemptions (see also section 3.2.1):
A minimum of three sites should be sampled twice a year (spring and late summer in order to identify species throughout all life-cycles) in each port, but more sampling sites may be required, depending on the size and type of port. All main substrate types are to be sampled for fouling organisms, benthic infauna, mobile epifauna and plankton. Thereby special attention must be given to high priority areas. The prescribed timing of surveys for maintaining an exemption is a minimum of every five years. Questions that need to be answered are:

- Are the target species present in both ports?
- Are the target species equally common in both ports?
- Do ports have different/similar salinities? How much do they differ?

In the case of the Dutch Wadden Sea, the "implementation of particular aspects of the environmental status not covered by the WFD or other EU legislation will be addressed within the framework of the Trilateral Wadden Sea Cooperation, not requiring the formal application of the MSFD to the Wadden Sea" (Wadden Sea Board 2012, p. 5).

In summary, information needs and monitoring requirements result from several European and global legal instruments. These questions concern trends in abundance, temporal occurrence, spatial distribution and impacts of invasive alien species (Hoffman *et al*., 2011; Trebitz *et al.*, 2009). These questions can be structured within the unified framework for biological invasions (Figure 2; Blackburn *et al.*, 2011) and different monitoring types apply to different invasion stages (Figure 3).

3.2.2 Monitoring in the Dutch Wadden Sea

Since 2009, a number of alien species inventories have been done in the Dutch part of the Wadden Sea, which can form the basis for a future long-term monitoring program. In addition, there exist a number of long-term monitoring programs which do have other objectives than the monitoring of alien species, but which could also provide data on alien species for use in a trilateral long-term monitoring of alien species.

By the end of 2014, three rapid assessments of the alien macroflora and macrofauna of the Dutch Wadden Sea had been performed in relation to mussel transports from the Oosterschelde to the Wadden Sea. In 2009 and 2011, only hard substrates were surveyed, whereas in 2014, both hard substrates and soft sediments were investigated. In addition, experiments with settlement plates and a unique inventory in

the military harbor of Den Helder have been done. The numbers are used as a reference for Table 9.

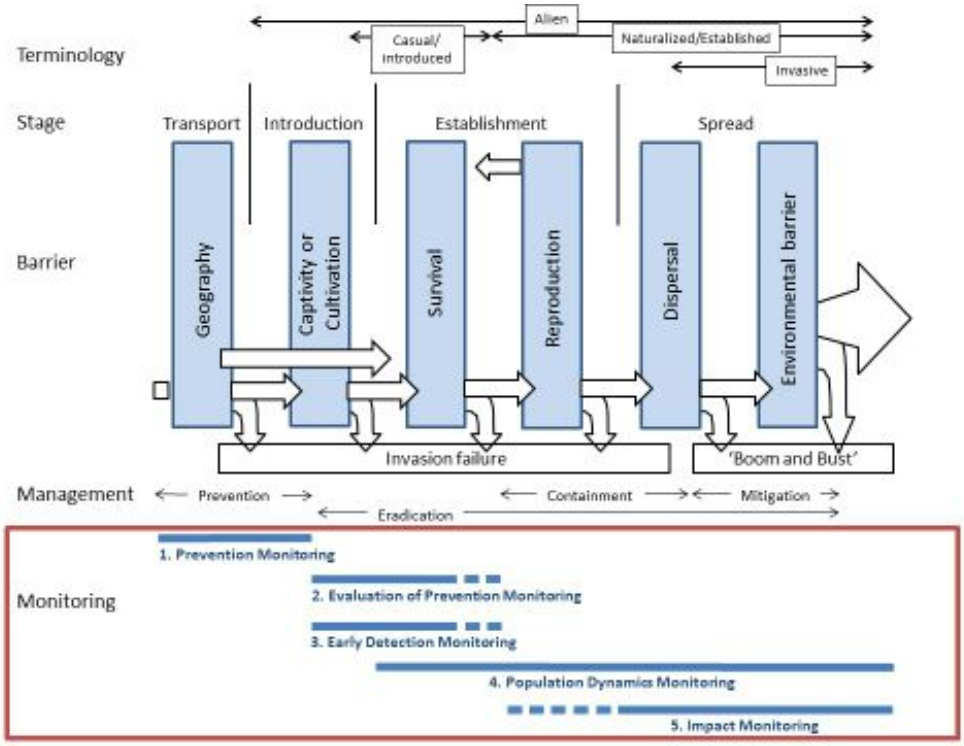

Figure 3 *The proposed unified framework for biological invasions developed by Blackburn et al. (2011), expanded by the different monitoring types that apply to stages of the invasion process and management interventions (red box) as described and used in this report. The dotted lines indicate that the time span that a monitoring spans can extend further, depending on the objectives of the monitoring program.*

1. Inventories of alien macroflora and -fauna in the Dutch Wadden Sea (2009 and 2011)

In 2009, the inventory for alien species was carried out within the framework of the "Covenant transition mussel sector and nature restoration" ("Convenant transitie mosselsector en natuurherstel Waddenzee") and was commissioned by the Team Invasive Alien Species of the Dutch Ministry of Agriculture, Nature and Food Quality (since 2012 Ministry of Economic Affairs). The inventory of alien species in 2011 was commissioned by the Dutch Mussel Culture Producers' Organisation (Producenten-organisatie van de Nederlandse Mosselcultuur) as part of a risk assessment of the South-North transport of mussel seed from the Oosterschelde to mussel culture plots in the Wadden Sea. Both inventories were primarily aimed at finding new alien species in the Wadden Sea. They will be continued if new licenses will be granted to the South-North transports of mussel seed.

In July and August 2009, GiMaRIS investigated the hard substrate of 83 locations with a variable salinity, ranging from 10 ppt (brackish) to 32 ppt (marine) (Gittenberger *et al*. 2009). Attention was paid to study as many different habitats as possible, e.g. mussel banks, marinas, and dikes, with various methods such as observations during snorkeling, the use of an underwater ROV (remotely operated vehicle) and fishing nets, and turning over rocks during low tide. Of the 129 species that were recorded, 28 were either alien or unknown to the region of which 12 species and one subspecies in turn had not been registered in the Dutch part of the Wadden Sea before. These findings increased the number of alien species or species with an unknown origin in the Dutch Wadden Sea recorded in the literature from about 50 species to 62.

In July till September 2011, the inventory as performed in 2009 was repeated and expanded by 13 locations, making it a total of 96 sample locations (Gittenberger *et al*. 2011). The salinity range was somewhat larger than in 2009, ranging from 8 to 33,5 ppt. Additionally, published and unpublished data on alien species in the Dutch Wadden Sea were included in the overview. Of the 159 species of macroflora and –fauna recorded, 34 species discovered in 2011 were either alien or of unknown origin. Eight of these were new discoveries for the Dutch Wadden Sea, and thus the total number of alien species for this subregion increased to 72.

2. Baseline study of non-native macroflora and -fauna of soft sediments and hard substrates in the Wadden Sea, including seed mussel plots (2014)
In the fall of 2014, the inventory performed in 2009 and 2011 was repeated, but this time extended to soft sediments in addition to hard substrates only (unpublished report Gittenberger *et al.* 2015, report status March 2015). The inventory was commissioned by the Team Invasive Alien Species of the Ministry of Economic Affairs and carried out by GiMaRIS for hard substrates and by NIOZ for soft sediments. The focus of the inventory was on new alien species, previously not described for the Dutch part of the Wadden Sea. The purpose of this inventory was to create a baseline of alien macroflora and macrofauna related to hard as well as soft sediments in the Dutch part of the Wadden Sea. The information is going to be used in the decision-making of the South-North transport of mussel spat and the trilateral discussions on alien species monitoring.

As in 2009 and 2011, the inventory focused on hard-substrate locations with a high chance of alien species' presence. The soft sediment sampling done by NIOZ made use of 100 of the random sample locations of the SIBES project. Samples were searched for all macroflora and -fauna and were not limited to certain species (groups). On the basis of species accumulation curves for the hard substrate inventory and the soft substrate inventory, respectively, rough indications of the percentage of the total number of species that could have been found and which were actually found with the methods used in the inventories, were generated.

3. SETL-project (since 2006)

Since 2006, experiments with PVC settlement plates have been performed by GiMaRIS in the harbours of Den Helder and Eemshaven. These experiments are part of the larger SETL-project, which investigates the fouling communities at 13 localities along the Dutch coast. With the help of the settlement plates, fouling alien species can be collected and the succession of marine fouling communities studied (e.g. Lindeyer & Gittenberger 2011, Gittenberger & van der Stelt 2011). Alien species that can be recorded with settlement plates mainly include ascidians, bryozoans, barnacles and, in more brackish waters, dreissenid bivalves (pers. comm. Arjan Gittenberger).

The design of this study is based on Ruiz *et al.* (2006). In the SETL-project, 125-150 grey, 14x14 cm large PVC plates are deployed horizontally at a depth of 1 m to observe which fouling communities grow on the underside of the plates over time. Every three months the settlement plates are being checked for new growth, photographed and species identified, and partly being replaced with new ones. Salinity of the surface water is known for all localities.

In the first instance, the SETL-project is used in the training of biology students who examine the settlement plates and analyse the data (pers. comm. Arjan Gittenberger). However, part of the project's data have also been used in policy, e.g. part of the data were collected for Rijkswaterstaat (part of the Dutch Ministry of Infrastructure and the Environment) in the frame of the implementation of the WFD and its pertinent monitoring, and have also been used in a report on risk assessments of hull-fouling for the Dutch Ministry of Economic Affairs (pers. comm. Arjan Gittenberger).

4. Inventory of alien species in the military harbour of Den Helder (2014)

In the autumn of 2014, an inventory of non-native macrofauna and -flora has been performed by GiMaRIS in the military harbour of Den Helder. The inventory was commissioned by the Team Invasive Alien Species of the Ministry of Economic Affairs with the objective to gain knowledge on alien species in this specific location. This inventory may give an idea of alien species transported by this different category of ships between (military) harbours that are not necessarily located along the common trading routes, thus possibly pointing to (groups of) alien species previously not appropriately accounted for in assessments of vectors and invasion pathways. No results are publicly available yet (status: February 2015).

5. Balgzand intertidal transect programme (since 1973)

On the tidal flat area "Balgzand" in the westernmost part of the Dutch Wadden Sea, the macrozoobenthos community has been monitored at 15 fixed sampling sites (12 transects 1 km long, and 3 squares 30 × 30 m) since the early 1970s. The monitoring programme comprises biannual (late winter: February-March, late summer: August-September) estimates of numbers (n m^{-2}) and biomass (g AFDW m^{-2}) of all macrobenthic animal species (those retained on 1 mm sieves). The sampling sites cover the entire intertidal depth range and have a wide range of sediment

compositions. Along each transect, 50 cores are taken at equal intervals of 20 m, covering a total of 0.45 m^2 (summer) or 0.95 m^2 (winter) per transect. In winter, larger samples are taken compared to summer, as numerical densities are generally lower in winter than in summer. In addition, 18 – 32 samples are taken per square, covering 0.95 to 1.7 m². Sampling depth is 35 cm. Samples are taken to the laboratory, live animals identified up to species level and counted, and bivalves are measured and allotted to year-class level.

6. Synoptic Intertidal Benthic Surveys (SIBES) (since 2008)

Macrozoobenthos and sediment particle sizes throughout the whole of the Dutch Wadden Sea have been investigated in the frame of the SIBES project at NIOZ since 2008. Goal of the project is the description of the species composition of the macrozoobenthic infauna (worms, crustaceans, bivalves) as well as the particle size distribution of tidal flats in relation to natural gas extraction in the Dutch Wadden Sea. With this information, long-term changes of the Wadden Sea macrobenthic fauna and the consequences for the carrying capacity of the Wadden Sea shall be investigated and described. Furthermore, SIBES aims at monitoring the introduction of alien species.

Information about alien macrozoobenthos can be retrieved from the database through a species-specific search or by searching for the term “alien species” in general. The database is limited to specific macrozoobenthic taxa and does not contain information on e.g. barnacles, hydrozoa and bryozoa. In the fall of 2014, 100 of the SIBES random locations were specifically surveyed for alien species. This survey included all macrozoobenthos as well as macrophytobenthos (see above for a more detailed description).

7. MWTL macrozoobenthos monitoring in the Wadden Sea and the Eems-Dollard (since 1990)

As part of the environmental monitoring network “Monitoring Waterstaatkundige Toestand des Lands” (MWTL) by Rijkswaterstaat (part of the Dutch Ministry of Infrastructure and the Environment), a number of sampling programs take place with potential relevance for a future monitoring program of alien species.

The MWTL (*Monitoring Waterstaatkundige Toestand des Lands*) is a long-term monitoring program of the Ministry of Infrastructure and Environment. The aim is to describe the water quality and biology of the Dutch waters and combines chemical, hydrographical and biological monitoring. Part of this program monitors the macrozoobenthos in the soft sediments communities in the North Sea, the Dutch coastal zone, the delta area and the Wadden Sea. Samples are taken twice a year in spring and autumn on fixed locations.

The MWTL Wadden Sea includes three transects in the western Wadden Sea (135 samples in total) that were sampled twice-annually from 1990 onwards up to 2011. Sampling intensity was increased to 17 transects, including the Eems-Dollard area in

1991 (60 samples) and Eastern Wadden Sea in 1998 (100 samples), that are sampled twice-annually. From 2011 onwards sampling is reduced to once every three years in spring and autumn, with an exception for the “high-risk” area of Eems-Dollard that is still sampled twice-annually. In a year with a complete program (e.g., 2014) 295 samples are taken in total, while in an intermediate year only 60 samples are taken in the Eems-Dollard area.

Measured variables include density (N/m^2) and biomass (mg $AFDWm^{-2}$) per species per sample with corresponding sampling area (in m^2) and sampling depth (in m under NAP), co-ordinates of sampling location, date and substrate type. In the Wadden Sea locations are visited on foot and samples are taken with a box corer of 0,078 m^2 surface area at 15 – 35 cm depth. Samples are washed with a sieve with a mesh size of 1 mm. Most species of all taxonomic groups are identified to species level. In some genera, individuals, that are not complete or in a juvenile stage, are regularly not identified at species level.

The monitoring information can be requested from the Service desk Data of the Ministry of Infrastructure and Environment. Alien species are not indicated as such and queries targeted only at alien species are not yet possible. The efficiency of the MWTL monitoring program of all marine and estuarine areas in detecting marine alien species has recently been evaluated (Didderen *et al*., 2015). This evaluation shows that the MWTL program has detected all relevant alien macrozoobenthos species occurring in marine and estuarine soft sediments (high detection rate). The time lag compared to alternative observations (by citizen science and other marine monitoring programs) is relatively small (1-2 years). Several recently introduced alien species have been detected first by the MWTL program (e.g., the large, polychaete worm *Marphysa sanguinea* (Wijnhoven & Dekker, 2010) and Manila clam *Ruditapes philippinarum* both in the Oosterschelde. The detection probability (or detection power), which depends on the number of samples in relation to total species richness (and also the number of rare species in the species assemblage), is relatively high in the Wadden Sea surveys. The number of marine alien species regularly occurring in soft sediments (and targeted by the MWTL surveys) is only a small proportion (roughly one tenth) of the total number of marine alien species found in the Netherlands. Despite this, alien species surveys of soft sediments are still of considerable importance, because soft sediments are an essential component of all marine, coastal and estuarine habitats of all marine, coastal and estuarine Natura 2000 areas in the Netherlands.

8. NIOZ fyke net monitoring (since 1960)

Since 1960, fish have been monitored near the southern part of Texel, de Hors, at the Western entrance of the Dutch Wadden Sea in spring (April–June) and autumn (September–October). A description can be found in Van der Veer *et al*. (2011). Fishing is done with a passive trap, which consists of a pound net and a fyke supported by wooden poles and with a leader of 200 m running from above the high water mark into the subtidal. At the end, two chambers catch and retain fish and other

species. The stretched mesh size of the leader and the two chambers is 20 mm. The fyke net is emptied every morning from Monday to Friday, irrespective of tidal phase, except on occasions of bad weather conditions. When catches are low, the net is emptied every other morning. All catches are sorted immediately down to species level and individuals are measured to the nearest cm in total length.

9. WOT Shellfish Shellfish Survey North Sea Coastal Zone

This survey is carried out since 1995 to assess the stocks of commercially relevant shellfish species, including *Ensis directus*. The Ministry of EZ commissions the program.

10. Long-term phytoplankton monitoring at the NIOZ Jetty (since 1974)

Since 1974, the Wadden Sea phytoplankton species composition has been determined as part of the long-term field observation program carried out at the NIOZ Jetty. A description can be found in Ly *et al.* (2011). The NIOZ Jetty is located in the Marsdiep basin near to the inlet between the North Sea and the Wadden Sea. Surface water samples have been collected using a bucket at a sampling frequency from once a month in midwinter and twice per week during spring blooms. Phytoplankton samples are being preserved with Lugol's iodine and the preserved cells are then counted with a Zeiss inverted microscope using 5-ml counting chambers. Most algae are identified to species level; some are clustered into coarser taxonomic and size groups (e.g. small flagellates).

11. ICES BTS IBTS and Demersal Fish surveys (DFS)

The Ministry of EZ commissions the monitoring to assess fish stocks including relevant macro- and megabenthic species by sediment trawling in the North Sea and North Sea coastal zone including delta area and Wadden Sea (de Boois & Bol, 2012).

12. PRODUS Subtidal macrozoobenthos western Wadden Sea (2008)

This survey sampled the macrozoobenthos in the subtidal of the western Wadden for comparison with earlier surveys (Dekker & Drent, 2013).

13. Pacific Oyster Survey

Subtidal and intertidal stocks of Pacific oyster *C. gigas* are annually assessed in the Wadden Sea and Delta area since 2011 as part of sustainable fisheries (Brummelhuis *et al.,* 2012). The Ministry of EZ commissions this program.

14. WOT shellfish sanitary/veterinary

The Central Veterinary Institute (Lelystad) monitors the occurrence of several infectious shellfish diseases (Bonamia, Marteilla) and several plankton species, which cause sanitary risks by producing toxic substances, which cause Paralytic Shellfish Poisoning (PSP). All species involved are also invasive alien species.

15. Risk assessments profiles of species/areas

Risk assessments of a number of marine and terrestrial invasive alien species and risk profiles of areas have been published (mainly in English), which were commissioned by the Ministry of EZ. An overview of species and references is presented in Appendix 4 with link to the website where the pdf's are available.

16. Import and export licensing aquaculture

Aquaculture imports and exports are regularly checked at border locations (airports, harbours) with respect to veterinary and sanitary risks. These include usually administrative inspections with additional random sampling.

17. Border control

Customs regularly inspects commercial goods and persons at border locations (airports, harbours) for general security, biosecurity and CITES listed species. After implementation of the new EU IAS regulation this inspections may also include IAS of EU concern.

18. Biomonitoring of microzooplankton in the Dutch marine waters

The species richness of the microzooplankton is determined at several locations in the North Sea, North Sea coastal zone, Delta and Wadden Sea and includes several alien species (Verweij *et al*. 2013). This monitoring program is part of the MWTL program and commissioned by the Ministry of I&M. It also has relevance (but is not officially linked) to ballast water management regulations.

3.2.2 Monitoring alien species on the Wadden Sea islands

Information needs and monitoring questions

Most parts of the dunes and salt marshes on the Wadden Sea islands is designated as Natura 2000 area and protected by the Nature Conservation Law 1998 (Natuurbeschermingswet 1998) and managed or owned by a Nature or Site Management Organisations (Terreinbeherende Organisatie) and managed as nature reserves according their own management plans.

The designation as protected area was based on factual information on the presence of special species assemblages from various sources. The quality of this information has gradually increased in the last decennia, in particular as a result of increasing quality in monitoring survey methods and implementation. These terrestrial monitoring programs were focused on vegetation and birds and much less attention was given to other taxonomic groups. Site management organisations initiated and controlled these monitoring programs traditionally, but the governmental responsibility has increased in particular as a result of the legal obligations following the designation as Natura 2000 areas. In this framework and as part of the Natura 2000 management plans the species included in the conservation goals have to be monitored on a regular basis.

Tabel 9 *An overview is presented of monitoring programs in the North Sea and coastal zone including Wadden Sea with subject, monitoring type (cf. Lehtiniemi* et al.*, 2015, see also Figure 3), program name, environment, focal species and relevant regulations.*

nr	subject	Monitoring/ survey type	Monitoring/survey program	environment	species	EU IAS	BMWC	IMO	MFSD/WFD	N2000	EU reg	OSPAR	ICES	OIE	Monitoring type
16	1. trade	Export licensing	*Border control*	aquaculture	IAS	x							x	x	1
17	1. trade	At border customs	*Border control*	ports, airports	IAS	x									1
18	2. shipping	Harmful aquatic organisms and pathogens	*Ballast water*	marine areas, ports	IAS		x								1
4	2. shipping	Port surveys	Den Helder 2014	ports	AS, biodiversity	x	x	x	x			?			2,3
4	2. shipping	Artificial hard substrate	Den Helder 2014	ports	AS, biodiversity	x		x	x			?			2,3
1,2	2.shipping	Marina surveys	Shellfish transports/ N2000 license (GiMaRIS)	marinas	AS, biodiversity	x		x	x	x		?			2,3
	3. alien species	environmental DNA	*experimental*	ports, marinas, soft sediments	AS		x		x						2,3
15	3. alien species	Risk assessment profiles of species/areas	National IAS Policy	ports, marinas, soft sediments	AS	x	x	x							1-5
3	3. alien species	Diver surveys, citizen science	SETL and others	ports, marinas, soft sediments	AS				x						2,3
1,2	4. aquaculture	Rapid assessment surveys	Shellfish transports/ N2000 license GiMaRIS	ports, marinas, soft sediments	AS		x		x	x					2,3
9	4. aquaculture	Shellfish biosecurity	WOT shellfish sanitary/veterinary	aquaculture	IAS						x		?	x	1,2
12	4. aquaculture	Long-term monitoring, bycatch in other surveys	PRODUS/NIOZ	aquaculture	zoobenthos, AS					x					4,5
13	4. fisheries	Target species	Pacific oyster survey	tidal & intertidal soft sediments	Pacific oyster				x	x					4,5
9	4. fisheries	Long-term monitoring, bycatch in other surveys	WOT Shellfish	soft sediments	zoobenthos, Ensis directus				?	?					4,5
8	4. fisheries	Long-term monitoring, bycatch in other surveys	BTS, IBTS, DFS	soft sediments, pelagic	fish, AS				?	?			x		4,5
7	5. biodiversity	Long-term monitoring, bycatch in other surveys	MWTL	soft sediments	zoobenthos, AS				x	x					3,4,5
6, 10	5. biodiversity	Long-term monitoring, bycatch in other surveys	SIBES	soft sediments	zoobenthos, AS					x					3?,4,5

Monitoring activities and programs

The Centrale Informatie Voorziening of the State Water Works Service (CIV, Delft) carries out vegetation surveys since the middle of the seventies in the 20th century. They have developed a standardized approach using *false colour* aerial photographs and which is implemented for example in the VEGWAD program (part of the MWTL-program). The aim of this monitoring program is to follow the vegetation developments on salt marshes as part of the water policy. This policy includes quantitative goals on the conservation of the area salt marsh and the quality as described by the vegetation composition. These mapping surveys are focused on vegetation units and give little room for mapping individual species. The vegetation is mapped from aerial photographs with subsequent ground truth.

The State Forestry Services (Staatsbosbeheer - SBB) and also the other site management organisations manage two types of monitoring programs:

- Vegetation mapping of botanically important areas (once every 10 years);
- Species mapping (birds, plants, other groups, once every six years).

As part of the Subsidy Program Nature and Landscape (SNL) areas should be monitored once every 12 years for the presence of relevant vegetation types and species. The expectation is that the vegetation and species monitoring of SBB and other site management organisations will adapt more and more to the SNL-approach.

Colonial breeding birds and rare and scarce breeding birds on the Wadden Sea islands are monitored annually and completely coordinated by SOVON. High tide counts of non-breeding birds are carried out monthly since the seventies of the 20th century. This monitoring program provides information about the number of birds, which forage during low tide on the intertidal areas and the location of the high tide roosts on the land. All the results of these monitoring programs are included in TMAP.

Unplanned observations of flora, fauna and fungi by amateurs are recorded in waarneming.nl (and recently also telmee.nl), which started about ten years ago. In these databases a lot of information of many taxonomic groups is assembled and stored, including records of alien species. The unplanned structure and lack of correction for multiple recordings, limits the use of the information. With proper guidance and validation these information systems can be part of an early detection program. In fact, new alien species are regularly recorded.

Analysis

Current management plans do not include any prevention actions related to alien species and the (planned) monitoring of the prevention efficiency for evaluation is currently absent. However, this information could indirectly be gathered for some species groups from current monitoring programs.

No planned early detection monitoring is currently implemented. Several monitoring programs, in particular breeding birds, and the unplanned recordings of biodiversity in

waarneming.nl or telmee.nl could be part of an early detection program, if accompanied with a sound validation system.

The species monitoring in some monitoring programs could be used to derive population dynamics of a number of alien species. Focused alien species surveys are absent on the Wadden Sea islands.

No planned impact-monitoring program yet exists, but useful information is available with the site management organisations.

Recommendations
As part of the implementation of the new EU IAS Regulation additional and focused monitoring of IAS of EU concern might become obligatory. This will depend on the completeness of the existing monitoring programs and the characteristics of specific pathways. Only after the list of IAS of EU concern has been determined it will become clear if additional monitoring efforts are needed, which will be on the relatively small and isolated Wadden Sea islands most likely less difficult compared to the mainland.

3.3 Management actions

The management actions, which are required by EU legislation, international and regional conventions are presented in Table 10, with management focus, management requirements (prevention, early detection, eradication or management), habitat scope, species scope and frequency. This comparative overview shows that the new EU IAS regulation will have the broadest scope with respect to species, pathways, while most current regulations and legislation derived from conventions is activity or pathway specific.

3.3.1 Management cycle

An adaptive management plan to reduce the negative impact of invasive alien species consists of a sequence of specific and concerted actions as part of a management cycle (Figure 2). The first step is detection of alien species, preferably **early detection** before (in the pathway) or shortly after introduction. After a proper **risk assessment** and **decision making** usually at a governmental level (or alternatively by nature reserve managers) **mitigation** measure will be implemented. These can be **prevention** to prevent new introductions, a rapid response (**eradication**) or management to limit negative impact if the species has already spread so widely that cost-efficient control is not feasible anymore. After mitigation the monitoring of the effect is important to evaluate its efficiency and to decide how management actions have to be improved or abandoned.

Table 10 Management actions are given, which are required by EU legislation, international and regional conventions.

Legislation and conventions	acronym	Management focus	Management requirements	scope/ habitat	scope/ species	frequency
EU Directive or regulation						
Council Regulation Management IAS 1143/2014	EU IAS	1. pathway / vector related 2. IAS	1. prevention, 2. early detection & rapid resonse, management	1. location specific 2. species/area specific	all IAS	continuous, annually
Bird & Habitat Directive	N2000	Project / activity related	prevention, early detection & rapid resonse, management	all habitats, N2000 conservation goals	all AS	activity related
Marine Strategy Framework Directive	MSFD	continuous	prevention, early detection	all habitats	all species/ all AS	continuous, annually
Council regulation 708/2007 aquaculture	EU aqua	activity related	prevention	location specific	activity related AS	activity related
Council Regulation 338/97 trade	EU trade	trade related	prevention	not relevant	specific trade species	not relevant
Global conventions						
Biological Diversity	CBD	not specified	-	-	-	-
Bonn Convention	Bonn	not specified	-	-	-	-
Convention on International Trade of Endangered Species	CITES	border control	prevention	border control	listed IAS	continuous
International Maritime Organisation	IMO	ballast water	prevention	ports	all AS	continuous
Internation Plant Protection Committee	IPPC/EPPO	border control	prevention, eradication	trade	all AS	continuous
Ramsar Convention	Ramsar	wetland birds	prevention	wetlands	waterbirds	annually
United Nations Convention of the Law of the Sea	UNCLOS	not specified	-	-	-	-
Regional conventions						
Bern Convention	Bern	project/species related	eradication	species specific	species specific	project period
African-Eurasian Waterbirds Agreement	AEWA	waterbirds	prevention	wetlands	all waterbirds/AS	annually
Helsinki Commission, Baltic Sea	HELCOM	ballast water	prevention	ports	all AS	annually
Oslo and Paris Commissions, Northeast Atlantic	OSPAR	ballast water	prevention	ports	all AS	annually

It is assumed that this general approach applies to both marine and terrestrial habitats, including introduction and recipient habitats. There is, however, a fundamental difference: all terrestrial natural areas are nature reserves that are owned and/or managed by site management organisations (including two private organisations and one semi-public). Most of the marine natural areas are part of the Natura 2000 network and are public areas, in most cases managed by different governmental authorities at regional or national level. In addition, introduction habitats (or the hubs in the hub and spoke model of Carlton, 1996) are usually situated outside the Natura 2000 areas or nature reserves and recipient habitats within the Natura 2000 areas are often explicitly included in the conservation goals of these Natura 2000 areas.

Therefore, on Wadden Sea islands management decisions and evaluation are the responsibilities of the site management organisations, while for the marine Natura 2000 areas these responsibilities reside with regional and national authorities. In addition, this applies mainly to the recipient habitats, while the introduction habitats, where new introductions of alien species are to be expected, are under the jurisdiction of different authorities (usually local councils) and other private stakeholders (e.g., marinas). The management and action plan for IAS in the trilateral Wadden Sea has to account for these important differences to become effective. The next important step is to adapt the management cycle to the requirements of the management and action plan for invasive alien species and the EU regulation on IAS (1143/2014, see section 3.1).

As discussed in chapter 2, the unified framework of Blackburn *et al.* (2011) proposes a standard terminology and relates the different types of management (prevention, eradication, containment (or control) and mitigation) to the respective invasion stages (transport, introduction, establishment and spread and impact on biodiversity, ecosystems and ecosystem services). This terminology is fairly similar to the definitions used in this report (Box 1). In addition, different monitoring approaches can be developed for different invasion stages, which are further elaborated in section 3.2.1 (Figure 3). These include (1) prevention monitoring before and if possible during transport and shortly after introduction, (2) evaluation of prevention monitoring and (3) early detection monitoring shortly after introduction, (4) population dynamics monitoring from establishment to spread and (5) impact monitoring mainly during spread. The importance of these monitoring approaches is likely to be different for marine and terrestrial habitats, as, for example, eradication is hardly feasible in marine habitats.

3.3.1 Current management actions

An overview of management actions, as required by EU regulations, directives, global and regional conventions, is given in Table 9 (p.44).

A number of organisations involved in management of relevant marine and terrestrial habitats in the Dutch Wadden Sea area have been interviewed to acquire information about their general awareness of alien species and possible management actions directed at them (Appendix 2 and 3, which also include the lists of questions). For the marine habitats several ports and harbours were selected, which are representative for all harbours and ports in the Dutch Wadden Sea and included Harlingen, Eemshaven, Delfszijl, Vlieland and Oudeschild (Texel) and one company, Damen Shiprepair Harlingen.

The current situation with respect to mussel transports from the Eastern Scheldt to the mussel culture plots in the Western Wadden Sea is described without interviews of stakeholders. The Producers Organisation Mussels (P.O. Mossel) is already involved in specific surveys and monitoring of alien species in the source area (Eastern Scheldt) and recipient areas in the Wadden Sea, fresh water treatment of mussel transports, relevant risk assessments and evaluation of prevention monitoring (see below).

For the terrestrial habitats representatives of the three major site management organisations on the Wadden Sea islands were interviewed (Natuurmonumenten - Nature Monuments, State Forestry Service – Staatsbosbeheer, and it Fryske Gea - Frisian Landscape, Appendix 3. These three organisations manage nearly all of the natural areas on the islands.

3.3.2 Marine habitats of the Wadden Sea

Officers of the following organisations or companies were interviewed: Harbour Service Harlingen, Damen Shiprepair Harlingen, Groningen Seaports, Wadden harbour Vlieland, Wadden Harbour Texel (Oudeschild) (see also Appendix 2).

Hull fouling

The interviewed stakeholders in the Dutch Wadden Sea are well aware of biofouling on objects in the water. In most cases, biofouling is a problem for stakeholders. It can either damage structures in harbours, reduce the effectiveness of emergency steps or can pollute sea bottoms (after removing hull fouling).

Companies who specialise in cleaning ship hulls, however, make a living with anti-fouling activities. For them biofouling is not a problem, but a source of income. Most stakeholders do not remove (under water) biofouling from structures in harbours. It is often difficult, time consuming and therefore generally considered too costly. After being removed from a ship's hull, the fouling material can contain contaminants from antifouling paints. This is a problem for ports, which are responsible for a good quality of the marine environment in the port. Some ports do not allow under water removal of hull fouling, specifically because of the aforementioned reason.

Normal cleaning of hull fouling is done in dry docks. In a dry dock, the ships hull is cleaned with high-pressure jet streams. After sampling of the removed fouling material

for toxic levels, it is discarded as waste and not returned into the water. Fouling with layers of molluscs can be impossible to remove with high-pressure jet streams. Instead, spades or chisels are being used. Professional applying of new anti-fouling systems in dry docks can only be done with certified paints.

There is an interesting initiative involving a robotic (under water) hull cleaning system. This system incorporates collecting the fouling material, preventing it from dropping to the sea bottom.

All stakeholders are aware of the occurrence of alien species in the Dutch Wadden Sea. Most stakeholders are somewhat aware of the fact that alien species can threaten the Wadden Sea ecosystem. All stakeholders are also aware that hull fouling can be a vector for the spread of alien species. Most stakeholders cannot name alien species, other than Pacific oyster. Only a few stakeholders are familiar with legislation or regulation preventing the spread of alien species. Groningen Seaports is clearly the most informed and pro-active organisation of all the stakeholders being interviewed. They know of the IMO regulations, implement them in their work and are active in high-end initiatives (port-based treatment facility, together with Damen Shipyards and under water robotic cleaning facilities).

Ballast water

Stakeholders in the Dutch Wadden Sea are aware of marine organisms occurring in ballast water. This is not a problem for the stakeholders, although at least one stakeholder (Groningen Seaports) is aware of the risk alien species from ballast water can have on harbour structures etc.

In the Dutch Wadden Sea, there are only a few commercial ports in which ballast water is discarded. Only Groningen Seaports, Harlingen haven and Den Helder can accommodate larger ships that require exchange of ballast water. The port of Den Helder, however, has hardly any cargo trade. Active management of ballast water to prevent the spread of alien species is virtually absent.

Damen Shipyards (based in Harlingen haven) and Groningen Seaports have developed a port-based ballast water treatment facility. This is a novel way of treating ballast water to eliminate most living organisms in the ballast water. Amsterdam and Rotterdam ports have shown interest in this system.

The volume of discharged ballast water is (potentially) highest at Groningen Seaports. They have the largest cargo trade in the Dutch Wadden Sea. However, up till now most ships enter Groningen Seaports with cargo. Discharge of ballast water at that point is not yet an issue. Ships offload their cargo, take in ballast water (at Groningen Seaports) and continue their journey. Groningen Seaports expects this to change in the future. Oil reserves, a large power plant (running on coals) and other developments will increase the frequency of ships entering Groningen Seaports with

empty cargo hulls. These ships will take in cargo at Groningen Seaports and therefore discharging their ballast water.

Both commercial ports are aware of guidelines preventing the spread of alien species through ballast water. Only Groningen Seaports could name the Ballast Water Directive. They actively work with this directive.

Aquaculture
Mussel farmers transport mussels with their ships from the Eastern Scheldt to the mussel culture plots in the Western Wadden Sea since 2012. The growth conditions in the Wadden Sea are superior to that of the Eastern Scheldt, where the carrying capacity for shellfish has decreased substantially since the spread of Pacific oysters (Smaal *et al*., 2013). Mussels are collected with mussel seed collectors floating in the Eastern Scheldt. The number of invasive alien species in the Eastern Scheldt is much higher than found in the Wadden Sea (see also section 2.1). These may include IAS, which are not yet present in the Wadden Sea and can potentially have a negative impact on the conservation goals of the Natura 2000 area Wadden Sea. These species are also defined as "problem species" (Appendix 1).

To reduce the risk of introducing the Shellfish Import Protocol is applied (Gittenberger, 2010, 2013), which forms part of the Nature Conservation Law license, which permits these transports under certain conditions as formulate in the Beleidslijn Verplaatsingen Schelpdieren 2012 (Policy rules on the transport of shellfish, Ministry of EZ, 2012). This protocol includes monitoring surveys of alien species in the area of origin (only the mussel culture plots in Eastern Scheldt from where the mussels are taken, not the surrounding habitats, Gittenberger, 2010), the application of additional fresh water submersion treatment (twice) during transport to the Wadden Sea, an inspection and test of treatment water salinity by the relevant authorities in Kornwerderzand (Wadden Sea) and the mussel sector (Gittenberger, 2010; Ministry of EZ, 2012), and posterior monitoring of the mussel culture plots where the mussels are deposited (Gittenberger, 2012). The mussel transports include mussels of all ages, which originate from mussel seed collectors and as half grown mussels from culture plots.

3.3.3 Wadden Sea islands

The nature reserves on the Dutch Wadden Sea islands are managed by three organisations: Staatsbosbeheer (SBB, State Forrestry Service, semipublic nature management, Texel, Vlieland, Terschelling, Ameland), Natuurmonumenten (NM, Nature Monuments, private nature conservation and management organisation, Texel, Schiermonnikoog) and it Fryske Gea (The Frisian Landscape, private nature management organisation, Ameland). The persons responsible for the daily management of these nature reserves have been interviewed (see Appendix 3 for the list of questions).

Awareness
All organisations are highly aware of the presence of alien species in their reserves, their distribution and abundance is monitored on all islands. Management to limit their impact is carried out if considered necessary.

Monitoring
The vegetation in the reserves is mapped every 8 to 10 years (SBB, Rijkswaterstaat, Water Works Service). The majority of alien species is not mapped separately. If a species becomes dominant and can be regarded as a vegetation type, then they are included in the monitoring by vegetation mapping.

All alien bird species are included in breeding bird surveys and non-breeding bird surveys.

Observations of all species, including alien species, by amateurs (citizen science) is recorded on several websites: waarneming.nl (similar to observado.org), telmee.nl ("join counting") and verspreidingsatlas.nl (distribution atlas). Staatsbosbeheer and Natuurmonumenten have their own databases with observations of plants, animals and fungi.

Prevention
Currently, the nature organisations carry out very few management actions to prevent new introductions of alien species into their nature reserves. Seed trees are occasionally cut within the reserves to prevent further seed dispersal and spread. Incidentally, nature managers take the initiative to inform or have meetings with local pet shops and garden centres about the threats posed by invasive alien species.

Management and eradication
The following species (with Dutch name between brackets) are managed on all larger Wadden Sea islands.

Rose hip or Japanse rose (rimpelroos) *Rosa rugosa*: colonizes open dune areas and forms uniform swards without any other vegetation within. These swards are managed in a few locations.

Black cherry (Amerikaanse vogelkers) *Prunus serotina* – colonizes open dune areas and forms dense shrubs and is managed on all islands.

Juneberry (krentenboompje) *Amelanchier lamarckii*: colonizes open dune areas and forms dense shrubs and is managed on all islands.

Giant hogweed (reuzenbereklauw) *Heracleum mantegazzianum*: only abundant locally and is managed on only one site.

Japanese knotweed (Japanse duizendknoop) *Fallopia japonica*: only abundant locally and managed on a few sites.

Cranberry (cranberry of lepeltjeheide) *Vaccinium macrocarpon:* this berry is found mainly only on Terschelling (introduced in 1845) and Vlieland, and in small areas on Texel in wet dune valleys. The cranberry harvest has become economically important on Vlieland and Terschelling. Topsoil removal in cranberry fields in wet dune valleys is used to rejuvenate cranberry swards and to increase natural values by colonization of pioneer species.

Greater Canada goose *Branta c. canadensis*: locally abundant and managed by fauna management units. Can be shot with a rifle throughout the Netherlands without special permit.

Egyptian goose (Nijlgans) *Alopochen aegyptiaca*: usually highly aggressive against all bird species within territory during breeding season. The species is managed on some islands.

Several species have been recently eradicated, which are native to the Netherlands but non-native to the Wadden Sea islands. These are red fox *Vulpes vulpes* (at least one pair introduced to Vlieland in 2009) and red deer *Cervus elaphus* on Terschelling (ten individuals were introduced in 2008). The red fox on Vlieland was functionally eradicated in January 2010 by shooting and by capture with secured snares (Bureau Mulder Natuurlijk). Possibly only one individual remained, which did not reproduce. The red deer on Terschelling were eradicated in 2009 by shooting with rifle and the costs were charged to the person who smuggled the red deer to the island in a truck.

Domestic cats *Felis catus domesticus* are considered a considerable threat to ground nesting birds and other animals. There are attempts to manage them, but permits for shooting with a rifle and trapping with cages are often successfully challenged in court by animal rights groups.

The nature organisations have limited resources for successful eradication or management of IAS. A considerable amount of management is carried out with the help of volunteers.

Recommendations
All nature organisations are in favour of more public awareness campaigns focused on IAS and need more resources for effective management, for example as part of Natura 2000 management plans. They also recommend creating more legal instruments for effective management of IAS, for example, in the new Nature Conservation Act, which is currently prepared in the Netherlands.

4 Analysis

4.1 Draft Strategic Framework: requirements and current situation

The draft Strategic Framework aims to comply with national and international legislation and conventions with relevance to alien species (see section 3.1). The objective of the Strategic Framework is to prevent threats to the Wadden Sea ecosystem through alien species and contains five elements: (1) prevention; (2) early warning and rapid response; (3) eradication and control; (4) raising awareness and (5) implementation.

The status of alien species and their pathways is dynamic and an update of the current situation, including risk assessments is given in chapter 2 and summarized in the next section (4.2). The compliance to a substantial amount of international legislation with relevance to the invasive alien species problem is analysed in section 4.3. Early detection and risk assessment required for an effective early warning system and an overview of current monitoring programs is presented in section 3.2 and analysed with respect to the requirements of the international legislation and Strategic Framework in section 4.4. Current management actions, including prevention, eradication and control are presented in section 3.3 and analysed in section 4.5.

The level of awareness is checked as part of the interviews of stakeholders (section 3.3). The draft Strategic Framework will be implemented by an IAS management and action plan (Figure 1) for which this report will provide the necessary information, but which is still under development and not yet available for review.

4.2 Risk assessments: species, habitats and pathways

Alien species are found in a wide variety of marine and terrestrial habitats in the Wadden Sea region. They range from man-made (introduction) habitats where alien species, including new ones, are constantly introduced and become established to natural (recipient) habitats, where invasive alien species become established after they have spread from their point of introduction or established populations elsewhere. The main pathways in the marine environment are shipping, aquaculture and natural dispersal and major hot spots are artificial hard substrates in harbours and marinas. The lower salt marshes are dominated by Cord grass, the lower intertidal and higher subtidal are dominated by Pacific oysters and have also invaded intertidal mussel beds.

On the Wadden Sea islands invasive alien species are in particular common in the man-made forests and older succession stages in the dune areas. Gardens, parks and agricultural areas are most likely the introduction habitats where alien species become established and spread further into the natural areas. The total number of

alien species and the distribution range of invasive alien species, in particular, are increasing in all habitats. Several invasive alien species have become very common in certain habitats and have a negative impact on native species. Risk assessments and horizon scanning studies show that more invasive alien species can potentially become established in the Wadden Sea regions (section 2.1). An overview of the risk assessments for alien species and pathways in the Netherlands and their references are presented in Appendix 4. The available risk assessments cover most of the relevant species, which are present in the Wadden Sea region and bordering regions. Information is lacking for live bait used by anglers, an important pathway which include worldwide transports of substantial amounts of polychaetes often packed in seaweed with associated species (Weigle *et al*., 2005).

4.3 Compliance with international legislation and conventions

Seven EU directives or regulations, seven global conventions and four regional conventions (18 legal instruments in total) include specific legal instruments to reduce the introduction of alien species, spread or impact on natural areas and economic activities (Table 5). Different ministries (Economic Affairs, Infrastructure and Environment) and different level over governmental authorities (councils, provinces and national services) implement these legal instruments. The Bureau Risk Assessment and Research of the Netherlands Food and Product Safety Service of the Ministry of Economic Affairs aims to coordinate these actions as part of the Policy for Invasive Alien Species (Invasive Alien Species Team). Several international legal instruments are not yet implemented (EU IAS Regulation by 1 January 2016, Ballast water regulation in near future) or involve voluntary guidelines (IMO hull fouling).

Most legal instruments aim directly or indirectly to reduce the rate of introduction, spread and impact of invasive alien species. However, there is currently a lack of common link between the different monitoring programs and surveys and the legal obligations and policy objectives. The total number of new alien species recorded annually by all monitoring programs and surveys together can serve as a proxy (surrogate) for the rate of new introductions of alien species. The efficiency of each monitoring program in detecting alien species can be evaluated by comparing the detection parameters (e.g., detection rate, detection probability and detection time lag) of these programs at different geographical scales. Overall there is in the Netherlands substantial compliance with most relevant international legislation and conventions with respect to the invasive alien species problem and no gaps are apparent in the available array of legal instruments. A more complete evaluation is not yet possible because several important regulations still have to be fully implemented (IMO ballast water and EU IAS).

4.4 Early detection: monitoring

At least 18 different monitoring programs and surveys are active in the Dutch Wadden Sea, which vary considerably in coverage of areas and habitats and frequency (Table 10). Each program usually has a narrow focus or scope with respect to species and habitats and often linked to specific national and international legal obligations and policies. Many monitoring programs are carried out and coordinated at the national level and pick up alien species as a side effect. Most regular monitoring programs and resulting databases do not label alien species as such. This hampers the rapid integration and applicability of the results to the alien species detection and monitoring. An increasing number of specific surveys of alien species have been carried out recently.

4.4.1 Different monitoring types

There is not just one monitoring type that can satisfy all information and monitoring needs. On the contrary, different monitoring types are needed to answer the various questions and in Figure 3 (p. 52) these are linked to the stages and barriers as described by Blackburn *et al*. (2011) in their unified framework for biological invasions (Figure 2).

1. Prevention monitoring
Prevention monitoring aims at detecting (known invasive) alien species before they become established in a new environment. Generally, vectors for transport of alien species are being targeted with this kind of monitoring (Transport Stage). Monitoring results can instantly be used to avert the spread of alien species. Examples are ballast water monitoring or the monitoring of alien species in shellfish transports in the Netherlands, which is based on comparing alien species present among the mussels of the export region and alien species present in the import region (Ministerie EZ, 2012).

Relevant policy documents:
- International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004): Ballast water compliance monitoring
- Joint HELCOM/OSPAR Guidelines: risk assessments in ports
- Dutch legislation on shellfish transports (Ministerie EZ, 2012)

2. Evaluation of prevention monitoring
This kind of monitoring would be conducted to assess the effectiveness of regulations aimed at stopping new alien species, and to maximise the likelihood of early detection of new invaders. Evaluation of prevention monitoring would be used to control whether preventative measures have been successful, and would take place at the (potential) introduction stage of an alien species. Ideally, this kind of monitoring would be preceded by prevention monitoring, but may also simply monitor the success or failure of general measures taken to avoid the introduction of alien species. An example could be the monitoring of Wadden Sea mussel seed plots and their

surroundings before and after seed mussels have been transplanted from other locations. In practice, this monitoring type is similar to early detection monitoring described below, but is mentioned separately here, as it would always be preceded by some measure of prevention which would not necessarily be the case for early detection monitoring.

3. Early detection monitoring

Early detection monitoring aims at detecting new alien species during the introduction or early establishment stage, thereby increasing the chances of a cost-efficient and successful eradication of the newly introduced species. Monitoring is focused on the most invasion-prone habitats ("hotspots") for new introductions. In the case of an "alert list" and profound knowledge of species' traits, habitat preferences etc., the monitoring of "hotspots" might be sufficient, whereas a broader approach might be more appropriate in the event that such knowledge is lacking. The rapid assessments of alien species performed in the Netherlands (Gittenberger *et al*. 2009, 2012 and 2014) and in Germany (Buschbaum *et al*. 2012, Lackschewitz *et al*. 2015) serve the purpose of early detection. Already existing monitoring programmes that create species lists can be used for this purpose as well, as is e.g. proposed by Andersen *et al*. (2014) for Danish marine waters.

Relevant policy documents:

- Marine Strategy Framework Directive
- Regulation of the European Parliament and of the Council on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (Chapter III)

4. Population dynamics monitoring

Population dynamics monitoring has the objective of describing the detailed population dynamics of an alien species over time and spatial scales, from its introduction and establishment to its (potential) later stage of further spreading. This kind of monitoring aims to help explain the mechanisms underlying the population dynamics. It cannot answer any questions with regard to the impacts of alien species (see 5. Impact monitoring). Examples include the monitoring of the population dynamics of Crassostrea gigas in the East-Frisian Wadden Sea in Germany (Wehrmann *et al*. 2006).

Relevant policy documents:

- Regulation of the European Parliament and of the Council on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (Chapter IV, Management of Invasive Alien Species that are widely spread)
- Marine Strategy Framework Directive (ANNEX III, Table 1: Biological features)
- Council Regulation concerning use of alien and locally absent species in aquaculture (Article 18(1))

5. Impact monitoring

Impact monitoring is the systematic identification and evaluation of the potential effects an alien species may have on its environment. Scientific experiments will usually precede this kind of monitoring in order to determine the presence and mechanisms of impacts. With the help of monitoring, these will then be quantified in the field to determine their extent. Hence, impact monitoring will not solely be directed at the alien species themselves, but also at variables they affect. This kind of monitoring can be combined with monitoring of the population dynamics of an alien species. Generally, evidence of impacts of alien species on marine ecosystems is weak, as only a minority of reported impacts have so far been inferred via experiments, not based solely on subjective judgments or correlations (Katsanevakis *et al.* 2014). Six alien species have been described as having already had or about to have effects on the composition of the existing biota in the Wadden Sea: cord-grass (*Spartina anglica*), Japanese seaweed (*Sargassum muticum*), bristle worm (*Marenzelleria viridis*), American razor clam (*Ensis americanus*), American slipper limpet (*Crepidula fornicata*) and Pacific oyster (*Crassostrea gigas*) (CWSS 2010). There are no clear-cut examples of impact monitoring in the Wadden Sea. To our knowledge, the research into the effects of the Pacific oyster on the native blue mussel, *Mytilus edulis,* (e.g. Diederich 2005, 2006, Eschweiler & Christensen 2011) and the monitoring of the Pacific oyster, including its occurrence on blue mussel beds in parts of the Wadden Sea (e.g. Wehrmann *et al*. 2006, Büttger *et al*. 2014) are the closest to impact monitoring to date, when applying the more rigorous demands like experimental testing on impact monitoring that Katsanevakis *et al.* (2014) suggest.

Relevant policy documents:

- Regulation of the European Parliament and of the Council on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (Chapter IV: Management of Invasive Alien Species that are widely spread)
- Council Regulation concerning use of alien and locally absent species in aquaculture (Article 18)
- ICES Code of Practice on the Introductions and Transfers of Marine Organisms (ICES 2005): relevant for marine aquaculture activities, re-stocking or enhancement purposes
- Marine Strategy Framework Directive (ANNEX I, Descriptor 2: “Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems”)

This short overview exemplifies that each monitoring approach fulfills a different task and can help answering different questions. That is why the objective (what do we want and need to know to answer the question we have got?) needs to be carefully chosen and defined. Often, monitoring approaches get intermingled as in the case of population dynamics monitoring and impact monitoring. The objectives (questions) thus need to be carefully defined.

4.4.2 Strengths and shortcomings of current alien species inventories and other long-term monitoring programs

To date there has been no specific long-term monitoring of alien species in the trilateral Wadden Sea according to the definition by Lindenmayer & Likens (2010). The longest running programmes, the SETL-project in the Netherlands only began in 2006. There is a number of long-term monitoring programs being established that could contribute to accumulating the necessary knowledge on alien species for management purposes (Table 10). The strengths and points of improvement are further discussed in Appendix 5 and Table A.3.

All methods being used in alien species monitoring have advantages and disadvantages with regard to different variables, including sensitivity, taxonomic resolution, and time and manpower required (Tables A.3 & A.4). Methods should be carefully chosen to account for various factors, such as the size of the area to be monitored (the larger the monitored location, e.g. a large port, the higher the chance of missing species), and the frequency at which the monitoring should be performed (e.g. zooplankton should be sampled monthly or bi-weekly to account for population dynamics, while longer lived biota can be sampled annually; for suggested sampling frequency requirements, see Lehtiniemi *et al*., 2015).

"Citizen science" and DNA technologies are two promising tools that could supplement "traditional" monitoring types, such as rapid assessments.

"Citizen science" and educational approaches

The invitation and active involvement of diving and fishing associations and NGOs, so called "citizen science", can lead to the reporting of alien species otherwise gone unnoticed. The advantages of this approach are that it is public-oriented, the costs are relatively low and locations that would have otherwise gone unvisited are also being investigated. The disadvantage is that the smooth running of citizen science-aided projects depends on a well-planned commitment of coordinators, as well as experts willing to assist in the identification of newly found species and the subsequent data management. A general, major drawback can also be the over-eagerness of laypersons reporting alleged alien species sightings, thereby tying up valuable resources in agencies to check the accuracy of these sightings. By restricting the call for participation to report alien species to informed laypersons like the above-mentioned members of diving and fishing associations and NGOs, this problem can be reasonably controlled.

In the Netherlands, the ANEMOON Foundation (Dutch: Stichting ANEMOON) played an important role in recording new alien species in the last two decades (pers. comm. A. Gittenberger). The foundation cooperates closely with expert taxonomists, and thus most records are checked and validated within days to weeks after a species is first discovered. Of particular interest is the foundation's project MOO (Dutch: "Monitoringproject Onderwater Oever"), a monitoring project in which volunteer divers

collect biological population information on native and alien species in various marine areas in the Netherlands.

Another promising approach is the close cooperation with educational organisations and institutions with a marine focus. As these already work together with schools, the public, and sometimes also universities, they can help increase public awareness of the problem of bioinvasions. One such “educational monitoring” example is the “Marina Aliens Project” in the UK, in which school groups examine the arrival and settlement of alien species in marinas via settlement plates (for this and further educational projects with a focus on alien marine species, see http://www-.marlin.ac.uk/marine_aliens/public_education.php or http://platewatch.nisbase.org/).

Table 11 *Organisations and projects with a marine educational mission in the trilateral Wadden Sea area, which could act as awareness multipliers for the topic of alien species.*

Country	Organisation, institution, etc.	Internet address
The Netherlands	Waddenvereniging	http://www.waddenvereniging.nl/
	Ecomare	http://www.ecomare.nl/
	Stichting Anemoon	http://www.anemoon.org/
trilateral	International Wadden Sea School	http://www.iwss.org/

DNA techniques: (meta)barcoding and eDNA

Species-level identification is historically conducted visually, and more recently with the use of DNA barcoding. DNA barcoding is a taxonomic method that uses a short, species-specific genetic marker in an organism's DNA to identify it as belonging to a particular species. It can be used for direct sampling of species whose taxonomic position is unknown (adding value to rapid assessments performed by experts).

Species in an environmental sample can be identified by comparing obtained sequences to a standard reference library of sequences from known organisms (the American National Center for Biotechnology Information’s GenBank, http://www.ncbi.nlm.nih.gov/genbank/, and BOLD, the Barcode of Life Data Systems, http://www.boldsystems.org/). This assumes that the genetic information stored in a gene reference bank is correct, i.e. that sequences are based on correctly identified species. Caution must also be taken to ensure that alien species are not misidentified as native species, e.g. when their DNA sequence is not yet known, but the closely resembling DNA of its native sister species is present in the reference bank. One disadvantage of any DNA-based technology is the current incomprehensiveness of gene reference banks, though it seems to be only a matter of time before this is rectified as gene sequences are constantly added, as also noted by Andersen *et al.* (2014).

An advantage of this technology is that early life stages of pelagic and benthic alien species and other small organisms (e.g. bacteria, parasites and viruses) can be identified with it. For several habitats (mainly terrestrial, freshwater and semi-enclosed water bodies), it has already been demonstrated that metabarcoded samples are

taxonomically more comprehensive, much faster to produce, and at lower costs, compared to standard morphological identification, which requires individual identification of large numbers of specimens by scarce expert taxonomists (Ji *et al*. 2013). However, whether this also holds true for the Wadden Sea will need to be investigated in more detail.

Another promising method for alien species monitoring is the environmental DNA technology. This uses a forensics approach to detect alien species. Whereas other methodologies require direct observations of species or, as in the case of barcoding, a direct sampling of the species itself, eDNA technology can detect species 'sight unseen'. eDNA was also named as one of the promising tools in the online WaLTER survey (http://www.walterwaddenmonitor.org/publicaties/#enquetes) performed by the Radboud University in the Danish proposal for the monitoring of alien species in Danish marine waters (Andersen *et al*. 2014).

This non-destructive technology is based on the principles that all aquatic species release genetic material into the environment (mucus, faeces, urine). These trace amounts of suspended eDNA can be collected in water samples, extracted and amplified. At a later step the presence of individual species can be detected through the recognition of diagnostic fragments. If the eDNA technology indicates the presence of an alien species, taxonomic experts will have to be contacted to verify the presence and assess the invasion extent. A review of the possible applications of eDNA for the detection of (invasive) species via eDNA can be found here: http://www.environmental-dna.nl/Portals/7/Herder%20et%20al%202014%20-%20Environmental%20DNA%20review.pdf

The application of the eDNA technology is hampered by some characteristics of marine habitats, namely the extreme water volume to biomass ratio, the effects of sea currents and wave action on dispersion and dilution of eDNA, and the impact of salinity on the preservation and extraction of eDNA (Thomsen *et al*., 2012). eDNA persistence in aquatic systems varies per species, ranging from a day up to a month (Thomsen *et al.* 2012, Rees *et a*l. 2014), making it impossible to obtain real-time information on an organism's location. Furthermore, conclusions about abundances of (marine) alien species are still impossible.

However, a promising avenue is the use of eDNA in combination with alert lists, e.g. by controlling for alien species that are being listed on the alert list under the European Regulation on the Prevention and Management of the Introduction and Spread of Invasive Alien Species. e-DNA samples could potentially be taken within the framework of the regular statutory water sampling programmes in the Wadden Sea and the Eems-Dollard. Similar to the proposal by Andersen *et al*. (2014), taking additional water samples for e-DNA research could easily be achieved. The fact that eDNA could possibly derive from organisms further upstream does not per se constitute a disadvantage, as this would inform IAS managers in advance of the arrival of a known invasive alien species. The same applies to the fact that eDNA

could derive from dead specimens, as it would alert IAS managers that the possibility of living specimens is present. Comtet *et al.* (2015) discuss these "false positives", which are "likely to occur at high frequency in highly diffusive and dispersive habitats", like seawater. The authors conclude that, as early detection is crucial to managing biological invasions, "an early detection of eDNA (…) is a "red flag" indicating that the sample was in some way exposed to the organism (…). Additional protocols, a good level of sampling replication and a verified sequence database are then necessary but their implementation may be much simpler because the potential hazard is known" (Comtet *et al.* 2015, p. 915). Also, the eDNA technology could be applied in (semi) enclosed areas such as marinas with no or hardly any current, and no ballast water management taking place (which would potentially release eDNA of dead organisms).

4.5 Management actions: prevention, eradication and management

Few management actions are currently implemented to reduce the rate of introduction or impact of alien species. These include the Shellfish Import Monitoring Protocol (SIMP) for the mussel transports from the Eastern Scheldt to the mussel culture plots in the Western Wadden Sea to prevent the introduction of new invasive alien species which can have a negative impact on the conservation goals of the Natura 2000 area Wadden Sea. This prevention monitoring in combination with fresh water treatment is required as part of the Nature Conservation Licence for mussel transports to the Wadden Sea since 2012. The efficiency of this protocol is not yet evaluated. A few successful eradications have been carried out on translocated native species (red fox on Vlieland and red deer on Terschelling). On the islands most site management organisations (SMO's) are engaged in management of certain invasive plant and bird species. These actions are not coordinated between SMO's and each SMO has its own framework for management decisions.

4.6 Awareness and implementation

The currently available legal instruments (Table 5, section 3.1), when considered together show no apparent gaps (see section 4.3) and should be generally sufficient for effective management of IAS, but have resulted in only few management actions. This limited implementation might be caused by the lack of sufficient:

- Awareness of stakeholders;
- Harmonization of terminology and definitions;
- Coordination of actions, in particular at different governmental levels, and
- Prioritization of actions with respect to species, areas and pathways.

Awareness

The level of awareness of the alien species problem is very different among stakeholder groups (high in SMO, aquaculture, larger ports, low in marinas and probably pet owners). The provision of frequent and low threshold information to all stakeholders in the Wadden Sea region about introductions of alien species in all

habitats is needed to enhance the level of awareness. This will also contribute positively to a general feeling of “level playing field”, that is all stakeholders in the Wadden Sea region are treated similarly.

Harmonization
Harmonization of terminology and definitions at the national level of all Wadden Sea states involved is essential. Alien species need to be labelled as such in all 18 current monitoring programs and surveys in all trilateral states. This is also an important prerequisite to harmonize all relevant legal instruments and their efficient implementation.

Coordination
Coordination at a national level of the implementation of all 18 different legal instruments relevant for IAS management is essential, before adequate coordination can become effective at the trilateral level. Most legal instruments are linked to legal obligations at the national level for regions, which are essentially larger than the Dutch Wadden Sea area (e.g., OSPAR regions, MSFD for North Sea, WFD for river catchment areas) except the N2000 network.

Prioritization
A considerable amount of information is now available about the presence of IAS in the Netherlands, together with proper risk assessments, impact studies and a few eradication campaigns (see Appendix 4). This information can be used and supplemented by new horizon scanning studies for marine species to prioritize the necessary management actions for species, habitats and pathways.

4.7 Gap analysis

With respect to the requirements of an efficient IAS management and action plan on IAS in the Wadden Sea region the following gaps have been identified:

- Our knowledge with respect to the new invasive alien species on the horizon is incomplete. Only a few marine species are included in the horizon scanning study of Matthews *et al*. (2014).
- New or little known pathways are (1) the live bait used by anglers (including marine polychaete worms); (2) pet species available in e-commerce (traded through websites). Angling is an important recreational activity on all islands and in the Wadden Sea, involving thousands of anglers using worms as live bait.
- These live baits include non-native species and are with increasing frequency imported from foreign countries (Weigle *et al*., 2005) or cultured in closed systems (aquaculture). The trade in pet species on the Internet is increasing and difficult to monitor. These species are also available for the island inhabitants (in addition to local pet shops) or taken with visitors on vacation, which lead to a constant escape or release risk.

- The strengths and shortcomings in early detection with respect to the monitoring programs are discussed in Appedix 5. Several monitoring types are distinguished (Figure 3) but the current monitoring programs are not yet suited for early detection and for following the population dynamics of an alien species.
- As discussed in section 4.3 few gaps in legislation will be apparent if all planned legal instruments, such as ballast water management regulations and the EU IAS regulation, and current legal instruments are fully implemented in due time.
- No information is yet available about the efficiency of current management actions (Shellfish Import Monitoring Protocol, IAS management on the islands).

4.8 Conclusions

To summarize the main conclusions for the implementation of the draft Strategic Framework for dealing with alien species in the Wadden Sea region and the requirements for an IAS management and action plan with respect to risks, compliance, early detection, management, awareness and implementation:

Risks: species and pathways

(1) A wide variety of marine and terrestrial habitats is present, including man-made habitats where alien species are frequently introduced and recipient, natural habitats where alien species settle after secondary dispersal (cf. hub and spoke model of Carlton, 1996);

(2) Different vectors and pathways of alien species are present, the number of pathways is increasing and new introductions of invasive alien species are on the horizon; more negative (and occasionally positive) impact on conservation goals is expected.

Compliance

(3) Different areas have different levels of (legal) protection depending on location in or outside Natura 2000 area. This is mainly limited to new activities within Natura 2000 areas, which can be prohibited if they lead to introductions of IAS with a negative impact on the conservation goals.

(4) 18 different and specific legal instruments apply, which, when taken together and fully implemented, are potentially sufficient to reduce new introductions, spread and impact of alien species; Points of attention are coordination, harmonization and prioritization of actions.

Early detection

(5) At least 18 different monitoring programs and inspections are currently carried out, which actually and potentially detect alien species usually as a side effect at varying levels of coverage and frequency, but many programs do not label alien species as such.

(6) Not all species groups can be detected and in most cases it is unknown if the detection is timely enough for rapid response or prevention monitoring if considered necessary and feasible after risk assessment.
(7) None of the inventories or monitoring programs is equally suited for early detection and for uncovering the population dynamics of an alien species.

Management actions

(8) Few management actions have been carried out, including prevention in aquaculture, eradication of translocated native species and management of plant species on islands. No information is available on the efficiency of these management actions.

Awareness and implementation

(9) Different authorities can implement different legal instruments at different levels (ministries, councils, provinces), which may hamper efficient management actions; too few management actions have been carried out for feasible evaluation;
(10) Different levels of awareness of both alien species and management options are present among stakeholders groups, which may limit the necessary information and support for management actions.

5 Recommendations

5.1 Draft trilateral Strategic Framework on Alien Species

The overall objective of the draft Strategic Framework for dealing with Alien Species in the trilateral Wadden Sea is to prevent threats to the Wadden Sea ecosystem and biodiversity through alien species.

There is general agreement that the efforts to address alien species in the Wadden Sea should focus on five main elements: (1) Prevention; (2) Early Detection/warning and rapid response (eradication); (3) Eradication and control; (4) Raising awareness; (5) Implementation. The first three elements are the three lines of defence (including risk assessments) and public awareness is also a requirement for successful implementation of the IAS management and action plan.

The overview in chapter 2 and 3 together with the analysis in chapter 4 concluded that there is a continuing risk of new introductions and pathways and identified several points for improvement in (a) compliance to international legislation and conventions, (b) early detection, (c) management actions, (d) awareness and (e) implementation. These points need to be addressed as required for a successful IAS management and action plan and specific recommendations are given below.

5.2 Compliance: national coordination

Thirdly, 18 legal instruments are currently implemented nationally at a larger scale than the Wadden Sea but have relevance for management of IAS in the Dutch Wadden Sea. National coordination and prioritization of management actions with respect to these legal obligations is, therefore, essential for effective trilateral cooperation.

5.3 Early detection: monitoring

Monitoring must be tailored to the specific objective of the monitoring approach and will sometimes need to involve close cooperation with research. In the following, recommendations that apply to the monitoring of alien species in the Wadden Sea in general and more specifically, recommendations for a monitoring approach with the objective of early detection of (invasive) alien species are listed, as latter objective is specifically strived for in the Strategic Framework for Alien Species.

5.3.1 General monitoring recommendations

- *Coordination:* Emphasis should be put on the coordination between responsible authorities with the aim of harmonising methodologies, data management and data assessment. It is recommended that each country has its own alien species task group consisting of scientists, policy makers and other stakeholders for all alien species in all habitats and pathways (similar to German FAG Neobiota), that can address all aspects of the national alien species management to assess potential threats and impacts associated with these organisms in a timely manner, and react accordingly. Beyond that, representatives of these national groups should come together regularly to ensure good communication and implementation of a trilaterally concerted IAS management.

- *Network of experts:* A solid, comprehensive network of experts is needed to ensure that species identification is done reliably and in the fastest possible way. The DAISIE Project created an Expertise Registry, which is currently no longer being updated. It is recommended to update and expand this registry or to substitute it with a similar one.

- *Prevention as priority:* Prevention should continue to be the cornerstone of management efforts, as eradication or control of IAS populations in the marine environment is near to impossible. In their paper on monitoring of marine alien species to serve legislative requirements, Lehtiniemi *et al*. (2015) also come to the conclusion that the management potential is the greatest during the "pre-border" stage, i.e. before alien species are being introduced into a new environment. With regard to the various relevant vectors, prevention of alien species transported by mussel transplants is most promising, as monitoring of mussel transplants has already successfully been done in the past and can be achieved with relatively low effort.

- *IAS alert or watch list:* Monitoring may need to focus on specific taxonomic groups to optimise the probability of detection. In order to devise or advance an alert list of high-risk species, horizon scanning should be (further) pursued for the trilateral region and the neighbouring countries to determine the most likely points of introduction of high-risk species.

- *Spatial and temporal scale of monitoring:* The whole of the Wadden Sea with all relevant habitats needs to be monitored in a standardised and regular manner, whereby special attention must be given to all anticipated or known hotspots, e.g. marinas, harbours and aquaculture operations. Depending on the methods chosen, the point in time in the course of a year will vary. Rapid assessments based on expert searches in the field will take place in summer/early autumn as this ensures that species can be detected and identified more easily (settlement of many species completed and individuals have reached a discernible size).

- *Online alien species database:* It is recommended to set up an easy-to-understand online database on detected alien species in the trilateral Wadden Sea, which includes the visualisation of findings of alien species, e.g. similar to the one by the US Geological Survey (see http://nas.er.usgs.gov/queries/-SpeciesAnimatedMap.aspx?speciesID=713) or the Marine Invader Tracking and Information System (MITIS; http://mit.sea-grant.net/mitis/). Another suitable option is AquaNIS, the "Information system on aquatic non-indigenous and cryptogenic species", although the (interactive) display of findings is not (yet) possible on this site. Online databases serve two functions. They can be used by scientists and managers for e.g. reporting purposes with regard to the MSFD subregional approach, and as information for the public to stimulate involvement by citizen science. Preferably, an online database will collect all data on alien species in the wider Wadden Sea area, irrespective of the vectors involved. Thus data collected through e.g. monitoring in aquaculture, ballast water management and basic monitoring, but also chance findings of alien species would all be stored in such a database, indicating any possible uncertainties related to the specific monitoring type taken. The database could then be part of the centralised information system collating all existing information on alien species in the Union, as proposed by the EU in its Regulation on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (European Commission 2014).

- *Public outreach:* Experience has shown that public outreach can have a positive effect on alien species management, if people are aware that their behaviour (e.g. recreational boating) can have an effect on the spreading of alien species (example of effective IAS management in New Zealand). A strong and long-lasting communications initiative could help to increase acceptance and participation in alien species management. The development of public outreach material has also been mentioned in the Strategic Framework for Dealing with Alien Species in the Trilateral Wadden Sea (2014), and could include a travelling exhibition on alien species, thereby joining forces with organisations with a marine educational mission.

- *Analysis of pathways of alien species:* Managing the pathways and vectors of movement of alien species is of major importance, as different pathways pose different risks for a given area and/or taxonomic groups (Pearce *et al*. 2012). For the Dutch Wadden Sea with its many marinas and relevance for the mussel industry, the presumed main pathways are recreational boating, aquaculture, natural drifting and, to a lesser degree, ballast water. Aside from the mapping of cluster areas of alien species (further described below) it would be advisable to analyse major travel routes of recreational boats in the Wadden Sea, hereby identifying the pathways that should be targeted in order of priority for early detection but also control purposes (as described in the EU Regulation 2014 for example). Information could be collected with the help of instruments such as

Real Life AIS, and via associations concerned with recreational boating (e.g. for NL: De Wadvaarders, ANWB, HISWA).

- *Study on fouling on recreational boats:* Congruent with the above pathway and vector approach, a study on resident and visiting boats could be done. Observations by Gittenberger *et al*. (in prep., pers. comm. A. Gittenberger) showed that resident boats had more fouling organisms on their hulls than visiting boats. Knowledge on the main group of recreational boats eases the management of recreational boating as a vector.

5.3.2 General recommendations for early detection monitoring

- *Use of new methods:* If eradication of an alien species is the objective of a management programme, then focus must be laid on the still rare (and thus most likely hard-to-detect) alien species, as chances for eradication are then highest. Consideration should be given to the use of eDNA in harbours or other semi-enclosed locations. There are a number of advantages to new methods such as eDNA, as for example taking frequent eDNA samples can ensure that various life stages of a species are being found. However, there are also a number of disadvantages (see subchapter “DNA techniques”).

- *Priority areas for monitoring:* Monitoring programmes should prioritise the areas with high likelihoods of both introduction and establishment. These can be based on past accounts of alien species that have become established, e.g. by mapping all locations of first detections of alien species for the whole trilateral Wadden Sea and thereby visualising “alien species cluster areas”. Although detection probabilities are highly correlated with search effort in a specific area and hence do not allow for the conclusion that there are no other relevant (unsearched) cluster areas, this approach could be useful in narrowing monitoring efforts should this be necessary. The alien species overview report by Gittenberger *et al.* (2015) for the Dutch part of the Wadden Sea can serve as knowledge bases for such a map, expanded by the results of alien species inventories and other (chance) reports. Such a map could have an additional layer of habitats, thereby serving as background information to lay out (future) alien species findings and to further assist in selecting the most suitable monitoring locations.

5.3.3 General recommendations for impact monitoring

- The *monitoring of impacts* of alien species forms an important part in EU regulations and guidelines. Impact monitoring is the systematic identification and evaluation of the potential effects an alien species may have on its environment, and generally requires scientific experiments to precede the monitoring. Close cooperation with researchers studying the alien species in question is therefore obligatory to enable reliable statements about impacts. Past research on impacts of alien species in the Wadden Sea (e.g. research by Diederich 2005, 2006, Eschweiler & Christensen 2011 on Crassostrea gigas) was commonly initiated

because researchers surmised that a specific invasive alien species could have an effect on native species or habitats. These research endeavours were usually not motivated by policy makers' needs for information for IAS management. This indicates the importance of scientists, policy makers and other stakeholders forming alien species task groups to enable direct interaction with regard to research needs (see above "Coordination"). The quantification and mapping of alien species' impacts is further complicated by (Katsanevakis *et al*. 2014):

- (1) the lack of coverage and resolution in the available natural and socioeconomic data (e.g. habitat mapping, spatial distribution of native and alien species);
- (2) gaps in assessments of marine ecosystem services […], which naturally precedes the assessment of any impact on them;
- (3) the inherent complexity of the problem.

5.3.4 Potential further avenues to advance alien species management

- *Create a Wadden Sea DNA collection:* DNA information collected by Lise Klunder during her PhD research at NIOZ (https://www.nioz.nl/staff-detail?id=445045) could provide a start for a Wadden Sea-wide DNA collection. The collection could be expanded by filling it with DNA information of all new (alien and native) species found in the Wadden Sea. This DNA collection could serve as a reference for future monitoring.

- *Map future risk areas for further bioinvasions:* Special attention should be paid to developments in the Wadden Sea or North Sea areas bordering the Wadden Sea. This includes offshore blue energy projects (e.g. wind farming, or ocean farming), as the pertinent structures will likely function as stepping-stones for new species (see Buschbaum *et al.*, 2012).

- *Stimulate further research on alien species in the Wadden Sea:* Current IAS management involves a number of assumptions, including those about vectors or connectivity. Further research can help improve IAS management, e.g. is it possible to identify hotspots for alien species in soft sediments possibly related to local currents for example? What is the importance of anthropogenic vectors such as boating or aquaculture in comparison to natural drifting of larvae for population connectivity? What percentage of alien species related to anthropogenic hard substrates such as the various habitats in marinas, can be found on natural hard substrates such as mussel beds, and are there differences with regard to the taxa that can be found on these anthropogenic and natural hard substrates? Bluntly said: should alien species that find a suitable habitat in man-made environments, such as marinas, not be managed if natural hard substrate habitats such as mussel beds are not prone to their colonisation and thus impacts on natural habitats are not to be expected?

5.3.5 Harmonization of monitoring programs

- Focus first on *harmonisation* of monitoring, lists and databases.
- Use *standardized* terminology and definitions.
- Assemble *national lists* of marine and terrestrial alien species with sufficient geographical solution (per N2000 area, per island) and enough details on date and presumed pathway(s) (cf. Lehtiniemi *et al*., 2015). This list is based on all available and relevant monitoring programs, surveys and citizen's science.
- The *detection parameters* of alien species of each monitoring program are generally known and evaluated (cf. Hoffman *et al*., 2011; Trebitz *et al*., 2009).
- *One national authority*, Invasive Alien Species Team, Ministry of Economic Affairs is responsible for national list of alien species and experts contribute to the open source. This list will be included in the National Species Register database.
- Alien species, including cryptogenic species, should be *labeled as such* in all marine and terrestrial monitoring programs and biodiversity databases.
- Construct a generally accepted *timeline* of alien species introductions/first observations in different N2000 areas and islands for reference and evaluation.
- Based on the national list assemble a *trilateral list* for all islands and all Nature 2000 areas for the Wadden Sea region.

5.4 Management actions: risk assessment and prioritization

- Use *risk assessments* that are currently available for several invasive alien species and pathways in the Netherlands (Appendix 4).
- Carry out risk assessments of recently established alien species and invasive alien species *on the horizon*, e.g., established elsewhere in trilateral countries and Europe, and similar climate zones elsewhere.
- *Prioritize* monitoring in introduction areas and habitats (e.g., gateways or hotspots);
- Carry out risk assessments of *new* or unknown pathways and prioritize management actions accordingly.

5.5 Awareness

Based on the analysis above it is argued that the planned IAS management and action plan should coordinate and facilitate the implementation of currently (or in near future) available legal instruments and obligations, which apply to the trilateral area. Many legal instruments, which apply to marine habitats, are globally implemented at the same time, to give related economic activities a level playing field. Well before implementation the stakeholders are fully informed about all risks involved and mitigation needed to reduce these risks. From this "level playing field" paradigma follows that the enhancement of this public awareness has currently the highest priority. All stakeholders involved should have a similar level of information about alien species, their pathways and their risks for nature, health and economic activities as well.

- Increase awareness of alien species, including related legislation and management actions for all stakeholder groups ("level playing field").
- Focus awareness on current private (Damen Shiprepair, SMO's) or private-public initiatives (e.g., Groningen Seaports, Water Plant Convenant). Other parties often follow good private initiatives.

5.6 Implementation: legal instruments and obligations

Coordination

- Develop a strategy and trilateral management and action plan, which is based on **current** national implementation of national and international legislation and legal instruments and aims to harmonize national approaches (in particular monitoring) and coordinate trilateral implementation.

Prioritization

- The trilateral IAS management and action plan should prioritize all actions in the trilateral Wadden Sea area.
- This analysis suggests that enhancing public awareness by public outreach among all stakeholders has the highest priority.
- Next priority is to improve early detection of alien species by standardization and harmonization of the current monitoring programs and to make further adaptations after evaluation with respect to detection efficiency.
- These two priorities will facilitate substantially further implementation of the current and new regulations with relevance to IAS management, in particular the EU IAS regulation 1143/2014.
- The management and action plan should be evaluated after several years and, if necessary, monitoring programs and management actions are adapted and new priorities are set (see Figure 1, management cycle).

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Appendix 1

List of EU regulations, directives, global and regional conventions and guidelines relevant for management of IAS in the Wadden Sea (adapted from NOBANIS website).

EU regulations and directives

Directive	**Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds (Birds Directive) (as ammended)**
	Birds Directive, In force: 1979
Special section(s) relevant to alien species	Article 11 of the directive affirms that member states shall se that any introduction of species of birds which do not occur naturally in the wild state in the european territory of the member states does not prejudice the local flora and fauna.
Content and coverage of regulation	The Directive 79/409/EEC provides a framework for the conservation and management of wild birds in Europe. It sets a broad objective regarding non-native birds, but leaves to the discretion of each Member State how compliance with these objectives is achieved.

Directive	**Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora directive)**
	Habitat Directive: Adopted: 1992; In force: 1992
Special section(s) relevant to alien species	Article 22, b of the Habitat Directive establishes that Member States shall ensure that the deliberate introduction into the wild of any species which is not native to their territory is regulated so as not to prejudice natural habitats within their natural range or the wild native fauna and flora and, if they consider it necessary, prohibit such introduction.
Content and coverage of regulation	The Habitat Directive aims to promote the maintenance of biodiversity in the Member States by defining a common framework for the conservation of wild flora and fauna and habitats of Community interest. The Directive establishes a European ecological network known as "Natura 2000". The Habitat Directive is a part implementation of the CBD Convention at European level.

Regulation	**Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora by regulating trade therein** **IAS Trade Regulation:** Adopted 1996; In force: 1997 ; Amended: 2003
Special section(s) relevant to alien species	In Article IV, 6d of Council regulation 338/97 it is stated that the Commission may establish restrictions relating to certain countries of origin, on the introduction into the Community of live specimens of species for which it has been established that their introduction into the natural environment of the Community presents an ecological threat to wild species of fauna and flora indigenous to the Community. The appendices included in regulation 1497/2003 mention several invasive species: Oxyura jamaicensis, Trachemys scripta, Rana catesbeiana. The appendices are regularly updated.
Content and coverage of regulation	The CITES convention has been implemented in Europe by Commission Regulation (EC) No 338/97. This Regulation was amended by Commission Regulation (EC) No 1497/2003 of 18 August 2003 amending Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora by regulating trade therein. In the annexes to the new directive a few invasive alien species that have become threats in importing EU-countries have been included. The alien species regulated through CITES are only the intentional introductions since it is based on an approval system.

EU regulations and directives - continued.

Directive	**EU Marine Strategy Framework Directive** MSFD: Adopted 2010.
Special section(s) relevant to alien species	Eleven generic qualitative descriptors are to be considered when determining the environmental status of waters. Alien species are specifically addressed in Annex I. Descriptor 2. Non-indigenous species introduced by human activities are at levels that do not adversely alter the environment. Criteria and indicators for determining if this qualitative descriptor is achieved are currently being developed. The proposed criteria that are under consideration are:
Content and coverage of regulation	* Prevention of new NIS introductions. Indicators for this are accounts of vectors associated with new introductions and changes in pathways and vectors Prevention of establishment and spread of NIS. Indicators are Inventories of newly arrived NIS and areas of their origin, trends in introduction of invasive alien species and accounts of newly colonised localities Change in Species composition. The indicator is the ratio between non-indigenous species and native species Prevention of spread of invasive alien species. Indicators are a target list on potentially harmful species and the abundance and distribution range of IAS. The absence of minimal level of IAS impact which disturb environmental quality. The indicator is the Biopollution index in which abundance, distribution range and impacts on native communities, habitats and ecosystem functioning are assessed. Annex III The initial assessment for alien species should be done by 2012 and include: An analysis of the current environmental status of waters which include an inventory of the temporal occurrence, abundance and spatial distribution of non-indigenous, exotic species or where, relevant, genetically distinct form of native species, which are present in the region/sub-region An analysis of the predominant pressures and impacts for introduction of non-indigenous species and translocations The EU Marine Strategy Framework Directive establishes a framework for the protection and preservation of the marine environment, the prevention of its deterioration and the restoration of that environment where it has been adversely affected. Marine strategies are be developed and implemented with the aim of achieving or maintaining good environmental status in the marine environment by the year 2021 at the latest.
Regulation	**Council Regulation (EC) no 708/2007 concerning use of alien and locally absent species in aquaculture**
Special section(s) relevant to alien species	The entire regulation
Content and coverage of regulation	This regulation aims to optimise benefits associated with introductions and translocations of alien and locally absent species used in aquaculture while at the same time avoiding alterations in ecosystems and preventing negative biological interaction including genetic change with indigenous populations and restricting the spread of non-target species and detrimental impacts on natural habitats. The main focus is on risk assessments of alien species before allowing introduction or translocation. Fifteen alien species are exempted from the regulations.

Global conventions

Agreement	**Convention on Biological Diversity**
	CBD, Adopted: 1992; In force: 1993
Special section(s) relevant to alien species	The CBD in article 8h. states that: "Each Contracting Party shall, as far as possible and as appropriate prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species;"
	COP decisions on or related to aliens:
	Decision IV/1 Report and recommendations of the third meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, and instructions by the Conference of the Parties to the Subsidiary Body on Scientific, Technical and Technological Advice
	Decision V/8 Alien species that threaten ecosystems, habitats or species
	Decision IV/5 annex, Programme area 5 Conservation and sustainable use of marine and coastal biological diversity, including a programme of work
	Decision VI/23 on alien species that threaten ecosystems, habitats or species.
	Decision VII/13 Alien species that threaten ecosystems, habitats or species (Article 8 (h))
	SBSTTA Recommendations on aliens:
	Recommendation IV/4 Development of guiding principles for the prevention of impacts of alien species and identifying priority areas of work on isolated ecosystems and giving recommendations for further development of the Global Invasive Species Programme
	Recommendation V/4 Alien species: guiding principles for the prevention, introduction and mitigation of impacts
	Recommendation VI/4 Alien species that threaten ecosystems, habitats or species
	Recommendation IX/15 Invasive alien species
Content and coverage of regulation	The Convention on Biological Diversity is an agreement to take action on specific points relating to biodiversity including on aliens species. Each party has to report it's actions and how effective this is in meeting the objectives of the Convention. More than 180 states are now parties to the CBD. The CBD addresses the introduction of alien species globally. The Convention also works through legally binding agreements such as the COP decisions mentioned above. The CBD covers both unintentional and intentional introductions.
	Aliens species is a cross cutting issue under the CBD - all information on aliens under the CBD can be reached through the Alien Species Portal

Global conventions – continued.

Agreement	Convention on International Trade in Endangered Species of Wild Fauna and Flora
	CITES, Adopted: 1973; In force: 1975
Special section(s) relevant to alien species	In Article XIV a provision states that the Convention shall in no way affect the right of Parties to adopt domestic measures restricting or prohibiting trade, taking, possession or transport of species not included in Appendix I, II or III. The provision has been used in Europe to adress specific alien species (see section on regional legal instruments.)
Content and coverage of regulation	CITES works by subjecting international trade of selected species to certain controls. The species covered by CITES are threatened species which are listed in three appendices according to the degree of protection they need in the exporting countries.

Agreement	International Convention for the Control and Management of Ships's Ballast water and Sediments
	IMO BWMC Adopted: 2004
Special section(s) relevant to alien species	The entire convention deals with the effort to prevent harmful aquatic organisms to be transfered through ballastwater and sediments
Content and coverage of regulation	Parties must prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments. The parties may take more stringent measures with respect to the prevention, reduction or elimination of the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments, consistent with international law.

Agreement	United Nations Convention on the Law of the Sea (UNCLOS)
	UNCLOS, Adopted: 1982; In force: 1994
Special section(s) relevant to alien species	Article 196 (1) of the Convention states that: "States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto."
Content and coverage of regulation	States oblige to protect and preserve the marine environment from a "significant and harmful change" from the pollution by the intentional or uintential introduction of aliens species.

Agreement	The Convention on Wetlands (Ramsar Convention)
	Ramsar Convention: Adopted: 1971; In force: 1975
Special section(s) relevant to alien species	Resolution VII/14 on Invasive species and wetlands
Content and coverage of regulation	The Convention's mission is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world. The Ramsar Convention has identified invasive species as one of the threats to wetlands.

Global conventions – continued.

Agreement	**International Plant Protection Convention (IPPC)**
	Adopted: 1951; In force: 1952; Amended: 1987
Special section(s) relevant to alien species	An IPPC workshop on invasive alien species has been held in 2003.
	See also FAO's forestry homepage, which has a section on alien invasive forestry trees.
Content and coverage of regulation	The International Plant Protection Convention is an international treaty relating to plant health. While the Convention applies mainly to quarantine pests involved with international trade it extends to the protection of natural flora and plant products. It also includes both direct and indirect damage by pests, thus including weeds. The provisions extend to cover conveyances, containers, storage places, soil and other objects or material capable of harbouring plant pests.
	Under the International Plant Protection Convention (IPPC), the European and Meditarenean Plant Protection Organization (EPPO) is the regional plant protection organization (RPPO) for Europe. EPPO maintains an alert list of invasive species.

Guidelines

Guideline/Code	**IUCN Guidelines for the prevention of Biodiversity Loss Caused by Alien Invasive Species, 2000**
Special section(s) relevant to alien species	The guidelines relate directly to the article 8h of the Convention of Biological Diversity (CBD).
Content and coverage of guideline/code	The guidelines are intended to assist governments and management agencies in their implementation of article 8h of the Convention on Biological Diversity. The overall aim is to reduce the negative effects of alien invasive species. The guidelines were prepared by the SSC Invasive Species Specialist Group.

Guideline/Code	**IMO Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens, 1997**
Special section(s) relevant to alien species	The guidelines deal with ballast water and ballast sediments. The Guidelines have been instrumental in defining the contents of the new International Convention for the Control and Management of Ships's Ballast water and Sediments.
Content and coverage of guideline/code	The objectives of these Guidelines, developed under technical and scientific guidance, are to assist Governments and appropriate authorities, ship masters, operators and owners, and port authorities, as well as other interested parties, in minimizing the risk of introducing harmful aquatic organisms and pathogens from ships' ballast water and associated sediments while protecting ships' safety.

Guidelines – continued.

Guideline/Code	IUCN/SSC Guidelines for Re-Introductions, 1995
Special section(s) relevant to alien species	The guidelines are intended to act as a guide for procedures useful to re-introduction programmes. They deal with the intentional introduction of captive-bred individuals and the measures taken to prevent unintentional introduction of alien pathogens.
Content and coverage of guideline/code	These guidelines are based on the IUCN Position Statement on the Translocation of Living Organisms in 1987, prepared by the SSC Re-introduction Specialist Group.

Guideline/ strategy	The Pan-European Biological and Landscape Diversity Strategy, 1995
Special section(s) relevant to alien species	The Strategy is a proactive approach to stop and reverse the degradation of biological and landscape diversity values in Europe. The Strategy reinforces the implementation of existing measures and identifies additional actions that need to be taken over the next two decades. The strategy utilizes the "Principle of Avoidance" on IAS: Introduction into the natural environment of exotic species should require environmental impact assessment if likely to have significant adverse effects on biological and landscape diversity.
	The subject of alien invasive species was specifically adressed at the econd Intergovernmental Conference in Budapest, 2002. Also at the third intergovernmental Conference in Madrid, 2003 IAS were discussed and an action plan proposed.
	In Kiev, 2003 Ministers and senior officials from 55 countries endorsed the goal of halting the degradation of Europe's biological and landscape diversity by the year 2010. One of the Europe-wide targets for stabilizing biodiversity by 2010 was implementing an agreed strategy on alien invasive species in at least half of the region's countries by 2008.
Content and coverage of guideline/code	The Strategy provides a framework to promote a consistent approach and common objectives for national and regional action to implement the Convention on Biological Diversity.

Guideline/Code	FAO Code of Conduct for Responsible Fisheries, 1995
Special section(s) relevant to alien species	Article 9,2,3: "States should consult with their neighboring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems."
	Article 9,3,1: "States should conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of origin. States should, whenever possible, promote steps to minimize adverse genetic, disease and other effects of escaped farmed fish on wild stocks."
Content and coverage of guideline/ strategy	This Code sets out "principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity."
	The code thus covers unintentional and intentional introductions related to fisheries, including aquaculture. The Code is voluntary.

Guideline/Code	ICES code of practice on the Introduction and transfer of Marine Organisms, 2003
Special section(s) relevant to alien species	The ICES Code of Practice recommends procedures and practices to reduce the risks of the intentional introduction and transfer of marine (including brackish water) organisms. See also report from the working group on introduction and transfer of marine organisms (2003).
Content and coverage of guideline/code	The International Council for the exploration of The Sea (ICES) is an organisation that coordinates and promotes marine research in the North Atlantic. This includes adjacent seas such as the Baltic Sea and North Sea.

Appendix 2

Interviews with stakeholders harbours and marinas Dutch Wadden Sea

List of questions

The following questions were used in the interviews with stakeholders.

Hull fouling

- Are you familiar with fouling of algae and animals on objects in the water?
- Is that a problem for your organisation?
- If so, what is the nature of that problem?
- How is it managed?
- A definition of alien species is given (an alien species is an introduced non-native species, that is, a plant, animal, fungus or microorganism, which by human activities actively or passively arrived outside their original distribution range.
- Do you know that alien species occur in the biofouling?
- If so, can you name an alien species?
- Are these alien species an extra problem for your company?
- Do these alien species threaten nature in the Wadden Sea?
- Can you name legislation focused on alien species?
- Do you know the voluntary IMO guidelines for hull fouling?
- Do you implement these guidelines?
- If so, what are roughly the costs?

*Ballast wate*r

The same questions but focused on ballast water.

Harbour service Harlingen

This organisation provides municipal shipyard services. The municipal shipyard service maintains the infrastructure in the Harlingen harbour. They are responsible for jetties, mooring posts, escape ladders and breakwaters.

- The harbour service is familiar with marine fouling on all sorts of structures.
- For the harbour service, fouling underwater is not an issue. It is a problem, however, for emerged surfaces (for example, growth of algae on pontoons, making them slippery).
- They do not remove fouling from under water surfaces, except for escape ladders.
- They use high-pressure jet streams to clean surfaces.
- They are familiar with alien species in the marine environment in the Dutch Wadden Sea.
- For the harbour service, alien species in the marine environment are not an issue.
- Alien species can be a problem to native species. However, they are considered unavoidable since the Wadden Sea is constantly changing. The company is aware that all sorts of ships from elsewhere from the world enter the Wadden Sea and can carry alien

species with them, e.g. via ballast water. An example was given, in which sand collected off the British coast has been transported to the Wadden Sea. Den Helder harbour was named as a harbour, which has problems and issues with fouling, following discharges of ballast water.

ICON Yachts

This company is part of the shipyard Harlingen. Due to time constraints they were not able to give an interview.

Damen Shiprepair Harlingen

This company is part of the shipyard Harlingen. Core-business of this company is repair, maintenance and cleaning of ships. Hull cleaning and applying anti-fouling is part of their core-business.

Hull-fouling

- The company is familiar with marine fouling on all sorts of structures, including hulls. Cleaning ship hulls and applying anti-fouling afterwards is daily business.
- For the company, fouling is not a problem in itself; it's in fact their living.
- They clean ship hulls with high-pressure jet streams. Exception are ships with a thick cover of fouling (e.g., molluscs from the tropics), they manually clean the hulls with spades. The organic material is discarded as chemical waste, since it holds paint parts.
- Several years ago, paints for anti-fouling containing copper were prohibited. After removing the fouling from ship hulls, the ships are re-painted. This is only allowed with certified paints.
- Damen Shiprepair is familiar with alien species in the marine environment in the Wadden Sea.
- An example was given of the explosive growth of Pacific oyster in the Wadden Sea. The consensus is that this species was transported with ballast water. Ships from tropical regions are observed to suffer more from fouling then ships from temperate regions. For example, ships from Brazil are often covered with molluscs and have to be cleaned with heavy material.

Ballast water

- The company is familiar with the fact that organism are being transported in ballast water.
- Most organisms in ballast water are too small for the naked eye.
- The company is aware of legislation in regard to alien species and that this will change in the coming years, but they are not able to name specific legislation.
- Damen Shiprepair Harlingen is developing a mobile, port-based ballast water cleaning facility, in collaboration with Groningen Seaports. The idea is a container with a cleaning unit and a pumping system. This port-based cleaning facility can either be installed on a ship or on a trailer. Installed on a ship, it can moor alongside a ship that needs to discharge its ballast water. This ballast water is being pumped into the cleaning unit and after treatment is directly discharged into the open water. Damen Shiprepair develops the idea

while Groningen Seaports provides a ship that can hold the container. A trailer holding the container is another option. In this way, the treatment facility is operated from the harbour's docking piers.

Groningen Seaports

This organisation is responsible for the port management of the harbours Eemshaven and Delfzijl. Two staff officers of the Haven Coördinatie Centrum (Harbour Coordination Centre) were interviewed.

Staff officer 1

Hull fouling

- The organisation is familiar with marine fouling on all sorts of structures, including hulls.
- The organisation is familiar with alien species in fouling (and ballast water).
- For Groningen Seaports this poses a problem, since cleaning ship hulls frequently releases toxic components (from the anti-fouling). Groningen Seaports is responsible for the quality of the port's sea bottom. It's their responsibility to keep the silt and sand at the sea bottom in the port as clean as possible. In order to accommodate ships, the port's sea bottom occasionally needs to be dredged. The silt and sand is then deposited in de Ems estuary. If this material is too polluted, Groningen Seaports is not allowed to deposit silt/sand in the Ems estuary. The port's sea bottom is currently quite clean and Groningen Seaports intents to keep it that way.
- At Groningen Seaports, there's two floating dry-docks providing cleaning facilities for ship hulls. Cleaning of hulls is done by high-pressure jet streams. The organic material including paint remnants is being sampled for toxic levels. Afterwards, the material is being discarded as (chemical) waste.
- Some ship-owners have requested Groningen Seaports to clean their ships underwater, using divers to scrub off the hull. Despite the attempt of sucking up the material while cleaning, Groningen Seaports refused the request. There's no guarantee that material won't fall to the sea bottom. The ship owner, in response, claimed this procedure was allowed at Rotterdam port. It's unclear whether this is true or not. Groningen Seaports has a clear policy on hull cleaning (and ballast water). They are well aware their port is located right next to the Waddensea. They are also aware the Wadden Sea is a Natura 2000 area and a UNESCO World Heritage Site. They take effort in informing the "green" stakeholders in the Wadden Sea about their sustainability policies.

Ballast water

- The organisation is familiar with marine organisms being transported through ballast water.
- The organisation is familiar with alien species in ballast water.
- Main trade of Groningen Seaports used to be of West-European origin.
- With the new power plant (running on coals) and strategic storage of crude oil, there's an increase in ship-movements for elsewhere around the world (e.g. southern Africa, Central and South America, Asia). These ships enter Groningen Seaports with cargo, so

discharging ballast water is not an issue. However, Groningen Seaports expects this to change. As of yet, ships dock for about 2 days to unload their cargo and then move on.

Staff officer 2

Hull fouling

- The organisation is familiar with marine fouling on all sorts of structures, including hulls.
- The organisation is familiar with alien species in fouling (and ballast water).
- In the Netherlands, the organisation is one of the leading parties in preventing the spread of alien species through ballast water.
- Two students of TU Delft University have developed a system to clean ship hulls under water, using a robot. This system also involves collecting the fouling (rather then letting is settle on the sea bottom). It seems a promising technique. Groningen Seaports has cooperated in the development of this technique. The Waddenfonds financed part of the project. Currently, commercial parties are also involved. Groningen Seaports has some doubts whether or not this robotic system completely collects the debris. In other words, Groningen Seaports is not (yet) convinced of its 100% accuracy. Groningen Seaports prohibits the under water cleaning of ship hulls, in order to prevent fouling material settling on the sea bottom.
- In itself, alien species are not an issue for Groningen Seaports. However, almost nothing is known of direct damages caused by alien species to harbour structures. This could be a potential problem. Preventing the spread of alien species and cleaning harbour structures is currently not on Groningen Seaports agenda. However, Groningen Seaports is aware of the fact that it might be wise to be more pro-active, in order to extend durability of harbour structures.
- Pacific oyster has increased rapidly within the harbour. They cause a problem due to their sharp edges and because they are difficult to remove from structures.
- Groningen Seaports hopes the Dutch government takes up their law enforcement tasks in regard to alien species.

Ballast water

- Groningen Seaports is the first port in the world with a port-based ballast water treatment facility. This facility was developed together with Damen Shipyards. The facility combines a pumping station and cleaning unit, integrated in a container.
- Groningen Seaports works with the Ballast Water Directive (International Marine Organisation). With the utilization of the port-based treatment facility, Groningen Seaports actually is ahead of the directive. Amsterdam and Rotterdam ports have indicated they are interested in the port-based treatment facility.
- The Ballast Water Directive is only operative when a minimum number of member states rectify the directive. Additionally, a minimum percentage of the total global cargo has to be represented by the member states. Currently, these criteria are not yet met. However, several European member states are about to rectify the directive.
- Legislation in regard to ballast water will only sort an effect when governments actively enforce the law. Groningen Seaports hopes the Dutch government takes up their law enforcement responsibilities in this regard.

Port of Den Helder

According to Groningen Seaports, the port of Den Helder has the highest number of ship movements in the Wadden Sea area. However, in comparison to other ports in the Wadden Sea area, it has a low cargo load rate. No staff officers could be interviewed.

Vlieland harbour

- The organisation is familiar with marine fouling on all sorts of structures.
- Fouling is a potential problem for Vlieland harbour. They use mainly floating jetties. With an increase in fouling, they become heavier in time. This in turn means the jetties lie lower in the water. Molluscs and seaweed commonly grow on the floating jetties.
- In and around the harbour Pacific oyster is common. The harbour considers this their biggest problem: they are very sharp, posing a risk for their visitors.
- Emergency steps in the harbour regularly get overgrown, making them slippery. The organisation uses anti-fouling on the emergency steps, but this only works for a limited time.
- The organisation has no specific maintenance focused on fouling. Under water cleaning is difficult, and lifting the jetties out of the water is a big and costly operation.
- Ballast water is not an issue in Vlieland harbour, there are only recreational ships coming in and out of the harbour.
- The harbour manager is not familiar with legislation in regard to alien species.
- The harbour manager wishes to receive a copy of this report. He seems to be interested in our findings concerning fouling (either native or alien).

Texel harbour (Oudeschild)

- The organisation is familiar with marine fouling on all sorts of structures.
- Fouling is not a problem for the Texel harbour. In the view of the harbour manager, fouling does not really accumulate because part of the organic matter dies of during winter.
- The jetties in the harbour have been in use for 15 years. They are still properly functioning. The organisation has no maintenance on the jetties. The harbour uses two small ships, in October they're lifted from the water, cleaned, have anti-fouling applied and stored during the winter.
- The majority (95%) of ships and yachts in the harbour are from the Netherlands and Germany. Long-term storage harbours of these ships are within the Lake IJssel. This is also the case with the German ships.
- Customers of the Texel harbour do not complain or make comments about fouling.
- Ballast water is not an issue in Texel harbour, there are only recreational ships coming in and out of the harbour.

Appendix 3

List of questions for nature reserve managers Dutch Wadden Sea islands

The terrestrial habitats, include salt marshes, dunes, beaches and polders.

The following questions were used in the interviews with stakeholders.

- *A definition of alien species is given (an alien species is an introduced non-native species, that is, a plant, animal, fungus or microorganism, which by human activities actively or passively arrived outside their original distribution range.*

- Which alien species do you know on the Wadden Sea islands?
- Are you familiar with alien species in your management area?
- Are alien species registered as such in your monitoring program?
- Is this information available?
- Are you familiar with the risks of alien species for nature in your management area?
- Can you name these risks?
- Are these alien species an actual risk for nature within or outside your management area on the Wadden Sea island?
- If so, what is the nature of those risks?
- How are these risks managed?
- Can you name legislation focused on alien species?
- Do you take measures to prevent or manage the impact of alien species?
- If so, what are roughly the costs?
- Which requests do you have for the future management of alien species?
- Do you have any other issues, which should be put forward but were not adressed?

Appendix 4 Risk assessments of alien species and pathways in the Netherlands.

The list of references of risk assessments reports of alien species and pathways actually or potentially occurring in the Netherlands is presented below (Table A.1). The numbers in the first column refers to Table A.2, whih included species names in English, Dutch and scientific name, potential occurrence in the Wadden Sea and Wadden Sea islands (0 = unlikely, 1 = likely) and reference number of the risk assessment report (usually in English) in Table A.1. All reports are available as pdf's of the website of the Invasive Alien Species Team, Office for Risk Assessment and Research, Food and Consumer Product Safety Service, Ministry of Economic Affairs, but this website does not (yet) provide a species overview.

www.nvwa.nl/onderwerpen/meest-bezocht-a-z/dossier/invasieve-exoten/risicobeoordelingen-reactieperiode/risicobeoordelingsrapporten

Table A.1 Risk assessment publications of alien species and pathways in the Netherlands.

Nr	Publication
1	Beemster N. & E. Klop 2013. Risk assessment of the Black swan (Cygnus atratus) in the Netherlands. A&W-report 1978. A&W, Veenwouden.
2	Boer E. 2011. Risk analysis *Rose rugosa*. Report, National biodiversity centre, Leiden.
3	Boer E. 2013. Risk analysis Ailanthus altissima. Report, National biodiversity centre, Leiden.
4	Boer E. 2014. Risk assessment cotoneaster spp. Report, Naturalis Biodiversity Centre, Leiden.
5	Boer E. 2015. Risk analysis Ailanthus altissima. Report, National biodiversity centre, Leiden.
6	Bouma S. & D.M. Soes, 2010. A risk analysis of the Chinese mitten crab in The Netherlands. Report 10-025, Bureau Waardenburg, Culemborg
7	Bugter R., F. Ottburg, I. Roessink, H. Jansman, E. van der Grift & A. Griffioen, 2011. Invasion of the turtles? Exotic turtles in the Netherlands: a risk assessment. Wageningen, Alterra, Alterra report 2186.
8	Bugter R.J.F., S. van de Koppel, R. Creemers, A.J. Griffioen en F.G.W.A. Ottburg, 2014. Uitheemse slangen in Nederland; Een analyse van de kans op introductie, vestiging, uitbreiding en schade. Wageningen, Alterra Wageningen UR (University & Research centre), Alterra-rapport 2496, RAVONRapport 2013.112, Natuurbalans-Limes Divergens-Rapport 12-181. Nijmegen.
9	de Bruijne W.J.J. & P. Pellinckhof 2009. Risicoanalyse *Sinelobus stanfordi.* Rapport, Arcadis, Apeldoorn.
10	Dekker J.J.A. 2012. De Amerikaanse nerts in Nederland. Rapport 2012.16. Zoogdiervereniging, Nijmegen.
11	Dijkstra V. & J. Dekker, 2008. Risico-assessment uitheems eekhoorns. VZZ rapport 2008.10. Zoogdiervereniging VZZ, Arnhem.
12	Fey F., A.M. van den Brink, J.W.M. Wijsman, O.G. Bos 2010. Risk assessment on the possible introduction of three predatory snails (Ocinebrellus inornatus, Urosalpinx cinerea , Rapana venosa) in the Dutch Wadden Sea. Report number C032/10, Imares, Wageningen
13	Gittenberger A. 2010. Risk analysis of the colonial sea-squirt Didemnum vexillum Kott, 2002 in the Dutch Wadden Sea, a UNESCO World Heritage Site. Rapport, GiMaRes, Leiden.
14	Gittenberger A. 2014. Risicoanalyse van de Amerikaanse langlob-ribkwal Mnemiopsis leidyi A. Agassiz, 1865. Rapport, GiMaRes, Leiden.
15	Gyimesi A. & R. Lensink 2010. Risk analysis of the Egyptian Goose in The Netherlands; biology and management options. Rapport 10-029, Bureau Waardenburg, Culemborg.
16	Hollander, H., 2013. Risico-analyse muntjak (Muntiacus reevesi). - Rapport 2013.09. Zoogdiervereniging, Nijmegen.
17	Koopman K.R., J. Matthews, R. Beringen, B. Odé, R. Pot, G. van der Velde, J.L.C.H. van Valkenburg & R.S.E.W. Leuven 2013. Risicoanalyse van de uitheemse Egeria (Egeria densa) in Nederland. Report, afd milieukunde, RUN, Nijmegen
18	Lammertsma D.R., G.W.T.A. Groot Bruinderink and A.J. Griffioen, 2012. Risk assessment of Sika Deer Cervus nippon in the Netherlands. Wageningen, Alterra, Alterra-Report 2295.
19	Lammertsma, D.R., G.W.T.A. Groot Bruinderink & S. Broekhuizen, 2008. Wasberen (Procyon lotor L.1758) in Nederland; verspreiding, ecologie en mogelijk gevolgen voor Nederland. Wageningen, Alterra, Report 2022.
20	Lemaire A.J.J. & P. Wiersma. 2011. Risicoanalyse van geïntroduceerde ganzensoorten in Nederland. SOVONinformatierapport 2010-06. SOVON Vogelonderzoek Nederland, Nijmegen.
21	Lensink R. & F. Van Vliet 2012. Risk analysis of Possums and Opossums in The Netherlands. Rapport 12-001, Bureau Waardenburg, Culemborg.
22	Lensink R. & T.M. Van der Have 2013. Risk analysis of the Vinous-throated Parrotbill in The Netherlands. Report 13-029, Bureau Waardenburg, Culemborg
23	Matthews J., R. Beringen, F.P.L. Collas, K.R. Koopman, B. Odé, R. Pot, L.B. Sparrius, J.L.C.H. van Valkenburg, L.N.H. Verbrugge & R.S.E.W. Leuven 2012. Risk analysis of non-native Curly Waterweed *(Lagarosiphon major*) in the Netherlands. Report 418, Milieukunde, RUN, Nijmegen
24	Matthews J., R. Beringen, F.P.L. Collas, K.R. Koopman, B. Odé, R. Pot, L.B. Sparrius, J.L.C.H. van Valkenburg, L.N.H. Verbrugge & R.S.E.W. Leuven 2012. Risk analysis of non-native Tapegrass (Vallisneria spiralis) in the Netherlands. Report 420, Milieukunde, RUN, Nijmegen
25	Matthews J., R. Beringen, F.P.L. Collas, K.R. Koopman, B. Odé, R. Pot, L.B. Sparrius, J.L.C.H. van Valkenburg, L.N.H. Verbrugge & R.S.E.W. Leuven 2013. Risk analysis of non-native Fanworth *Cabomba caroliniana* in the Netherlands. Report 442, Milieukunde, RUN, Nijmegen

Nr	Referentie
26	Matthews J., R. Beringen, F.P.L. Collas, K.R. Koopman, B. Odé, R. Pot, L.B. Sparrius, J.L.C.H. van Valkenburg, L.N.H. Verbrugge & R.S.E.W. Leuven 2013. Risk analysis of the non-native Monkeyflower (Mimulus guttatus) in the Netherlands. Report 419, Milieukunde, RUN Nijmegen.
27	Mulder J.L. 2011. The raccoon dog in the Netherlands – a risk assessment, Rapport, Bureau Mulder-Natuurlijk, De Bilt.
28	Noordijk J., 2010. A risk analysis for fire ants in the Netherlands. Report, EIS, Leiden
29	Noordijk J., J. Vos & B. Schoelitsz 2013. Risicobeoordeling van zwarte weduwen en verwante spinnensoorten. – EIS-Nederland, Leiden & Stichting KAD, Wageningen.
30	NVWA 2013. Signaaladvies over de vestiging van de Aziatische hoornaar *Vespa velutina* in Nederland en de mogelijke risico's voor inheemse bijnenvolken. Brief 4 november 2013.
31	Odé B., R. Beringen, F.P.L. Collas, K.R. Koopman, J. Matthews, G. van der Velde, J.L.C.H. van Valkenburg & R.S.E.W. Leuven 2015. Risicoanalyse van de uitheemse Gifsumak (Toxicodendron radicans) in Nederland. Rapport 480, Milieukunde, RUN Nijmegen.
32	Schiphouwer M.E., N. van Kessel, J. Matthews, R.S.E.W. Leuven, S. van de Koppel, J. Kranenbarg, O.L.M. Haenen, H.J.R. Lenders, L.A.J. Nagelkerke, G. van der Velde, B.H.J.M. Crombaghs, R. Zollinger. 2014. Risk analysis of exotic fish species included in the Dutch Fisheries Act and their hybrids. Report, RAVON, Nijmegen
33	Slaterus R., Aarts B. & van den Bremer L. 2009. De Huiskraai in Nederland: risicoanalyse en beheer. SOVON-onderzoeksrapport 2009/08. SOVON Vogelonderzoek Nederland, Beek-Ubbergen.
34	Smits R.R., P.W. Van Horssen & J. Van der Winden 2010. A risk analysis of the sacred ibis in The Netherlands; Including biology and management options of this invasive species. Report 10-005, Bureau Waardenburg, Culemborg.
35	Soes D.M. & A.J. Winter 2011. Risicoanalyse van de Spaanse wegslak Arion lusitanicus in Nederland. Rapport 11-115, Bureau Waardenburg, Culemborg.
36	Soes D.M. & B. Kroeze 2010. Invasive crayfish in the Netherlands: a preliminary risk analysis. Report EIS 2010-01, EIS/BW, Culemborg/Leiden.
37	Soes D.M. & P.B. Broeckx 2010. A risk analysis of exotic trout in the Netherlands. Report 10-144, Bureau Waardenburg, Culemborg
38	Soes D.M., R.S.E.W. Leuven, J. Matthews, P.B. Broeckx, O.L.M. Haenen & M.Y. Engelsma 2011. A risk analysis of bigheaded carp (Hypophthalmichthys sp.) in the Netherlands. Report 11-174, Bureau Waardenburg, Culemborg.
39	Soes D.M., S.J. Cooke, H.H. Van Kleef, P.B. Broeckx & P. Veenvliet 2011. A risk analysis of sunfishes (Centrarchidae) and pygmy sunfishes (Elassomatidae) in the Netherlands. Report 11-042, Bureau Waardenburg, Culemborg.
40	Spikmans F. N. van Kessel, M. Dorenbosch, J. Kranenbarg, J. Bosveld & R. Leuven 2010. Plaag Risico Analyses van tien exotische vissoorten in Nederland. Nederlands Centrum voor Natuuronderzoek: Stichting RAVON, Radboud Universiteit Nijmegen, Stichting Bargerveen & Natuurbalans – Limes Divergens, Nijmegen.
41	Spitzen – van der Sluijs A.M. & R. Zollinger, 2010. Risk Assessment on the American bullfrog and the fungus Batrachochytrium dendrobatidis. Stichting RAVON, Nijmegen, the Netherlands.
42	van Belle J. & J. Schut 2011. Risicoanalyse stinkdieren in Nederland. Rapport 1629, A&W, Veenwouden.
43	Van de Koppel S., N. van Kessel, B.H.J.M. Crombaghs, W. Getreuer & H.J.R. Lenders, 2012. Risk Analysis of the Asp Viper (Vipera aspis) in the Netherlands. Natuurbalans - Limes Divergens BV, Nijmegen / ReptielenZoo SERPO, Delft /Netherlands. Radboud University, Nijmegen.
44	Van de Koppel S., N. van Kessel, B.H.J.M. Crombaghs, W. Getreuer & H.J.R. Lenders, 2012. Risk Analysis of the Russian Rat Snake (Elaphe schrenckii) in the Netherlands. Natuurbalans - Limes Divergens BV, Nijmegen / ReptielenZoo SERPO, Delft / Radboud University, Nijmegen.
45	van Delft J.J.C.W., A.M. Spitzen-van der Sluijs, E. Goverse, R.P.J.H. Struijk & R.C.M. Creemers, 2012. Risicoanalyse van de springkikker (Rana dalmatina) in Nederland. Rapport, RAVON, Nijmegen.
46	van Kleunen A. & Lemaire A.J.J. 2014. A risk assessment of Mandarin Duck (Aix Galericulata) in the Netherlands. Sovon-report 2014/15. Sovon Dutch Centre for Field Ornithology, Nijmegen.
47	van Kleunen A., van den Bremer L., Lensink R. & Wiersma P. De Halsbandparkiet, Monniksparkiet en Grote Alexanderparkiet in Nederland: risicoanalyse en beheer. SOVON-onderzoeksrapport 2010/xx. SOVON Vogelonderzoek Nederland, Nijmegen
48	van Loon A.J. 2009. Risicoanalyse van de plaagmier Lasius neglectus. Rapport EIS, Leiden.
49	Van Vliet A.J.H., S. Mulder, R.L. Terhürne, W.A. Bron, 2009. Toekomstschets Ambrosia,Leerstoelgroep Milieusysteemanalyse, Wageningen Universiteit, Wageningen, Pp. 38.

Table A.2 List of alien species with reference to the risk assessment report (Table A.1) and Wadden Sea or Wadden Sea island potential.

Taxon	Common name	Nederlandse naam	Scientific name	WS	Ref.
1. Amphibian	Agile frog	Springkikker	*Rana dalmatina*	1	45
1. Amphibian	American Bull frog	Amerikaanse brulkikker	*Batrachochytrium dendrobatidis*	1	41
2. Reptile	Aesculapian snake	Esculaapslang	*Zamenis longissimus*	1	8
2. Reptile	Asp viper	Aspisadder	*Vipera aspis*	1	43
2. Reptile	Asp viper	Aspisadder	*Vipera aspis*	1	8
2. Reptile	Blandings turtle	Amerikaanse moerasschilpad	*Emydoidea blandingii*	1	7
2. Reptile	Bog turtle	Mühlenbergs schilpad	*Clemmys muhlenbergii*	1	7
2. Reptile	Chinese softshell turtle	Chinese drieklauw	*Pelodiscus sinesis*	1	7
2. Reptile	Common garter snake	Gewone kousebandslang	*Thamnophis sirtalis*	1	8
2. Reptile	Common musk turtle	Muskusschilpad	*Sternotherus odoratus*	1	7
2. Reptile	Cumberland slider	Geelwangschilpad	*Trachemys scripta troostii*	1	7
2. Reptile	Diamant python	Diamantpython	*Morelia spilota*	1	8
2. Reptile	Dice snake	Dobbelsteenslang	*Natrix tessellata*	1	8
2. Reptile	Eastern Long-necked turtle	Langnekslangehalsschilpad	*Chelodina longicollis*	1	7
2. Reptile	Eastern water snake	Ooostelijke ringslang	*Natrix natrix persa*	1	8
2. Reptile	European pond turtle	Europese moerasschilpad	*Emys orbicularis*	1	7
2. Reptile	False map turtle	Onechte landkaartschilpad	*Graptemys pseudogeographica*	1	7
2. Reptile	Japanse rat snake	Japanse rattenslang	*Elaphe climacophora*	1	8
2. Reptile	King rat snake	Taiwanese stinkslang	*Elaphe carinata*	1	8
2. Reptile	Mexican milk snake	Melkslang	*Lampropeltis triangulum*	1	8
2. Reptile	Northern map turtle	Landkaartschilpad	*Graptemys geographica*	1	7
2. Reptile	Northern water snake	Noordelijke waterslang	*Nerodia sipedon*	1	8
2. Reptile	Painted turtle	Sierschilpad	*Chrysemys picta*	1	7
2. Reptile	Red rat snake	Rode rattenslang	*Pantherophis guttatus*	1	8
2. Reptile	Red-bellied slider	Roodbuiksierschilpad	*Pseudemys rubriventris*	1	7
2. Reptile	Red-eared slider	Roodwangschilpad	*Trachemys scripta elegans*	1	7
2. Reptile	Russian rat snake	Russische rattenslang	*Elaphe schrenckii*	1	44
2. Reptile	Russian rat snake	Russische rattenslang	*Elaphe schrenckii*	1	8
2. Reptile	Snapping turtle	Bijtschilpad	*Chelydra serpentina*	1	7
2. Reptile	Sonoran gopher snake	Stierslang	*Pituophis catenifer*	1	8
2. Reptile	Spiny shoftshell turtle	Doornrandweekschildpad	*Apalone spinifera*	1	7
2. Reptile	Spotted turtle	Druppelschilpad	*Clemmys guttata*	1	7
2. Reptile	Viperine water snake	Adderringslang	*Natrix maura*	1	8
2. Reptile	Western hognosed snake	Westelijke haakneusslang	*Heterodon nasicus*	1	8
2. Reptile	Western pond turtle	Pacifische waterschilpad	*Clemmys marmorata*	1	7
2. Reptile	Western rat snake	Westelijke rattenslang	*Pantherophis obsoletus*	1	8

Taxon	Common name	Nederlandse naam	Scientific name	WS	Ref.
2. Reptile	Wood turtle	Bosbeekschilpad	*Clemmys insculpta*	1	7
2. Reptile	Yellow-bellied slider	Geelbuikschilpad	*Trachemys scripta scripta*	1	7
3. Bird	Alexander parakeet	Grote alexanderparkiet	*Myiopsitta monachus*	1	47
3. Bird	Bar-headed goose	Indische gans	*Anser indicus*	1	20
3. Bird	Black swan	Zwarte zwaan	*Cygnus ater*	1	1
3. Bird	Canada goose	Canadese gans	*Branta canadensis*	1	20
3. Bird	Egyptian goose	Nijlgans	*Alopochen aegyptiaca*	1	15
3. Bird	Emperor goose	Keizergans	*Anser canagicus*	1	20
3. Bird	Indian house crow	Huiskraai	*Corvus splendis*	1	33
3. Bird	Mandarin duck	Mandarijneend	*Aix Galericulata*	1	46
3. Bird	Monk parakeet	Monniksparkiet	*Psittacula eupatria*	1	47
3. Bird	Rose-ringed parakeet	Halsbandparkiet	*Psittacula krameri*	1	47
3. Bird	Ross' goose	Ross' gans	*Anser rossii*	1	20
3. Bird	Sacred ibis	Heilige ibis	*Threskiornis aethiopicus*	1	34
3. Bird	Snow goose	Sneeuwgans	*Anser caerulescens*	1	20
3. Bird	Swan goose	Zwaangans	*Anser cygnoides*	1	20
3. Bird	Upland goose	Magelheangans	*Chloephaga picta*	1	20
3. Bird	Vinous-throated parrotbill	Bruinkopdiksnavelmees	*Paradoxornis webbianus*	1	22
4. Mammal	American Hog-nosed skunk	Varkenssnuitskunk	*Conepatus leuconotus*	1	42
4. Mammal	American mink	Amerikaanse nerts	*Neovison vison*	1	10
4. Mammal	American red squirrel	Amerikaanse rode eekhoorn	*Tamiasciurus hudsonicus*	1	11
4. Mammal	Caucasian squirrel	Kaukasuseekhoorn	*Sciurus anomalus*	1	11
4. Mammal	Common Brushtail Possum	Voskoesoe	*Trichosurus vulpecula*	1	21
4. Mammal	Eastern chipmunk	Amerikaanse grondeekhoorn	*Tamias striatus*	1	11
4. Mammal	Eastern spotted skunk	Oostelijke gevlekte skunk	*Spilogale putorius*	1	42
4. Mammal	Gray Four-eyed Opossum	Grijze vieroogbuidelrat	*Philander opossum*	1	21
4. Mammal	Gray Short-tailed Opossum	Huisbuidelspitsmuis	*Monodelphis domestica*	1	21
4. Mammal	Grey squirrel	Grijze eekhoorn	*Sciurus carolinensis*	1	11
4. Mammal	Hooded skunk	Gekraagde skunk	*Mephitis macroura*	1	42
4. Mammal	Japanese squirrel	Japanse eekhoorn	*Sciurus lis*	1	11
4. Mammal	Muntjac	Muntjak	*Muntiacus reevesi*	1	16
4. Mammal	Pallas' squirrel	Pallas eekhoorn	*Callosciurus erythraeus*	1	11
4. Mammal	Prevost squirrel	Prevost eekhoorn	*Callosciurus prevosti*	1	11
4. Mammal	Raccoon	Wasbeer	*Procyon lotor*	1	19
4. Mammal	Raccoon dog	Wasbeerhond	*Nyctereutes procyonoides*	1	27
4. Mammal	Siberian chipmunk	Siberische grondeekhoorn	*Tamias sibiricus*	1	11
4. Mammal	Sika deer	Sikkahert	*Cervus nippon*	1	18
4. Mammal	Small Fat-tailed Opossum	Woestijnmuisopossum	*Thylamys pusilla*	1	21

Taxon	Common name	Nederlandse naam	Scientific name	WS	Ref.
4. Mammal	Striped Possum	Gestreepte buideleekhoorn	*Dactylopsila trivirgata*	1	21
4. Mammal	Striped skunk	Gestreept stinkdier	*Mephitis mephitis*	1	42
4. Mammal	Swinhoes striped squirrel	Chinese boomeekhoorn	*Tamiops swinhoei*	1	11
4. Mammal	Variegated squirrel	Dorsalis eekhoorn	*Sciurus variegatoides dorsalis*	1	11
4. Mammal	Virginia Opossum	Virginia opossum	*Didelphis virginiana*	1	21
4. Mammal	Western spotted skunk	Westelijke gevlekte skunk	*Spilogale gracilis*	1	42
4. Mammal	White-eared Opossum	Witooropossum	*Didelphis albiventris*	1	21
Freshwater fish	Amur sleeper	Amoergrondel	*Perccottus glenii*	0	40
Freshwater fish	Arctic char	Beekridder	*Salvelinus alpinus*	0	32
Freshwater fish	Aspius	Roofblei	*Leuciscus aspius*	0	32
Freshwater fish	Brook trout	bronforel	*Salvelinus fontinalis*	0	37
Freshwater fish	Common carp	Karper	*Cyprinus carpio*	1	32
Freshwater fish	Eared sunfish	Grootoorzonnebaars	*Lepomis auritus*	1	39
Freshwater fish	Eastern mudminnow	Hondsvis	*Umbra pygmaea*	1	32
Freshwater fish	Fathead minnow	Dikkopelrits	*Pimephales promelas*	1	40
Freshwater fish	Grass carp	Graskarper	*Ctenopharyngodon idella*	1	32
Freshwater fish	Green sunfish	Groene zonnebaars	*Lepomis cyanellus*	1	39
Freshwater fish	Hybrid ‘cross carp’	Kruiskarper	*Cyprinus carpio x Carassius sp.*	1	32
Freshwater fish	Japanese weather loach	Chinese modderkruiper	*Misgurnus anguillicaudatus*	1	40
Freshwater fish	Kesslers goby	Kesslers grondel	*Neogobius kessleri*	0	40
Freshwater fish	Largemouth bass	Forelbaars	*Micropterus salmoides*	1	39
Freshwater fish	Largescale silver carp	grote zilverkarper	*Hypophthalmichthys harmandi*	1	38
Freshwater fish	Monkey goby	Pontische stroomgrondel	*Neogobius fluviatilis*	0	40
Freshwater fish	Northern whitefin gudgeon	Witvingrondel	*Romanogobio belingi*	0	40
Freshwater fish	Pike-perch	Snoekbaars	*Sander lucioperca*	0	32
Freshwater fish	Prussian carp	Giebel	*Carassius gibelio*	1	32
Freshwater fish	Pumpkinseed sunfish	zonnebaars	*Lepomis gibbosus*	1	39
Freshwater fish	Racer goby	Naakthalsgrondel	*Neogobius gymnotrachelus*	0	40
Freshwater fish	Rainbow trout	regenboogforel	*Oncorhynchus mykiss*	0	37
Freshwater fish	Rock bass	steenbaars	*Ambloplites rupestris*	1	39
Freshwater fish	Round goby	Zwartbekgrondel	*Neogobius melanostomus*	0	40
Freshwater fish	Sea trout	Zeeforel	*Salmo trutta trutta*	1	32
Freshwater fish	Silver carp	zilverkarper	*Hypophthalmichthys molitrix*	1	38
Freshwater fish	Smallmouth bass	Kleinbekbaars	*Micropterus dolomieu*	1	39
Freshwater fish	Stone moroko	Blauwband	*Pseudorasbora parva*	0	40
Freshwater fish	Vendace	Houting	*Coregonus albula*	1	32
Freshwater fish	Western tubenose goby	Marmergrondel	*Proterorhinus semilunaris*	0	40
Freshwater invertebrate	Australian redclawed crayfish	Australische roodklauwkreeft	*Cherax quadricarinatus*	1	36
Freshwater invertebrate	Eastern crayfish	Gevlekte Am. Rivierkreeft	*Orconectes limosus*	1	36
Freshwater invertebrate	Marbled crayfish	Gestreepte Am. rivierkreeft	*Procambarus acutus*	1	36

Taxon	Common name	Nederlandse naam	Scientific name	WS	Ref.
Freshwater invertebrate	Marbled crayfish	Marmerkreeft	*Procambarus acutus*	1	36
Freshwater invertebrate	Red swamp crayfish	Rode Amerikaanse rivierkreeft	*Procambarus clarkii*	1	36
Freshwater invertebrate	Signal crayfish	Californische rivierkreeft	*Pacifastacus leniusculus*	1	36
Freshwater invertebrate	Stone crayfish	Steenkreeft	*Austropotamobius torrentium*	1	36
Freshwater invertebrate	Turkish crayfish	Turkse rivierkreeft	*Astacus leptodactylus*	1	36
Freshwater invertebrate	Virile crayfish	Geknobbelde Am. rivierkreeft	*Orconectes virilis*	1	36
Freshwater plant	Curly waterweed	Verspreidbladige waterpest	*Lagarosiphon major*	1	23
Freshwater plant	Egeria	Egeria	*Egeria densa*	1	17
Freshwater plant	Straight Vallisneria	Vallisneria	*Vallisneria spiralis*	1	24
Freshwater plant	Water milfoil	Waterwaaier	*Cabomba caroliniana*	1	25
Marine invertebrate	American oyster drill	Amerikaanse oesterboorder	*Urosalpinx cinerea*	1	12
Marine invertebrate	Chinese mitten crab	Chinese wolhandkrab	*Eriocheir sinensis*	1	6
Marine invertebrate	Colonial sea-squirt	Druipzakpijp	*Didemnum vexillum*	1	13
Marine invertebrate	Japanse oyster drill	Japanse oesterboorder	*Ocinebrellus inornatus*	1	12
Marine invertebrate	Sea walnut	Amerikaanse ribkwal	*Mnemiopsis leidyi*	1	14
Marine invertebrate	Stanfords tanaid shrimp	Stanfords schaarpissebed	*Sinelobus stanfordi*	1	9
Marine invertebrate	Veined whelk	geaderde stekelhoorn	*Rapana venosa*	1	12
Terrestrial invertebrate	American black widow	Zwarte weduwe Amerika	*Latrodectus mactans*	1	29
Terrestrial invertebrate	Asian hornet	Aziatische hoornaar	*Vespa velutina*	1	30
Terrestrial invertebrate	Australian black widow	Zwarte weduwe Australie	*Latrodectus hesperus*	1	29
Terrestrial invertebrate	Black imported fire ant	Zwarte brandmier	*Solenopsis richteri*	1	28
Terrestrial invertebrate	Imported fire ant sp.	Bleke brandmier	*Solenopsis geminata*	1	28
Terrestrial invertebrate	Invasive garden ant	Plaagmier	*Lasius neglectus*	1	48
Terrestrial invertebrate	Portugese slug	Spaanse wegslak	*Arion lusitanicus*	1	35
Terrestrial invertebrate	Red imported fire ant	Rode brandmier	*Solenopsis invicta*	1	28
Terrestrial invertebrate	Redback spider	roodrugspin	*Latrodectus hasselti*	1	29
Terrestrial plant	Common monkeyflower	Gele maskerbloem	*Mimulus guttatus*	1	26
Terrestrial plant	Common ragweed	Ambrosia	*Ambrosia artemisiifolia*	1	49
Terrestrial plant	Cotoneaster sp.	Dwergmispel sp.	*Cotoneaster ambiguus*	1	4
Terrestrial plant	Poison ivy	gifsumak	*Toxicodendron radicans*	1	31
Terrestrial plant	Robinia	Robinia	*Robinia pseudoaccacia*	1	3
Terrestrial plant	Rugose rose	rimpelroos	*Rose rugosa*	1	2
Terrestrial plant	Tree of heaven	hemelboom	*Ailanthus altissima*	1	5

Appendix 5 Strengths and shortcomings of current monitoring programs

Tables A.3 gives an overview of relevant monitoring programmes and inventories that could become (part of) a future long-term monitoring programme for alien species. It includes details on their suitability in answering the monitoring questions and information needs stemming from policies and guidelines, namely with regard to early detection, evaluation of prevention monitoring and monitoring of population dynamics. Table A.4 presents an overview of advantages and disadvantages of methods used in monitoring alien species.

Some conclusions that can be drawn from Table A.3 are:

- None of the inventories/programmes survey all of the taxa listed in the table. It must be stressed that the list of taxa in table 2 is not conclusive, as there are alien species groups that have not yet been monitored (in much detail) and therefore do not show up in the table, e.g. microorganisms or parasites.
- The spatial extents of inventories and programmes vary, from good or very good coverage of the whole extent of the respective national Wadden Sea area (as is the case for the inventories by GiMaRIS, and the SIBES project), to single sampling locations for fish (NIOZ fyke net), phytoplankton (NIOZ jetty monitoring), or single tidal flat areas (Balgzand monitoring). However, the latter single monitoring locations in the Dutch Wadden Sea are situated at the Southern “gateway” to the Wadden Sea and may potentially function as early warning systems should new alien species arrive with currents (or other vectors) from further south. Also, alien species found here can be expected to show up further north in the future, should their larvae be capable of spreading via currents.
- Only the dedicated alien macrobenthos inventories by GiMaRIS (2009, 2011), GiMaRIS and NIOZ (2014), the SETL project and the surveys performed under the Joint HELCOM/OSPAR Guidelines sample clearly known hotspots of alien species, such as marinas or mussel beds. It is not known whether there are hotspots for endobenthic alien species in soft sediments or where these would be, and a search for alien species therefore resembles a “blind poking” leading to “chance findings”. However, it is possible to visually search for soft sediment-related species living on the sediment (epibenthos), such as algae or crustaceans.
- None of the inventories or monitoring programs are equally suited for early detection and for uncovering the population dynamics of an alien species. This, of course, lies in the nature of the alien species inventories/rapid assessments as these are “aimed to detect as many alien species as possible, combining an efficient use of given resources in manpower and available time with the highest gain of information” (Buschbaum *et al*. 2012). On the contrary, monitoring programmes like the Balgzand intertidal transect programme or the SIBES project are set up to monitor long-term changes in populations of Wadden Sea

macrobenthic fauna in detail, and are therefore much more time-consuming. In order to judge whether the "good environmental status" of alien species under the MSFD is met, questions about the trends in abundance or the temporal occurrence of alien species in the Wadden Sea have to be answered. It is debatable whether the statement of pure "presence/absence" as achieved in alien species inventories/rapid assessments is good enough to comply with the MSFD. In any case, the table illustrates that the current MWTL programme for macrozoobenthos is neither suited for early detection, nor for uncovering the population dynamics of alien species, as the time intervals between sampling are too large.

The recent dedicated alien species inventories carried out in the Netherlands both give a good indication of the presence of alien benthic macrofauna and -flora on hard substrates at a national Wadden Sea scale.

One shortcoming of these inventories is that that they looked at benthic macroflora and macrofauna only, thereby neglecting possibly relevant smaller sized alien species (such as phyto- or zooplankton). Buschbaum *et al*. (2012) restricted their inventory in the German Wadden Sea to macrobenthos because alien micro- and meiobenthos are not known for the Wadden Sea. However, this can also be attributed to a reduced search effort for species in these groups and thus incomplete knowledge (Reise *et al*. 2006). Furthermore, the inventories focused on benthic species, thereby neglecting pelagic taxa such as fish and jellyfish, which can also contain important invasive alien species. However, with regard to pelagic taxa, it can be argued that these can also arrive in the Wadden Sea via natural drifting and it is very difficult, if not impossible, to assess whether they have been transported via vectors for alien species that can and should be managed. It has been suggested to deal with them at the scale of the entire North Sea (Buschbaum *et al*. 2012). Further trilateral discussions on how to deal with these species groups therefore seem necessary.

The Wadden Sea's natural values are related to the soft sediments and its mussel beds. While mussel beds have received attention in hard substrate inventories for alien species, soft sediments have received less attention in inventories dedicated to alien marine species, as the sampling of soft sediments is 1) more difficult to perform due to technical limitations, and 2) the endobenthic species to be sampled are invisible when in the ground, which complicates their discovery ("chance findings"). For soft sediment sampling programmes, the area sampled and the abundance of organisms found are extrapolated to larger areas of relevance for processes in the Wadden Sea. The current soft sediment sampling programmes/projects (Balgzand, SIBES) offer the opportunity to detect alien species related to soft sediments in the first place (albeit eradication may not be possible) and, as they are located at the gateway to the trilateral Wadden Sea, can function as early warning systems as described above. They also allow for the evaluation of prevention monitoring and monitoring of population dynamics. Both SIBES and the Balgzand intertidal transect program have advantages and disadvantages with regard to efficiency and accuracy.

*Table A.3 Overview of alien species inventories and other monitoring programmes that could be used to draw conclusions about alien species in the Dutch Wadden Sea. The list of additional programmes that could be used to draw conclusions about alien species is a non-conclusive enumeration. For more inventories or programmes, see chapter 3. Their suitability to answer aspects relevant to early detection and the monitoring of population dynamics of alien species is **based on subjective judgement**.*

++ well suited, + suited, +/- partially suited, - unsuitable, n/a not applicable, ? not enough knowledge available, E early detection, P population monitoring.

Inventory/programme	**Species groups**										
	Hard Substrates		**Soft Sediments**								
	Benthic Macroflora	**Benthic Macrofauna**	**Benthic Macroflora**	**Benthic Macrofauna**	**Phytoplankton**	**"Small" Zooplankton**	**Fish**	**Jellyfish**	**Extent**	**Alien species hotspots included**	**Comments**
Inventory GiMaRIS (2009)	E++ P-	E++ P-	-	-	-	-	-	-	++	++	Qualitative inventory, no conclusions about abundances (population dynamics) possible
Inventory GiMaRIS (2011)	E++ P-	E++ P-	-	-	-	-	-	-	++	++	Qualitative inventory, no conclusions about abundances (population dynamics) possible
Inventory GiMaRIS & NIOZ (2014)	E++ P-	E++ P-	E+/- P++	E+/- P++	-	-	-	-	++	++ (hard subst.) - (soft sed.)	Hard substrate: qualitative inventory, no conclusions about abundances (population dynamics) possible; soft sediments: quantitative inventory, but visual focus on (endobenthic) alien species hotspots in soft sediments is not possible ("chance findings"), soft sediment related epibenthic species can be found
SETL-project	E+ P-	E+ P-	-	-	-	-	-	-	+/-	++	only one habitat (settlement plates) being studied, small extent (two harbours only), focus on specific taxa, cheap
Inventory Den Helder harbour	E++ P-	E++ P-	-	-	-	-	-	-	-	++	Very small extent (only one harbour) but possibly unique information about military ships as vector (results not yet published)

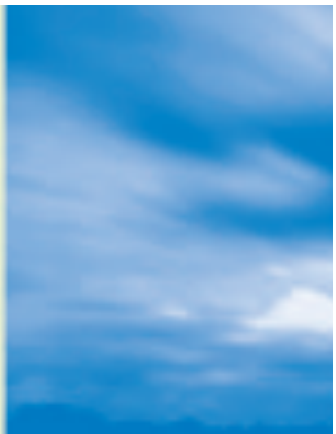
Table A.3 Continued.

	-	-	-	E+/- P++	-	-	-	-	+/-	-	Quantitative inventory, sampling takes place in late winter and late summer which enables detection of variations within one year and conclusions about population dynamics of common species, hard substrate elements on soft sediments in the survey are included (e.g. sea shells covered with bryozoan), Balgzand at gateway to trilateral Wadden Sea, thus an important sampling location
SIBES	-	-	-	E+/- P+	-	-	-	-	++	-	Quantitative inventory, variations within one year cannot be detected as sampling takes place once a year only, some macrofauna groups are not included (e.g. sessile organisms on mussels)
MWTL macrozoobenthos monitoring	-	-	-	E- P-	-	-	-	-	++	-	No conclusions about population dynamics possible as sampling takes place every 3 years only, also no early detection possible due to long interval between sampling
NIOZ fyke net	-	-	-	-	-	-	++	+	-	?	Some (life stages of) jellyfish can be monitored with this programme: solid, larger jellyfish are caught with the net, while more fragile and smaller species can evade the net or deteriorate in the net, fyke net placed at gateway to Wadden Sea, potentially important sampling location
NIOZ phytoplankton monitoring	-	-	-	-	E? P+	-	-	-	-	?	at gateway to Wadden Sea, potentially important sampling location

Table A.4 Overview of advantages and disadvantages of methods used in the monitoring of alien species.

Monitoring approach	Description	Advantages	Disadvantages	References
Marine experts	Search and direct observation of marine alien species, usually at regular intervals at previously specified locations (invasion hotspots)	+ taxonomic resolution currently often higher than with molecular techniques (dependent on expert, species, DNA database) + able to estimate local species diversities and infer population dynamics + able to find newly invaded species aside from the ones on a metabarcoding alert list + widely deployable	- experts have specialised taxonomic knowledge, thus success in finding species dependent on expertise - high workload, possibly resulting in fewer visits to bioinvasion hotspots - (very) small species might be overlooked - not many persons with taxonomic expertise, loss of expertise due to expert retirement	i.a. Buschbaum *et al*. (2012)
Metabarcoding	Rapid method of biodiversity assessment combining 2 technologies: DNA based identification and high-throughput DNA sequencing. Uses universal PCR primers to mass-amplify DNA barcodes from a) mass collections of organisms or from b) environmental DNA. PCR product is sent to next generation sequencer, result is a wealth of DNA sequences	+ taxonomically comprehensive + quick to produce (only about a quarter of person-hours necessary) + less reliant on taxonomic expertise + auditable by third parties + abundant laboratory skills guarantee fewer delays before sample processing + can uncover morphologically cryptic species (complexes) + can collect DNA of difficult-to-trap taxa + cheaper than traditional methods	- presence and location of a particular species still needs to be verified by fieldwork - metabarcode data sets subject to error and loss of information - necessary to generate and maintain individually barcoded and curated specimens in museum collections to be able to link metabarcoding sequences to species - many marine alien species have their origin in SE Asian marine waters and for these, species descriptions and DNA in database are lacking or incomplete (pers. comm. Karsten Reise)	i.a. Ji *et al*. (2013)

Environmental DNA technology	forensics approach to detect species through recognition of diagnostic DNA fragments of released genetic material in the environment such as mucus, faeces, and urine	+ able to census vagrant species + very sensitive + high specificity + low costs + rapid reporting	- great water-volume to biomass ratio in marine habitats - effects of sea currents and wave action on dispersion and dilution of eDNA - salinity impacts preservation and extraction of eDNA - positive detection of eDNA only possible if target species was in area recently, as DNA degrades over time (days to month) - negative result does not imply that organism was not in area, just that there was no eDNA in sample - no quantification of number of organisms possible (no abundance) - cannot give real-time information on organism's location - possibly expensive if presence of all species recorded with eDNA and unknown for the Wadden Sea has to be verified by fieldwork	http://www.environmental-dna.nl/Portals/7/Herder%20et%20al%202014%20-%20Environmental%20DNA%20review.pdf



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