Feasibility studies in relation to the IMO Ballast Water Convention

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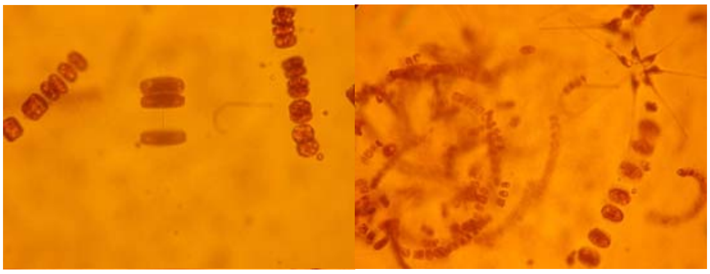

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Contents

Summary

This project is aimed to develop possibilities to overcome the difficulties which arise from the implementation of the Ballast Water Convention (IMO 2004). For this purpose, three feasibility studies have been conducted:

1. assessment of the applicability of small scale test systems;
2. development of protocols for testing active substance residues;
3. risk assessment of ballast water discharge.

The following conclusions and recommendations were drawn from the feasibility studies:

1. Assessment of the applicability of small scale test systems
Small volume artificial marine ponds have been developed at the IMARES test facilities in Den Helder. With these ponds a pilot experiment was run to examine the feasibility of using these facilities for evaluating ballast water test systems (BWTS). From the pilot test we can conclude that it is very well possible to have practically year-round availability of small volume test systems with sufficient particle/organism density. While large scale tests are costly and the systems are limited in their availability (only a few large scale test systems are available throughout Europe), the small volume test systems are relatively low in cost and multiple systems (up to 16) can be set up in parallel.

The pilot test further showed that sufficient particle density can be reached within a two-week period; enabling short term planning and ad-hoc testing of BWTS (completed or under development).

It is recommended that the current pilot test is followed by a practical application with one or more BWTS, in order to confirm that the systems meet most of the requirements of the Convention. If so, and when a certain protocol with small volume tests has been successfully validated, a lobby is required to reduce the need for costly large scale tests.

2. Development of protocols for testing active substance residues
The original intention was to draft the outlines for protocols for testing residues of active substances used for ballast water treatment, with the aim of locating suitable funds for further development of such protocols. However, potential funds were identified during the project and a project proposal was drafted with leading European institutes to be funded by Interreg IVB. The project was awarded in December 2008. With the award of the Interreg IVB project, the initial objective of this element of the seedmoney project is met. The basis for international cooperation in the field of ballast water treatment is laid by this project. IMARES will report on the progress of this project in the various national maritime fora.

It is worthwhile mentioning that IMARES is looking for partners that are willing to co-operate in this Interreg IV-B project through IMARES. By co-financing (part of) the IMARES share in the project, partners will gain early access to the projects' results. Mostly, such participation is arranged through dedicated projects that run in parallel to the Interreg IVB project, aiming to apply its results to the partners needs.

3. Risk assessment of ballast water discharge
We have demonstrated that it is possible to make a (semi-quantitative) assessment of the risk of introducing exotic species with ballast water discharges. Such assessments are relevant as they could assist in defining the need for adequate treatment of ballast water originating from a specific region.

It would be very valuable to carry out a full risk assessment for the main Dutch harbours. This would imply an analysis of the origin of ballast water that is discharged in or near Dutch harbours, based on the areas where full or partial cargo loading has taken place. For the most relevant areas (e.g., covering 80% of the cargo tonnage transported to the Netherlands) a risk assessment then needs to be carried out following the method as developed in this project. Based on the outcome of the risk assessment, ballast water management options can be suggested for different regions, involving, for example, specific treatment or alternative routing.

1 Introduction

The North Sea has relatively high shipping densities. The discharge of ballast water from ships is a main vector for introducing exotic (i.e. non-native) species. The North Sea is particularly vulnerable to invasion of non-native species, because of the ecological values (i.e. the Voordelta, Wadden Sea and the North Sea Coast as proposed Natura 2000 sites and the Wadden Sea as designated Ramsar area), the economical values (e.g. tourism, fishing and aquaculture) and public health (e.g. toxic algae). Furthermore, due to climate change the chance of survival of non-native species is increasing and therewith the threat of invasive species.

To reduce this threat the International Maritime Organisation – United Nations (IMO-UN) Ballast Water Convention has been accepted (IMO 2004). New ballast water treatment installations need to be approved by IMO on request of a member state. The member state first needs to assess whether the treatment meets the requirements of the Ballast water Convention (IMO 2005b).

An important part of the certification of a ballast water treatment installation is the effectiveness of the treatment. Effectiveness tests need to comply with the IMO guidelines (G8 (IMO 2005a) and G9 (IMO 2005c)), such as a minimum number of organisms to be present in the test water. This requirement can complicate the test as water with a high plankton density only occur in the grow season (i.e. April to September). Another requirement complicating the certification process is the need for 5 replicas with two water types to be stored during 5 days in surrogate ballast tanks of at least 200 m^3 (G8). The availability of large test facilities is limited. It is however expected that when sufficient research is conducted on a small scale, the number of replicas required for large scale tests could be reduced.

Another important issue within ballast water treatment is to determine the actual risk of ballast water discharge, so that the treatment installations can be implemented in a dynamic way instead of the current static approach with general threshold values. A dynamic approach could be beneficial for the shipping industry. For example, port duration could be reduced when it is determined that an acceptable risk is achieved with low intensity treatment. Currently, the IMO regulations do not allow this dynamic approach. However, considering the above described complications within the certification process and with sufficient knowledge to support this approach, dynamic implementation of ballast water treatment based on risk assessment could be possible in future.

This project is aimed to develop possibilities to overcome the difficulties, which arise from the implementation of the Ballast water Convention. For this purpose, three feasibility studies are conducted:

- assessment of the applicability of small scale test systems;
- development of protocols for testing active substance residues;
- risk assessment of ballast water discharge.

The studies are described in this report (Chapter 2, 3 and 4, respectively). In a final Chapter conclusions are drawn and recommendations are made for future developments and potential implementations.

2 Test systems

An important feature of ballast water treatment systems (BWTS) is the performance with regard to organism removal. IMO has set specific requirements regarding particle load and organism abundance that have to be met during performance tests. As a consequence, performance testing is limited to the growth season (April-September) in order to fulfil these requirements.

Especially during the developmental phase, a lack of particles/organisms in natural surface waters may hamper development of new BWTS. Small volume artificial ponds can be used to culture plankton communities throughout the year. At the IMARES test facility at Den Helder, small volume artificial ponds are available. During the year these were re-designed from (traditional) freshwater ponds into (novel) stagnant marine ponds. No other facilities of this kind are found in Europe.

One of the marine pond systems was filled with natural sea water and the autonomous development of phytoplankton was monitored during the summer period. Late autumn when natural light conditions become to low to enable sufficient phytoplankton growth, this pond was provided with an additional light source. It was expected that this would be sufficient to boost plankton production in the artificial pond, but if necessary additional nutrients can be added.

An important outcome from this pilot-experiment is a) the possibility of developing year-round availability of marine surface water with sufficient particle/organism density to allow for (prototype) testing of BWTS, and b) the identification of the time needed to produce sufficient particle densities to plan such tests.

2.1 Material & Methods

Two outdoor experimental test systems were installed on November 11th. Both systems were filled with 5m^3 sea water from the Oosterschelde. The systems were continuously illuminated with 4 TL-lights each. Aeration was installed in the middle of each system, near the bottom in order to create water circulation. Both systems received a different nutrient-addition. A relatively rich growth medium (adapted Walne medium; Nut1) was added to system M3, while standard F2-medium (Nut2) was added to the M2 system. Both formulations were initially dosed at 10% of the concentration used for indoor algal-cultures.
Nutrients were added starting November 28Th (Nut2) and December 1st (Nut1).
The development of the systems was monitored by measuring water parameters (temperature, pH, salinity and oxygen content) and phytoplankton development. Phytoplankton was mainly characterised by chlorophyll-a concentration, measured by fluorescence measurements discriminating for green algae, diatoms, cryptophycacea and blue-green algae. Also the number of particles up to a diameter of 60µm was analysed using a particle counter. Additionally, the composition of the phytoplankton community was assessed by microscopic examination of samples stored in lugol.

2.2 Test results

An overview of the results obtained during the test is available in Appendix B. Below, we'll provide a brief description of the outcome of the test.

Development before first nutrient addition
Initially (November 14th), the fresh sea water contained >40.000 particles/ml. Approx. 60% of these particles were <2µm and were probably suspended silt particles. The total number of particles decreased steadily to reach the lowest concentration at the end of the month (7000-9000 part/ml). As the small particles remained in suspension longer due to the recirculation, on November 17th they made up ca. 70% of the total number of particles. Thereafter, the fraction 2-3 µm was the dominant fraction (20-40%).

The chlorophyll-a content in the sea water was low (ca. 1.5 µg/l) and all four main phytoplankton groups were present, but only the diatoms developed higher concentrations in time. Due to the light treatment, the phytoplankton started to grow on the nutrients already present in the sea water. In M3, chlorophyll-a density reached a maximum value of 17.3 µg/l on November 25th. In M2, chlorophyll density reached a maximum of 22.2 µg/l on November 28th. After this peak concentrations, the chlorophyll-a concentration collapsed and nutrient dosing was started. To M3, nutrient were added on November 28th when the chlorophyll concentration was decreased to 9.6 µg/l. M2 received the first nutrient addition on December 1st, when the chlorophyll-a concentration had decreased to 12.2 µg/l.

Water temperature was 12°C at the start and declined to ca. 7°C at the end of November. The oxygen level generally varied between 102 and 109% saturation, temporarily reaching levels up to 120% saturation at or just after the first phytoplankton bloom (end of November). The pH gradually increased from 8 at the start to 8.3 in M2 and 8.5 in M3. Salinity was 32.4‰ on November 14th and decreased to 31.7 at the end of the month due to some rainfall.

Development during nutrient additions
Nut1 addition immediately resulted in a rapid phytoplankton growth in M3, lasting nearly a week. Subsequent nutrient additions (Dec 5th and Dec 8th) further stimulated phytoplankton development to nearly 150 µg chl-a/l on Dec 12th (Figure 1). During this period, the water temperature stabilised at 4-5°C. The oxygen level varied between 106 and 110% saturation and pH gradually increased to 8.9, while the salinity decreased to 29 ‰.
The first addition of Nut2 had no clear effect and phytoplankton only started to develop after the second addition on Dec 4th. The growth rate seemed to decrease again after the 3rd addition on Dec 8th, reaching a level of 69.4 µg chl-a/l on Dec 12th. The water temperature stabilised at 4-5°C and the oxygen level between 104 and 110% saturation. Initially the pH decreased to 8.2 on Dec 5th, but from then on it gradually increased to 8.6 as the phytoplankton started to develop. The salinity slowly decreased to 29.3‰ due to rainfall.

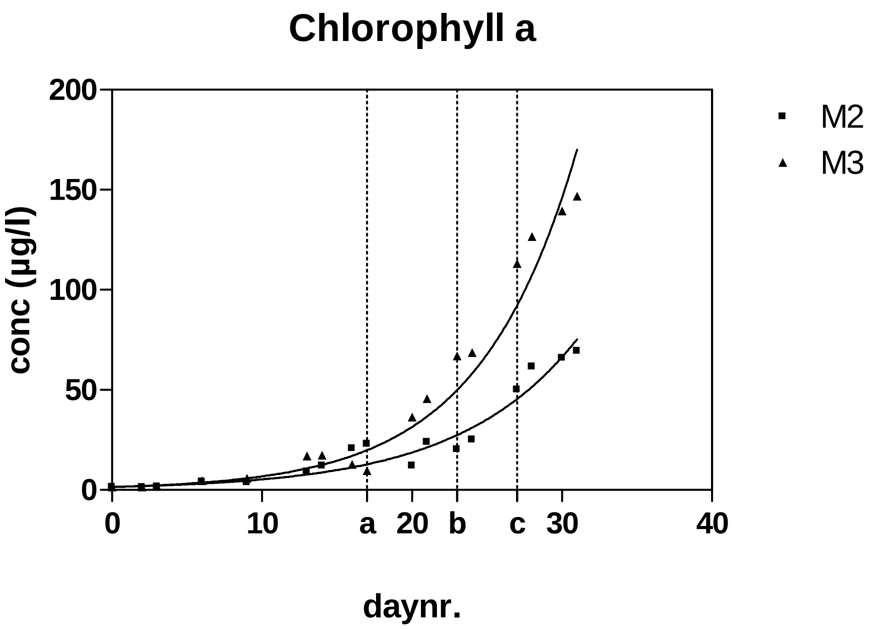

Figure 1 Phytoplankton development (as total chlorophyll-a) in the test systems (Nutrients added at a, b, and c).

The phytoplankton community is dominated by the diatom species *Asterionella japonica, Thalassiosira spp., Chaetoceros spp.* and *Skeletonema costatum*. Some flagellates are also present, of which the most obvious is the spring blooming *Phaeocystis pouchetti*, which is responsible for the scum forming at the beach during late spring when the bloom collapses.

The number of particles rapidly increased to 12000 (M2) and 17000 (M3) particles per mL due to phytoplankton growth. This is in the range preferred for efficacy testing (10^4 particles/mL in the size range 10-50 µm; IMO G8).

2.3 Conclusions and recommendations

From the pilot test we can conclude that it is very well possible to have practically year-round availability of small volume artificial marine pond systems with sufficient particle/organism density. As surface water does not meet the density requirements in wintertime, these test systems are very well suitable for BWTS testing throughout the year. Furthermore, the small volume test systems are very suitable to prepare for the (for the Convention required) large scale tests. While these large scale tests are costly and the systems are limited in their availability (only a few large scale test systems are available throughout Europe), the small volume test systems are relatively low in cost and multiple systems (up to 12) can be set up in parallel.

The pilot test further showed that sufficient particle density can be reached within a two-week period; enabling short term planning and ad-hoc testing of BWTS (completed or under development).

It is recommended that the current pilot test is followed by a practical application with one or more BWTS, in order to confirm that the systems meet most of the requirements of the Convention. If so, when a certain protocol with small volume tests has been successfully validated, a lobby needs to be started to reduce the need for costly large scale tests.

3 Protocols

Where a BWTS has to be very efficient with regard to removal (*i.e.* killing) organisms in the ballast water, the ballast water that is discharged should not pose any risk to the receiving environment. This is especially relevant for BWTS using (or producing) active substances. The IMO has set up generic requirements for biological testing of the environmental risk of treated ballast water, which is based upon the EU Technical Guidance Document on risk assessment (EU-TGD) (European Communities 2003). Additional information may be demanded by the national authorities of the countries where the application is submitted.

A coherent, harmonised system for the assessment of ecological risks of the discharge of treated ballast water to the receiving water body is, however, lacking. It is part of the Interreg IVb "Ballast Water Opportunity" proposal to draw up a harmonised protocol for the assessment of the ecological risk of the discharge of treated ballast water and to give more guidance on the use and performance of biological tests.

During the course of the seedmoney project IMARES was involved in the preparation of a project proposal for Interreg IVB, with the title "North Sea Ballast Water Opportunity". Major European institutes are involved in this proposal, including BSH (Bundesamt für Seeschifffahrt und Hydrographie / Federal Maritime and Hydrographic Agency in Germany) as project coordinator, NIOZ (Royal Netherlands Institute for Sea Research), Loyds, engineering institutes and manufacturers of ballast water treatment systems. Development of protocols for the assessment of the ecological risk of the discharge of treated ballast water is included in one of the workpackages of the Interreg Project. In december 2008 it was announced that the project was awarded. The overall project budget is appr. 10 million Euro.

3.1 Interreg IVB – North Sea Ballast Water Opportunity

3.1.1 Aim of the programme

1. Regional cohesion
Through regional harmonisation and difining common standards for enforcement, we will facilitate the needed technological development and the widespread and timely adoption of the Ballast water convention (BWC). This will maintain and improve the accessibility of the region as ships and ports are equiped to handle the ballast water effectively and reduce the delay (0,5-1 day) needed for ballast water exchange or port side treatment in and outsite the NSR. Thus harmonization can strengthen the North Sea Region (NSR) economic position.

2. Regional research and innovation program
Aided by clear standards a market over 8 bln € will grow to meet the BWC. To capitilize on this market the NSR maritime sector will be handed the opportunity, through our Public-Private Partnership, to boost innovation. In this we aim provide for knowledge exchange, dedicated research, development, and recognised test beds for their products.

3. Regional future Strategies
The IMO convention focuses on BW as a vector for invasive and pathogenic species. It will reduce the risk of these invasions, but can not exclude them. Next to the remaining organisms in the BW the ship-hull's bio-fouling is also an important vector for aquatic invasive species. Thus future strategies and legislation are needed to further reduce these invasion. The Ballast Water Opportunity will on one hand identify technological opportunities for further reduction while on the otherhand they will aid in the mitigation through monitoring and early warning system for bio-invasive outbreaks, and dissimination of strategies to prevent, contain and possibly eradicate them.

3.1.2 Project Structure

The project is divided in 5 strongly linked and integrated work packages. The 5 work packages are:

Work Package 1: Project Management
The overall project management activities are carried out by a project group, consisting of a project manager, a project coordinator and a financial manager and 4 work package (sub) coordinators. This group is responsible for the day-by-day activities and will coordinate with the project. The project coordinator and manager are the contact point for the Interreg NSP. The project will adopt the lead partner principle. However, we will decentralise the financial management.

Work Package 2: Regional Cohesion
Within this WP information will be collected and working papers, work conferences, and coherence papers will be prepared:

1. Approval of BWM Systems.
2. Operation and Surveys of BWM Systems.
3. Approval of Monitoring Systems.
4. Compliance Control.
5. Ballast Water Exchange.

These papers will provide model regulations for enforcement, best practices, and a synthesis on economical and ecological stakes, scientific and technological barriers and opportunities.

Work Package 3: Innovation
To boost innovation, knowledge, research, and testing facilities need to be shared to enable companies to capitalise upon this opportunity. To achieve this project partners will set up a collaboration between various public institutes in the region and private companies to develop monitoring tools and provide for BWT equipment and facilitiate their application through testing, validation, and certification.

Work Package 4: Strategies:
Although implementation of the BWC reduces the number of invasions, it will not eliminate these completely. Opportunities provided by scientific and technological developments for further BWT or elimination of hull borne organisms or mitigation strategies for identified bio invasive threads will be utilised to facilitate the reduction of ship borne bio-invasions. Actions involved are:

1. Aid monitoring, reporting and central registration of exotic bio-invasions.
2. Investigating new strategies for prevention of ship borne bio-invasions.
3. Develop risk assessment and mitigation strategies to limit the effects of ship borne bio-invasions in the NSR.

Work Package 5: Dissemination
The project involves all types of stakeholders. In WP2 their problems are identified and their need for information, training, and mode for effective communication will be established. This will certify effective dissemination of the project results and stimulate implementation by all stakeholders.

3.2 Conclusions and recommendations

The original intention was to draft the outlines for protocols for testing residues of active substances used for ballast water treatment, with the aim of locating suitable funds for further development of such protocols. However, potential funds were identified during the project and a project proposal was drafted with leading European institutes to be funded by Interreg IVB. The project was awarded in December 2008. With the award of the Interreg IVB project, the initial objective of this element of the seedmoney project is met. The basis for international cooperation in the field of ballast water treatment is laid by this project. IMARES will report on the progress of this project in the various national maritime fora.

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4 Risk assessment

4.1 Introduction

4.1.1 Scope

This chapter describes a methodology for assessing the risk of introducing exotic species as a result of ballast water discharges. The suggested approach is demonstrated in a case study. The advantages and limitations of the assessment are discussed and recommendations are made for future application.

4.1.2 IMO regulations

The International Convention for the Control and Management of Ships' Ballast Water and Sediments (hereafter the Convention) was prepared and was adopted in a Diplomatic Conference in 2004 (IMO 2004). This Convention aims to prevent, minimise and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of harmful aquatic organisms and pathogens via ships' ballast waters. The Guidelines on Risk Assessment (G7) is part of a set of 15 guidelines that support the uniform implementation of the Convention and provide technical guidance to support the implementation of the Convention principles. The G7 aims to allow Parties to exempt vessels from compliance with Ballast Water Management (BWM) requirements prior to discharge if an acceptably low risk can be discerned. The Convention introduces the selective BWM approach, where exemptions can be given on the basis of Regulation A-4, while additional measures may be introduced based on Regulation C-1 (Figure 2). Risk assessment is thus an important part of the BWM and can determine whether a ship may be exempted from BWM requirements (if the level of risk is acceptable) or may be requested to take additional measures (if the risk is identified as (very) high).

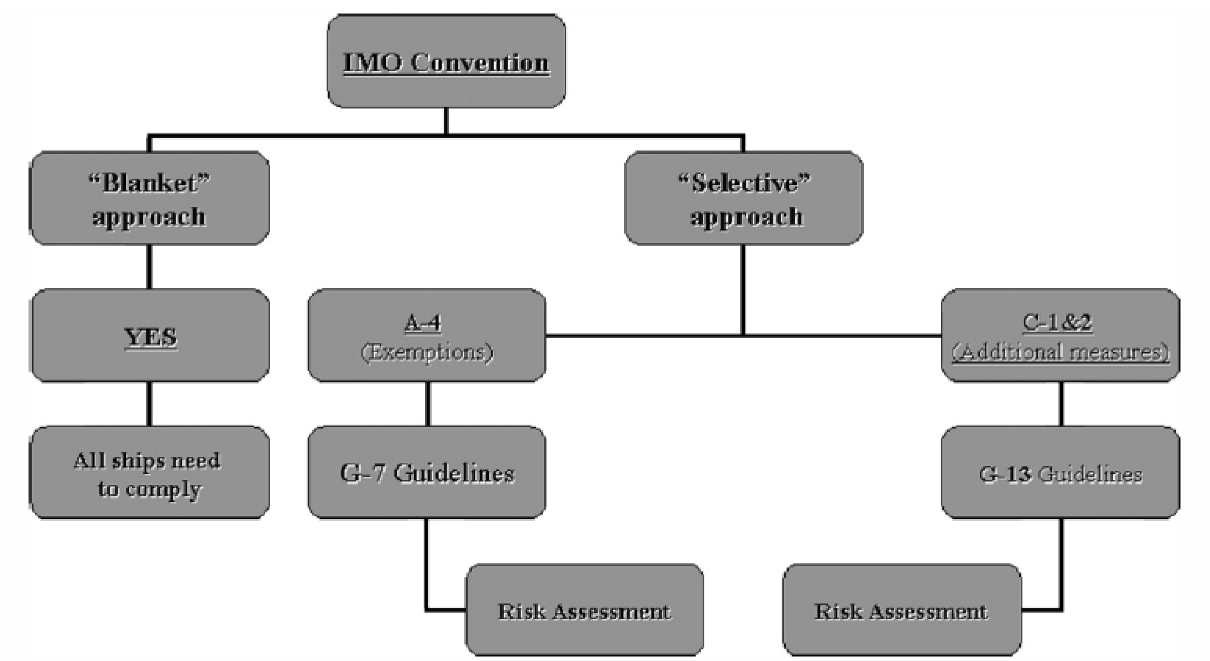

Figure 2 Risk assessment procedures according to the IMO Convention (Gollasch et al. 2007).

4.1.3 Approaches

The impact of invasive species on an ecosystem is difficult to predict. The likelihood of an introduced organism becoming established in the new environment depends on the characteristics of the species (its intrinsic properties) and the environment (the circumstances) into which it is introduced. The more similarity exists between the native and the new environment, the more likely it is that a species will be able to become established there. However, species can survive under a wide range of circumstances as long as these are within the species specific environmental tolerances (Hewitt & Hayes 2002).

The significance of the effect that the establishment of exotic species may have on the local ecosystem depends on the life history of the species involved and a chain of events and coincidences within the system. It is not feasible to get a complete knowledge of this system and to forecast the future development.

Within the European Union (EU), risk assessment is defined as: "*A process of evaluation including the identification of the attendant uncertainties, of the likelihood and severity of (an) adverse effect(s)/event(s) occurring to man or the environment following exposure under defined conditions to (a) risk source(s)*" (European Communities 2000). Based on this definition, risk assessment of invasive species should include a quantification of the likelihood and severity of biological effects. The risk inherent to ballast water and sediment discharge can be defined as: "*the likelihood of an undesired event occurring as a consequence of ballast discharge from a ship*" (Gollasch et al. 2007).

Risk assessment under the Convention has two different approaches, i.e. "environmental matching" and the "species specific" approach (Gollasch et al. 2007). A species specific risk assessment approach considers the characteristics of the organism. An environmental similarity risk assessment approach compares physical conditions (e.g. salinity and temperature (Gollasch et al. 2007)) of the source and destination locations (Barry et al. 2008). Appendix A provides an overview of ballast water risk assessments that have been developed since 1992. It shows that many risk assessment studies have been performed during the last 16 years, based on either one of, or both, of the approaches.

Besides the two different approaches as described above, the IMO Guidelines include a species' bio-geographical risk assessment (IMO 2007). Bio-provinces are identified as being large enough to represent environments as surrogates for species living there (Gollasch et al. 2007). The environmental matching approach is used if the source and destination ports are located in different bio-regions. In the case that the source and destination ports are in the same bio-region, it is assumed that environmental conditions are similar, hence species specific risk assessment is needed.

Various concepts exist to divide the world's oceans into bio-provinces and after considerable discussions the IMO recommends the use of Large Marine Ecosystems (LME, see e.g. http://www.edc.uri.edu/lme/) for risk assessment based exemptions. LMEs are relatively large regions that have been defined according to continuities in their physical and biological characteristics (Gollasch et al. 2007).

After determining the bio-provinces of both the source and destination ports and therewith the required approach (i.e. environmental matching and/or species specific), the risk should be assessed. Risk assessment can be conducted on a qualitative basis, i.e. determining whether the risk is acceptable or not, or quantitatively, i.e. providing an actual measurement of risk on a specific scale.

From expert judgment the potential risks can be identified qualitatively. This has been tried in a study on the import of exotic species due to mussel transport (Snijdelaar et al. 2004). In this study the experts agreed that it is hard to predict the impact of a species on forehand due to the fact that in most of the cases the knowledge about the (aut)ecology of the species is very limited at that stage. The disadvantage of a qualitative approach is that often low probability/high consequence events tend to be overestimated, while high probability/low consequence events tend to be underestimated (Haugom et al. 2002). By separately describing the risk of the two parts (i.e. probability and consequence), the outcome of the second part will not be influenced by the results of the first part. This approach has been applied in studies by IMARES of the risk of introducing exotic species in the Netherlands (Wijsman & Smaal 2006, Wijsman et al. 2007b, a) and will be used for our assessment. The method combines the two approaches as described by (Barry et al. 2008), i.e. it is based on species specific characteristics and environmental conditions.

4.2 Methodology

4.2.1 Overview

In this study, a semi-quantitative risk assessment is made on the risk of introducing hazardous exotic, non-indigenous species into the Netherlands by ballast water transport. Roughly this risk assessment is divided in tree steps (Figure 3):

1. identifying potential target species;
2. assessing the chance of successful introduction of the potential target species;
3. assessing the impact of successfully introduced target species.

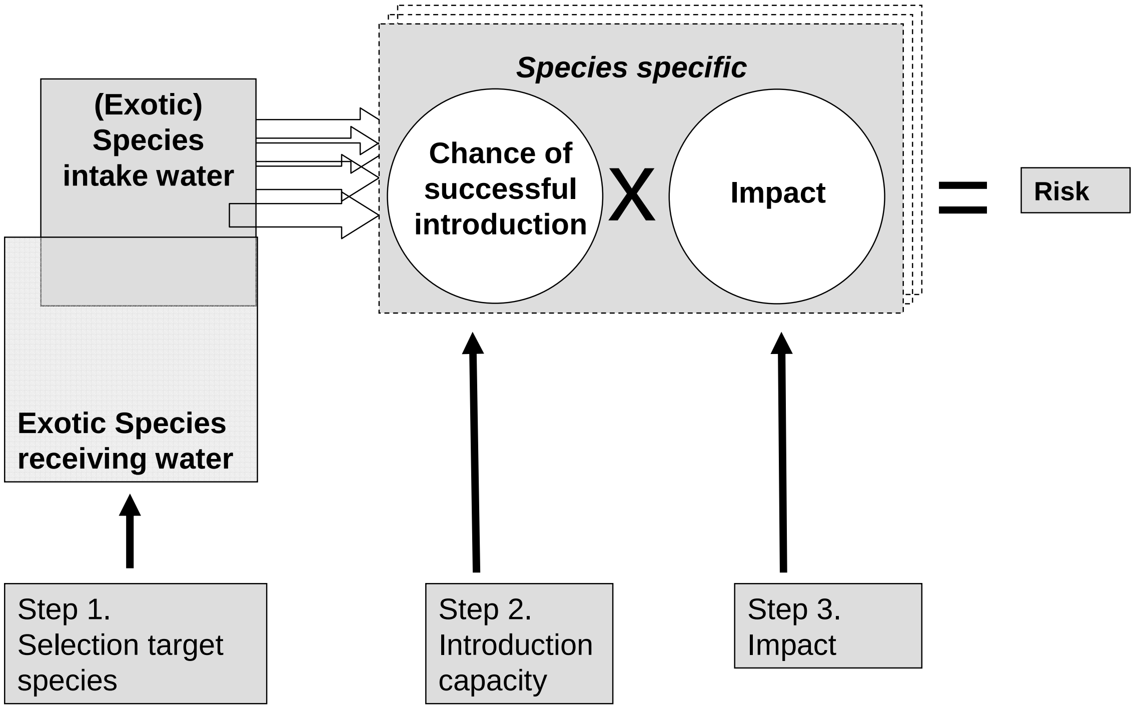

Figure 3: Overview of the set-up of the risk analysis.

4.2.2 Identification of potential target species

In the first step, the potential target species are identified. Target species meet specific criteria indicating that they may impair or damage the environment, human health, property or resources and are defined for a specific port, State or bio-geographic region (IMO 2007). Potential target species are (exotic) species that can be found in the intake waters and are not known to be present in the Netherlands. The scope of the identification of potential target species should be adjusted to the geographical scope of the ballast water transfer (Figure 4). The IMO Guidelines on risk assessment have identified bio-geographic regions, which are defines as: "*a large natural region defined by physiographic and biologic characteristics within which the animal and plant species show a high degree of similarity. There are no sharp and absolute boundaries but rather more or less clearly expressed transition zones*" (IMO 2007). IMO recommends the use of the Large Marine Ecosystems (LME) scheme within the risk assessment of ballast water.

At global scale, marine ecosystems can be divided into units (Spalding et al. 2007):

- realms: very large regions of coastal, benthic, or pelagic ocean across which biotas are internally coherent at higher taxonomic levels, as a result of a shared and unique evolutionary history;
- provinces: large areas defined by the presence of distinct biotas that have at least some cohesion over evolutionary time frames and their boundaries are circumscribes by distinctive abiotic features;
- ecoregions: areas of relatively homogeneous species composition, clearly distinct from adjacent systems.

Within a province, species are able to travel with natural transport mechanisms and whether or not a species will establish a population depends on the suitability of the environment. In principle, all species which are present in the donor location (i.e. location where the ballast water is taken onboard (IMO 2007)) and not in the recipient location (i.e. location where the ballast water is discharged (IMO 2007)) form the potential target species for the risk assessment. However, for ballast water transfer within the same ecoregion or province, it can be assumed that indigenous species of the donor location, that are not present in the recipient location, are not able to form a self-sustaining population. Therefore, only exotic non-indigenous species which are present in the donor location, but not (yet) in the recipient location are considered potential target species for ballast water transport within the same marine province.
The potential target species are identified by comparison of a list of species that live in the donor location and a list of species that can be found in the recipient location, according to the selection criteria in Table 1. The required information could be derived from a global database of non-native species, which is online available at http://marine.rutgers.edu/OBIS/ (Stocks et al. 2000). The number of non-native species currently recorded as established in the ecoregion North Sea is 77 (Molnar et al. 2008).

Table 1 Schematic presentation of the selection of the potential target species that could potentially be introduced

Scope	**Within marine province**			**Across marine provinces**		
Species to be assessed	**Exotic non-indigenous species**			**All species**		
	A	B	C	A	B	C
Present in donor location? Present in recipient location (e.g. North Sea)?	No Not relevant	Yes Yes	Yes No	No Not relevant	Yes Yes	Yes No
Potential target species?	**No**	**No**	**Yes**	**No**	**No**	**Yes**

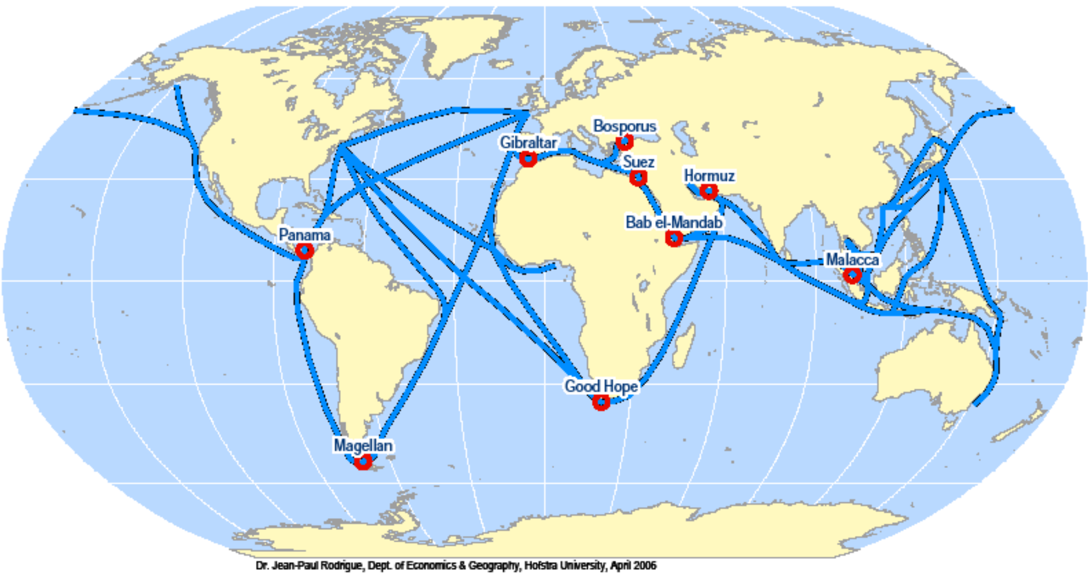

Figure 4 Maritime routes (Rodrigue et al. 2006).

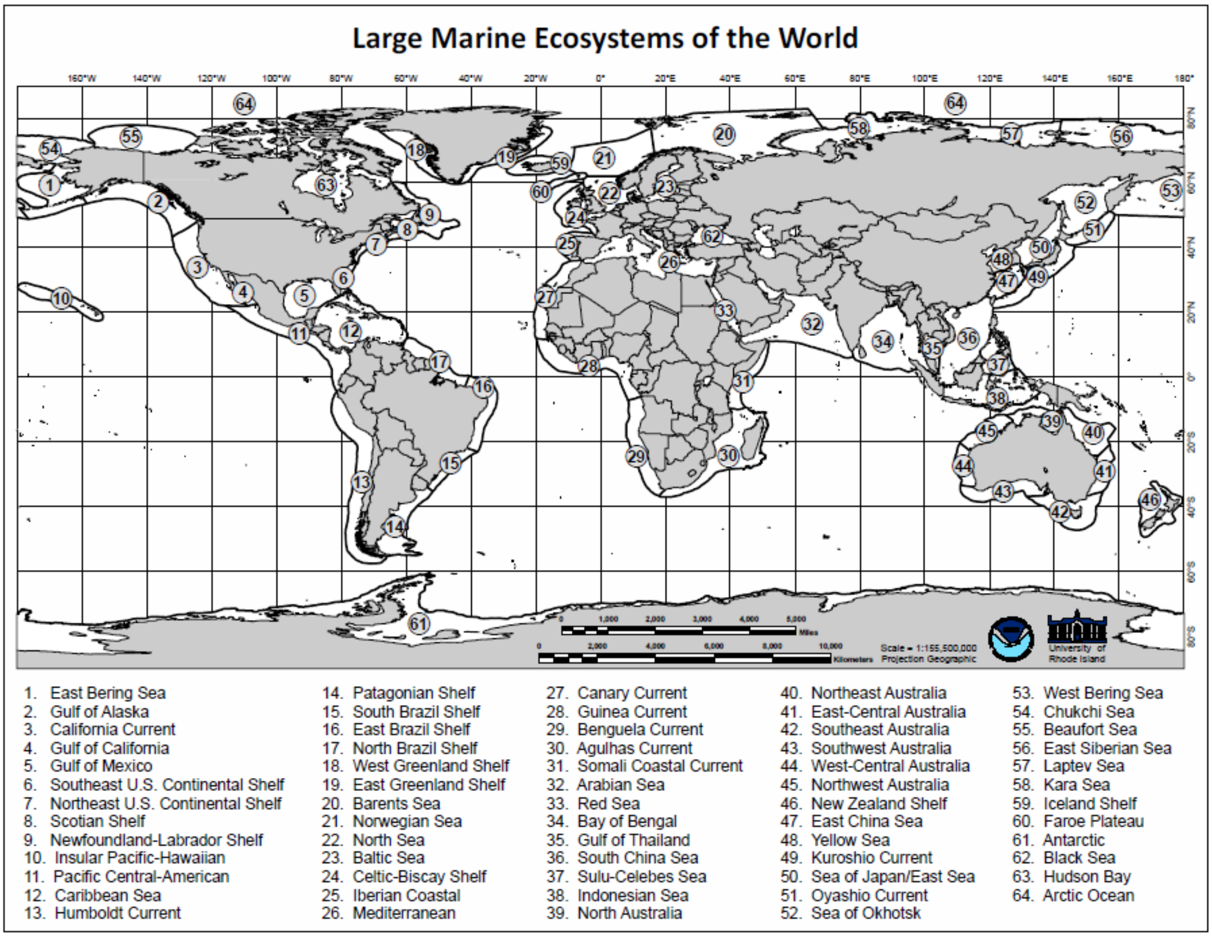

Figure 5 Marine biogeographic regions (NOAA 2009).

4.2.3 Chance of successful introduction

The second step is to quantify the chance of introduction of these potential target species in the Netherlands with the transfer of ballast water and the possibility that they will become permanently established. Two stages can be distinguished: (1) Change of survival in the ballast water tank, depending on the conditions in the ballast water tank and the effectiveness of treatment and (2) Change of survival after ballast water discharge. The assessment is based on available information on ecological and physiological characteristics of the selected species. The available information is compared with (1) the conditions in the ballast water tank (including effect of treatment) and (2) the environmental conditions in the North Sea.
A question to be answered is: which of the potential target species may be collected and transported together with the ballast water? This is primarily dependent on the presence of the species on the ballast water intake sites. Planktonic species or life stages can easily be transported with the water. To be successfully transported these species must be capable to survive the conditions during transport to the Netherlands. There are several options to consider for transport conditions:

- Ballast water exchange. It is recommended to exchange at least 95% of the ballast water at preferably 200 nautical miles (or at least 50 nautical miles) of the coast and in water of at least 200 meters deep (IMO 2005b). This will change the donor location of ballast water and therewith the potential target species. Species from the open oceans have less chance of surviving coastal conditions and vice versa. There is always a chance that some species will remain in the ballast water tank, e.g. due to incomplete exchange or attachment to the inside of the tank.
- Ballast water treatment. The ballast water is treated so chances of survival will decrease, depending on the efficiency of treatment and the species. From the year 2014/2016 all ships must comply with the IMO criteria for ballast water discharge (IMO 2005b), which in most cases means the water should be treated.

- None. As ballast water treatment is not yet mandatory (IMO 2005b) and ballast water exchange is only a recommended option, it is very plausible that ballast water conditions are not changed during transport (i.e. no treatment and no exchange).

When required information is unknown, we assume the worst case scenario for this risk assessment, thus the one that gives the maximum change that the potential target species will survive: no treatment and no exchange. This worst case approach is consistent with the IMO Guidelines, that includes the precautionary principle as a key principle of risk assessment and specifically note that the absence of, or uncertainty in, any information should be considered an indicator of potential risk (IMO 2007).

The likelihood that a species is transferred from the donor location to the recipient location is scored as a range between 1 (very unlikely) and 5 (certain). The starting point for this qualification is a score of '5' (i.e. 'worst case') for each potential target species. Based on available knowledge this score can be lowered. In these cases where insufficient knowledge is available, the high score (worst case) is maintained.

4.2.4 Impact assessment

The third step is to identify the impact that a potential target species will have on the ecosystem in the North Sea, assuming successful introduction and can be based on the judgment of a group of experts and/or literature on impact of invasive species. For example, it has been reported that of the 77 non-native species found in the North Sea, 51 are found to be harmful (Molnar et al. 2008).

The probability of species having substantial ecological impact is scored as a range between 1 (very unlikely) and 5 (certain). The starting point for this qualification is a score of '5' (i.e. 'worst case') for each potential target species. Based on available knowledge this score can be lowered. In these cases where insufficient knowledge is available, the high score (worst case) is maintained (precautionary approach, see above).

Besides an ecological impact upon which this study is focused, the introduction of exotic species can also have economical, social and safety related impacts (Haugom et al. 2002). Substantial ecological impact will in many cases also affect the other aspects. Reduction of the fishery/aquaculture production or tourist attraction will, for instance, have economical and social impact. Safety could be at risk when, for instance, toxic algal blooms occur in areas that are used for swimming or shellfish production. On the other hand there are circumstances possible where economical impact can occur without a substantial change of the ecosystem. This is for instance the case when exotic fouling organisms are clogging cooling water pipes. The economical consequences of introduction of exotic species situations are not covered in the case study.

4.3 Case study

4.3.1 Identification of potential target species

The methodology, as described in this chapter, is demonstrated in a case study. The results provide an indication of the potential risk of introducing exotic species in the North Sea by ballast water exchange. Furthermore, it will show the applicability of this method for assessments on a larger scale (i.e. global) or focused on specific areas, treatments or species. The case study is based on the exchange of water from Norway to the Netherlands with the transfer of live mussels. Because the exchange is within the same province, i.e. the Northeast Atlantic, the analysis is focused on exotic, non-indigenous species for the Northeast Atlantic that have not (yet) been established in the North Sea. For these species, the transport and discharge of water will advance the introduction, i.e. it forms an additional transport mechanism besides the natural transport mechanisms such as water currents.

With the transfer of ballast water within the Northeast Atlantic, also species that are native species for the Northeast Atlantic shelf waters but non-indigenous for the Netherlands, could be introduced. Some of these species might settle for a couple of years. However, eventually they will disappear because the environmental conditions in the North Sea are not suitable to form a self-sustaining population (Wolff 2005). If these species should be able to become established in the North Sea, they would have been able to colonize the area in the past without the 'help' of ballast water transfer.

As explained above, all exotic non-indigenous species that are present in the donor location (i.e. Norway) and not in the North Sea form the potential target species for this study. These potential target species were identified by comparison of a list of species that live in the donor location and a list of species that can be found in the Netherlands.

With the transfer of ballast water also bacteria and viruses can be introduced causing diseases of wild flora and fauna. This type of introductions can have an important effect on the ecosystem but these small organisms are not covered in the case study of this report.

Parasites can also cause diseases of wild flora and fauna. If identified, parasitic species are included in this case study, but it is possible that the list of parasites is not complete. Two parasite species (*Pseudodactylogyrus* spp.) in European eel have been found in Norway. These species are therefore included in this assessment.

The final list of potential target species contains 14 species (Table 2). These are the exotic species that can be found in the Norwegian waters, but are not yet reported to be present in the Netherlands.

Several exotic species found in Norway, have already been introduced, or in some cases even established. This is the case for the algae *Alexandrium tamarense* and *Heterosigma japonica*, which have become permanently established in the Netherlands (Wolff 2005), although they are not yet reported as inhabitants of the Wadden Sea. According to (Wolff 2005), the macro algal species *Bonnemaisonia hamifera* are regularly found washed ashore along the Dutch coasts, but as yet has not become established. The algae *Prorocentrum minimum* (Peperzak 2003) and the ctenophore (comb jellies) *Mnemiopsis leidyi* (Faasse & Bayha 2006) are found in the Netherlands. The tentacled lagoon worm *Alkmaria rominji* has already been established in the Netherlands, and is regarded a native species (pers. comm. Prof. W.J. Wolff). The status of *Alkmaria rominji* in the Wadden Sea was reported as being critical (Petersen et al. 1997). In the Dutch part of the Wadden Sea the species is extinct. Regarding its status in the Netherlands, this species is not selected as a potential target species.

It is good to realise, that this selection of the potential target species is based on reported observations made in the area's of interest, and that it is not unlikely that more species are present without being observed. Moreover, this list describes a snapshot of a situation that is continuously changing. New exotic species are discovered regularly in European waters. Clearly such species cannot be accounted for in the present risk analysis.

Table 2 Selected potential target species: Exotic non-indigenous estuarine and marine species that have become established in Norway and are not yet observed in the Wadden Sea.

Taxonomic group	**Species name**
Algae	*Aglaothamnion halliae*
	Codium fragile subsp *atlanticum*
	Codium fragile subsp *scandinavicum*
	Fucus evanescens
	Verrucophora farcimen (SYNONYM: *Chattonella aff verruculosa*)
	Karlodinium micrum
	Olisthodiscus luteus
Polychaeta	*Scolelepis korsuni*
Cirrepedia	*Lepas anatifera*
Malacostraca	*Homarus americanus*
	Paralithodes camtschaticus
	Chionoecetes opilio
Bivalva	*Ruditapes philippinarum*
Platyhelminthes	*Pseudodactylogyrus bini*

4.3.2 Chance of successful introduction

The likelihood that a certain exotic species can become established in the Netherlands due to the transfer of ballast water, is the resultant of two processes, both with a different probability:

1. the probability that potential target species survive the ballast water transport;
2. the probability that transferred species are able to become established.

The assessment of these probabilities is based on available knowledge about the physiology and ecology of the species involved, on the environmental conditions in the Netherlands and on ballast water treatment efficiency. Furthermore, expert opinions are used to assess the probability that the potential target species are able to become established in the Netherlands. These expert opinions are derived from a study on the risk of introducing exotic species by mussel transport (Wijsman & Smaal 2006, Wijsman et al. 2007b, a) for which an expert panel has assessed the chance of successful introduction of potential target species.

The probability that potential target species are successfully transferred

The probability that species are successfully transferred depends on the likelihood that the species are taken in with the ballast water and subsequently survive transportation.

Because the transport conditions of this case study are unknown, we assume the worst case scenario for this risk assessment, thus the one that gives the maximum change that the potential target species will survive: no treatment and no exchange. The likelihood that a species is transferred from Norway to the Netherlands is scored as a range between 1 (very unlikely) and 5 (certain). The starting point was a score of '5' (i.e. 'worst case') for each species. Based on available knowledge this score could be lowered. In these cases where insufficient knowledge was available the high score was maintained. As a rule of thumb it was decided that all planktonic species and species with a clear planktonic life stage have a high potency of being transported with the ballast water. Therefore, the likelihood that these species will be transferred was scored as 'certain' (score 5). Based on the available information of the species the chance of being transported is assessed as 'certain' (score 5) for all potential target species.

The probability that transferred species are able to become established

Those species that are supposed to be able to survive the transport can be introduced in the Netherlands. Each species has its own needs and tolerance for physical characteristics of the seawater (salinity, dissolved oxygen concentration, water temperature, etc.) and structural characteristics of the recipient location (substrate type, currents, etc). The combination of these characteristics determines the suitability of the environment for a specific species and thus the possibility for the introduced organisms to establish a self-sustaining population. The probability for a species to establish a self-sustaining population in the Netherlands was determined in two ways: by expert-judgment and by literature assessment (based on its ecological profile).

The probability that a species is able to establish a self-sustaining population in the Netherlands was scored as a range between 1 (very unlikely) and 5 (certain), in the same way as was the probability that a species was transferred. Again, the starting point was a score of '5' (i.e. 'worst case') for each species. In cases where insufficient knowledge was available, the high score was maintained. This was the case for *Aglaothamnion halliae*. This species is difficult to distinguish from other species in the *Aglaothamnion* genus, and might thus be underreported. Also no relevant information could be found on the worm *Scolelepis korsuni* and the macro algae *Codium fragile* ssp *scandinavicum.* A short summary of relevant information that has been found on other species is provided in this paragraph.

The individual scores for transfer and establishment were multiplied and divided by 5 in order to calculate the overall score for the likelihood that potential target species become established in the Netherlands due to water transport from Norway. Based on this list (Table 3) it seems (at least) likely that 8 out of the 13 potential target species are able to become permanently established in the Netherlands (score 3 or higher).

Table 3 Overall score based on literature for the likelihood that potential target species become established in the Netherlands due to water transfer from Norway, based on (Wijsman et al. 2007a). The score (i.e. the chance of successful introduction) is formed by the product of the 'transfer' and the 'establishment' score divided by 5. The species are ranked according to the overall score. Score: 1 very unlikely/certainly not; 2 unlikely; 3 likely; 4 very likely; 5 certain

Species name	Taxon. group	Score	
Aglaothamnion halliae	Algae	5	"certain"
Codium fragile subsp scandinavicum	Algae	5	"
Olisthodiscus luteus	Algae	5	"
Scololepsis korsuni	Polychaeta	5	"
Verrucophora farcimen	Algae	5	"
Karlodinium micrum	Algae	4	"very likely"
Homarus americanus	Malacostraca	4	"
Ruditapes philippinarum	Bivalva	4	"
Fucus evanescens	Algae	2	"unlikely"
Lepas anatifera	Malacostraca	2	"
Pseudodactylogyrus bini	Malacostraca	1	"very unlikely"
Paralithodes camtschaticus	Platyhelminthes	1	"
Chionoecetes opilio	Cirrepedia	1	"

Table 4 The assessment of marine biology experts of the chance of successful introduction of potential target species, based on (Wijsman et al. 2007a). Score: 1 very unlikely/certainly not; 2 unlikely; 3 likely; 4 very likely; 5 certain. Presented are average and range of the scores and (between parenthesis) the number of experts that indicated a score for this species. The species are ranked according to the overall score

Species name	Taxon. Group	Score		
		Average	Range	
Scolelepis korsuni	Polychaeta	5.0	– (1)	"certain"
Verrucophora farcimen	Algae	4.0	2 – 5 (4)	"very likely"
Olisthodiscus luteus	Algae	4.0	2 – 5 (4)	"
Aglaothamnion halliae	Algae	3.8	2 – 5 (4)	"
Karlodinium micrum	Algae	3.7	2 – 5 (3)	"
Codium fragile ssp scandinavicum	Algae	3.5	2 – 5 (4)	"
Fucus evanescens	Algae	3.4	2 – 5 (5)	"likely"
Ruditapes philippinarum	Bivalva	3.3	2 – 5 (7)	"
Lepas anatifera	Cirrepedia	3.1	1 – 5 (6)	"
Pseudodactylogyrus bini	Platyhelminthes	3.0	– (1)	"
Homarus americanus	Malacostraca	2.6	1 – 4 (7)	"
Paralithodes camtschaticus	Malacostraca	1.6	1 – 2 (7)	"unlikely"
Chionoecetes opilio	Malacostraca	1.6	1 – 2 (5)	"

4.3.3 Impact assessment

As described in the methodology, there are several steps in the prediction whether an exotic species will be able to develop into an ecological nuisance, *i.e.* a pest species. A basic requirement is that the species can successfully settle. This depends on its ability to arrive in the Netherlands and its ability to survive and successfully reproduce considering the local environmental conditions. This is considered in the previous paragraphs.

The next step, described in this paragraph, is to identify the impact that a species can potentially have on the marine ecosystem of the Netherlands, assuming successful introduction. Once established, the species may develop into a nuisance, provided the environmental conditions are very favorable for the species concerned. In historical times, many species have expanded their range and colonized new ecosystems. Some of these colonization's were spontaneous, whereas others were closely linked to human activities. There are no indications that it has resulted in large scale (European) species-extinctions and impairment of ecosystem functioning, but locally this has resulted in disappearance of some native species (Reise et al. 2006). The Pacific oyster (*Crasostrea gigas*), which was introduced in the Netherlands for aquaculture purposes in 1963 has recently developed exponentially and has lead to a nuisance in large areas, including the Wadden Sea. The relatively mild winters that have occurred recently might have played an important role in the successful introduction of new species, especially from the South.

The impact assessment conducted for this case study is based on a previous risk assessment study of mussel transfer (Wijsman et al. 2007a). It comprises a literature assessment on the impact of invasive species and judgment of a group of experts. The literature research was conducted to answer a few key questions for each species: whether the species are known as pest species; whether the species could (potentially) displace native species; distribution of the species, habitat and food preference and other relevant ecological factors. Based on the available knowledge, the potential impact was assessed. The results are summarised in Table 5.

In order to assess the probability that additional new exotic invaders will have a detrimental effect on the ecosystem of the Dutch marine waters as it is currently developing, an expert panel was requested to judge the list of potential target species and to indicate for each species that it lead to detrimental ecological effect once established in the Netherlands. The risk was scored from 1 (very unlikely/certainly not) to 5 (certain). Nine experts were able to fill in the list. The results of the expert judgment are included in Table 5.

Table 5 Assessment of the probability of potential target species having substantial ecological impact on the Dutch marine ecosystem after successful introduction, based on literature and expert judgment from (Wijsman et al. 2007a). Score: 1 very unlikely/certainly not; 2 unlikely; 3 likely; 4 very likely; 5 certain. Presented are average scores and range of the expert judgment scores and (between parenthesis) the number of experts that indicated a score for this species.

		Literature	**Expert judgment**	
Taxon. Group	**Potential target species**	**Score**	**Average score**	**Range**
Algae	*Aglaothamnion halliae*	2	2.5	1 – 5 (4)
	Codium fragile ssp scandinavicum	3	3.5	2 – 5 (2)
	Fucus evanescens	2	3.3	2 – 5 (3)
	Verrucophora farcimen	4	4.3	3 – 5 (4)
	Karlodinium micrum	3	3.0	2 – 4 (2)
	Olisthodiscus luteus	4	3.0	2 – 4 (2)
Polychaeta	*Scolelepis korsuni*	5	2.0	- (1)
Cirrepedia	*Lepas anatifera*	2	2.5	1 - 5
Malacostraca	*Homarus americanus*	4	3.3	2 – 5 (6)
	Paralithodes camtschaticus	4	4.3	2 – 5 (4)
	Chionoecetes opilio	3	3.5	2 – 5 (2)
Bivalva	*Ruditapes philippinarum*	4	3.8	2.5 – 5 (7)
Platyhelminthes	*Pseudodactylogyrus bini*	2	3.0	- (1)

4.3.4 Overall risk assessment

The risk assessment, as presented in this case study, indicates that it is very likely that a number of exotic non-indigenous species will be able to establish self sustaining populations in the Netherlands after being transferred with water from Norway. Table 6 summarises the assessments based on literature and expert judgment, respectively. Ten species are (very) likely to be successfully introduced and pose a threat to the ecosystem of the Netherlands (sore 3 or higher) (Wijsman et al. 2007a).
The algal species *Codium fragile* ssp *scandinavicum* and *Verrucophora farcimen* are considered a risk for the marine waters of the Netherlands. However, there are indications that these species are already present in the Netherlands. In this case, there will be no additional risk by water transfer from Norway. It is therefore recommended to verify these observations. Based on available literature, the algae *Olisthodiscus luteus* is considered very likely to be successfully introduced and pose a threat to the marine ecosystem of the Netherlands. Successful introduction of this species could lead to toxic algal blooms. The polychaeta *Scolelepis korsuni* is assessed with the highest score. Because there is very little known about this species, the literature

assessment is a worst case assumption. The expert judgment is based on only one score of the chance of successful introduction of this species. The potential impact of this species on the ecosystem is unknown. Although this results in a high score of the overall assessment, the lack of information could also indicate that this species poses no threat. The lobster *Homarus americanus* is considered likely to have a substantial impact on the ecosystem, mainly because it is a long lived predator that could cause competition with native predators. The bivalve species *Ruditapes philippinarum* is also likely to cause competition, in this case with other filter feeders.

The dinoflagellate *Oxytoxum criophilum* is identified as a species with a high overall risk. This is due to its bloom - and mucilage forming capabilities, as described in literature. The expert panel however, considers the risk for this species as very unlikely. Another species with a maximum overall risk score is *Pleurosira laevis*. This is a chain forming species and found to be a stable large producer of the toxic compound $CHCl_3$. Both the literature assessment as the expert panel indicates the probability of this species to have a substantial impact as certain.
The trematode *Pseudobacciger harengulae* is a parasite of several herring species and therefore considered a risk for the Dutch marine ecosystem. However, the expert panel considers the probability of a substantial risk unlikely. *Dissodinium pseudocalani* is ectoparasitic on copepod eggs and is can therefore form a potential risk for the Dutch marine ecosystem.

Table 6 Overall assessment of the risk that non-indigenous species that are introduced with water from Norway into the Netherlands, will have substantial impact on the ecosystem, based on (Wijsman et al. 2007a). The overall judgment is the maximum (worst case) of the independent score based on literature data and expert judgment. Score: 1 very unlikely/certainly not; 2 unlikely; 3 likely; 4 very likely; 5 certain.

Taxon. Group	**Potential target species**	**Literature assessment**	**Expert judgment**	**Overall assessment**	
Polychaeta	*Scolelepis korsuni*	5.0	2.0	5.0	certain (worst case assumption)
Algae	*Verrucophora farcimen*	4.0	3.4	4.0	very likely
Algae	*Olisthodiscus luteus*	4.0	2.4	4.0	very likely
Malacostraca	*Homarus americanus*	3.2	1.7	3.2	likely
Bivalva	*Ruditapes philippinarum*	3.2	2.5	3.2	likely
Algae	*C. fragile* ssp *scandinavicum*	3.0	2.5	3.0	likely
Algae	*Karlodinium micrum*	2.4	2.2	2.4	unlikely
Algae	*Fucus evanescens*	0.8	2.3	2.3	unlikely
Algae	*Aglaothamnion halliae*	2.0	1.9	2.0	unlikely
Platyhelminthes	*Pseudodactylogyrus bini*	0.4	1.8	1.8	very unlikely
Cirrepedia	*Lepas anatifera*	0.8	1.5	1.5	very unlikely
Malacostraca	*Paralithodes camtschaticus*	0.8	1.3	1.4	very unlikely
Malacostraca	*Chionoecetes opilio*	0.6	1.1	1.1	very unlikely

4.4 Uncertainties

4.4.1 Identification of potential target species

The potential target species for this case study were identified by comparison of the lists of reported exotic non-indigenous marine and brackish species from Norway with that of the Netherlands. It can not be excluded that more species are present at these locations without being observed. This could on one hand mean that more exotic species can be transferred with ballast water to the Netherlands in which case the risk is under estimated. On the other hand it is possible that species that are assumed absent in the Netherlands are actually already there. This will lead to an over-estimation of the risk.

Moreover, it must be clear that the introduction of non-indigenous species is a dynamic non-stop process, while the species list describes only a snapshot of recent situation. New exotic species are discovered regularly in European waters, some even being new to science. On bases of this knowledge, (Streftaris et al. 2005) conclude that the numbers of non indigenous species across European seas remains an underestimate.

As described in the methodology, species that are not reported as inhabitants in the Netherlands, but are known to be native in the Northeast Atlantic, were not identified as potential target species for this study. For species indigenous to the Northeast Atlantic, the influence of ballast water transfer from Norway is considered of little significance. If the marine waters of the Netherlands form a suitable habitat for these species, they would already be established due to natural transport mechanisms.

4.4.2 Potential for establishment of self-sustaining populations

The assessment of the potential target species to establish a self-sustaining population was hampered by the lack of knowledge about the ecology and physiology of some of the species (i.e. *Scolelepis korsuni, Aglaothamnion halliae* and *Codium fragile ssp scandinavicum*). Due to the precautionary principle that a lack of information would result in a worst-case assessment, this has probably lead to an overestimation of the probability that the introduced species will become permanently established in the Netherlands.

Insight in the physiological and ecological characteristics of specific species can increase the certainty about the probability that a species will be able to invade a new environment. From that point of view life history based risk assessments are considered useful (Hewitt & Hayes 2002). However, the number of factors that have to be taken into account to assess the probability of a species to be able to invade a region are enormous, and it is recognized that it is impossible to exactly predict which organism will survive and establish in new habitats (Gollasch 2002).

4.4.3 Potential for ecological impact

History shows that not all problems that are caused by invasive species are simple to predict. It has been estimated that ca. 10% of the introductions will lead to an invasion and that ca. 10% of these invasions will lead to a plague (Van Der Weijden et al. 2005) and sometimes the plague comes as an surprise. The potential that the introduction of exotic species in the Netherlands could lead to substantial ecological impact may therefore be underestimated.

4.5 Conclusions and recommendations

With the case study we have demonstrated that it is possible to make a (semi-quantitative) assessment of the risk of introducing exotic species with ballast water discharges. Such assessments are relevant as they could assist in defining the need for adequate treatment of ballast water originating from a specific region.

It is recommended to verify this assessment with some specific research for these species. With that knowledge it may be possible to take measures to reduce the risk for these species being imported to the Netherlands with ballast water. Of course these measures are only useful if also other potential vectors are restricted. Because the introduction of non-indigenous species in new areas is a continuous process, it will be necessary to monitor the presence of new exotic species in the donor locations regularly in order to prevent the transportation of unknown species with ballast water.

It would be very valuable to carry out a full risk assessment for the main Dutch harbours. This would imply an analysis of the origin of ballast water that is discharged in or near Dutch harbours, based on the areas where full or partial cargo loading has taken place. For the most relevant areas (e.g., covering 80% of the cargo tonnage transported to the Netherlands) a risk assessment then needs to be carried out following the method as developed in this project. Based on the outcome of the risk assessment, ballast water management options can be suggested for different regions, involving, for example, specific treatment or alternative routing.

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Justification

Rapport C082/09
Project Number: 199.730.3101

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

Approved: Drs. P. de Vries
Researcher

B.a.

Signature:

Date: August 2009

Approved: Drs. J.H.M. Schobben
Head of department environment

Signature:

Date: August 2009

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Number of graphs:	5
Number of appendix attachments:	2

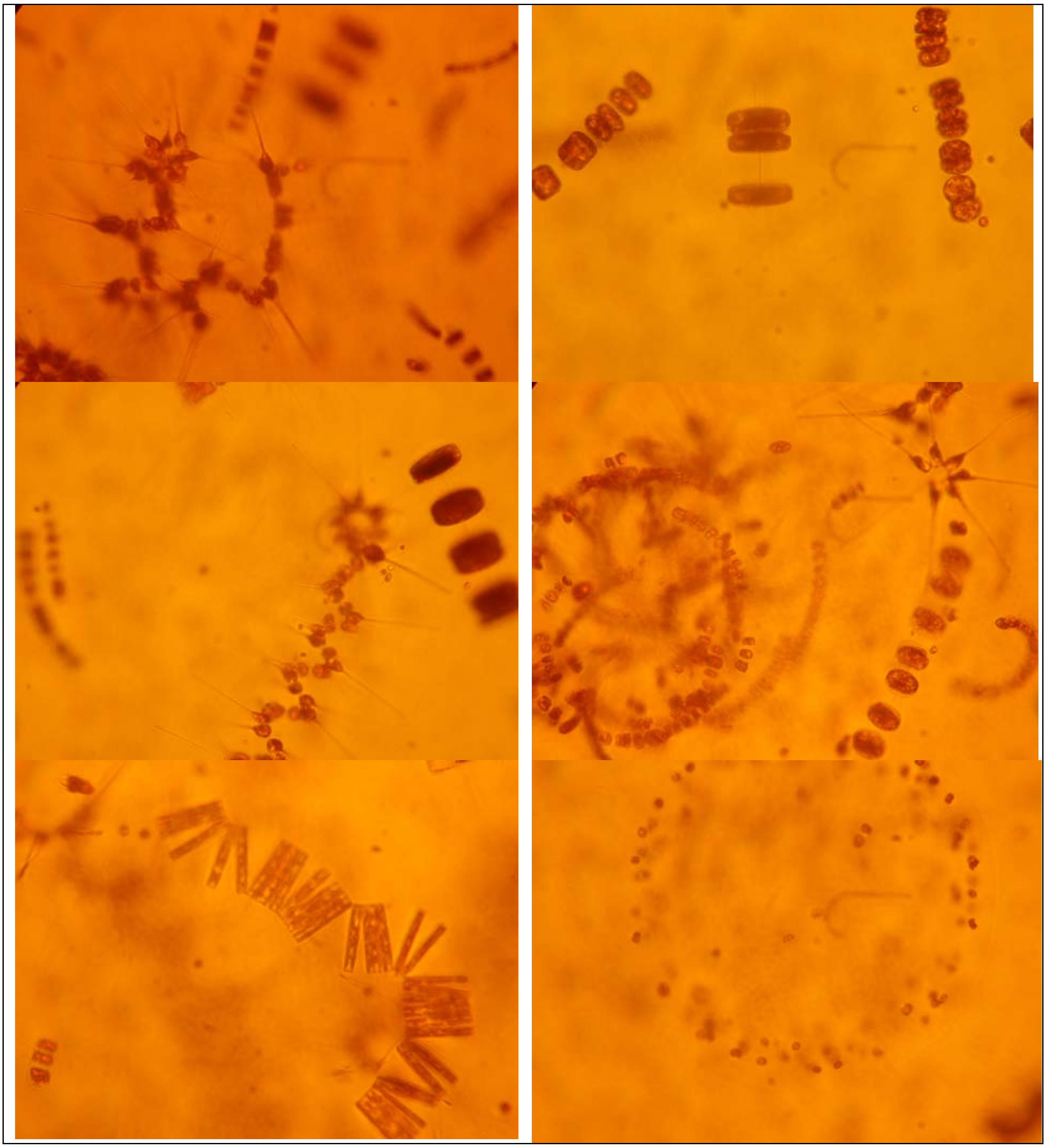
Appendix A. Overview of ballast water risk assessments

(Barry et al. 2008)

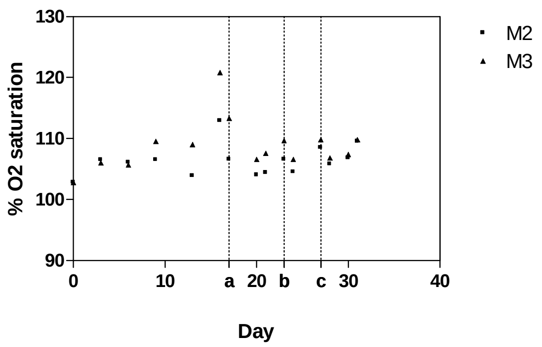
Name	Method summary	Approach	EV[a]	Endpoint	Time unit[b]	Purpose	Date
Australian Decision Support System	Models four steps in the bioinvasion process: source port infection, vessel infection, journey survival, and survival in the recipient port	Species-specific, quantitative	1	Target species life cycle completion in recipient port	Monthly	Identify low risk routes, vessels, and tanks	1997–ongoing
Globallast	Environmental similarity between localities, weighted by target species presence in the donor location and inoculation factors	Environmental similarity, semi-quantitative	37	Identify and rank high and low risk ports	Seasonal	Enhance awareness and recommend ballast water management strategies between ports	2002–2004
Norwegian ballast water risk assessment	Alt 1. Environmental match between donor and source localities Alt 2. Models four steps in the bioinvasion process: source port infection, vessel infection, journey survival, and survival in the recipient port	Species-specific, quantitative	2	Target species life cycle completion in recipient port	Monthly	Identify low risk routes, vessels, and tanks	1998–ongoing
Nordic ports risk assessment	Environmental match between donor and source localities and listing of potentially hazardous species	Environmental similarity and species-specific, qualitative	5	N/A—Hazard analysis	Annual	Identification of high risk routes and species in NORDIC countries	1998/1999
Ports Corporation of Queensland	Environmental similarity between localities, weighted by target species presence in the donor location and inoculation factors	Environmental similarity, semi-quantitative	37	Identify and rank high and low risk ports	Seasonal	Enhance awareness and recommend ballast water management strategies between ports	1995–1997
Dinoflagellate bioeconomic risk assessment	Estimates probability of establishment, bloom, and impact of a toxic dinoflagellate species	Species-specific, quantitative	1	Tourism and aquaculture impact	Annual	Economic impact of *Gymnodinium catenatum* on aquaculture and tourism	1993/1994
German ballast water risk assessment	Environmental match between donor and source localities and listing of potentially hazardous species	Environmental similarity and species-specific, qualitative	2	N/A—Hazard analysis	Annual	Identification of high risk routes and species in German coastal waters	1992–1996
Great Lakes risk assessment	Species-based tolerance and taxa concentrations in vessels with no-ballast on board (NOBOB)	Quantitative	2	Journey survival of target species	Per journey	Estimate risk associated with NOBOB vessels entering the Great Lakes	2002

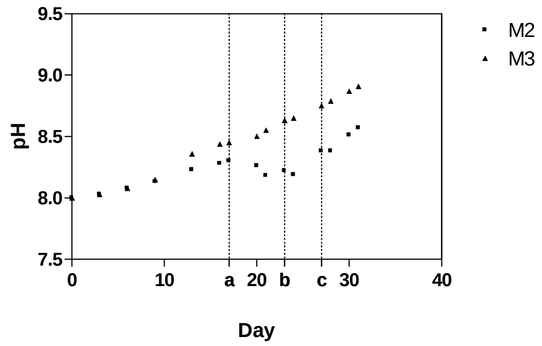
[a]Number of environmental variables used in the assessment.
[b]Period over which risk is assessed.

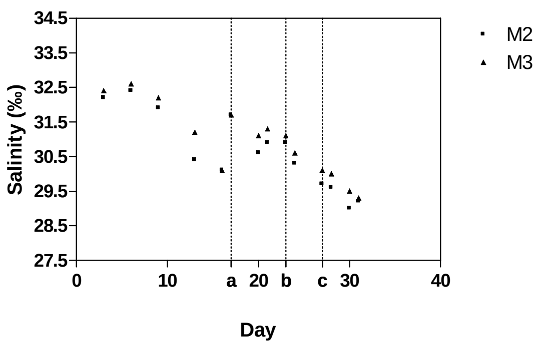
Appendix B. Overview of test results

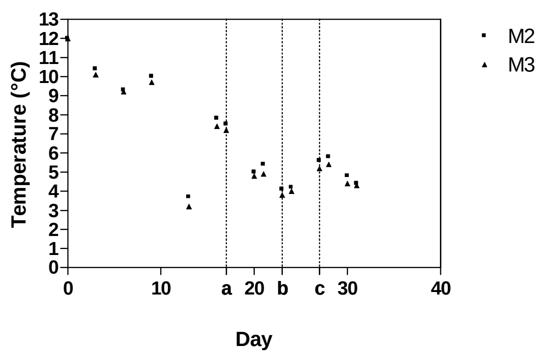


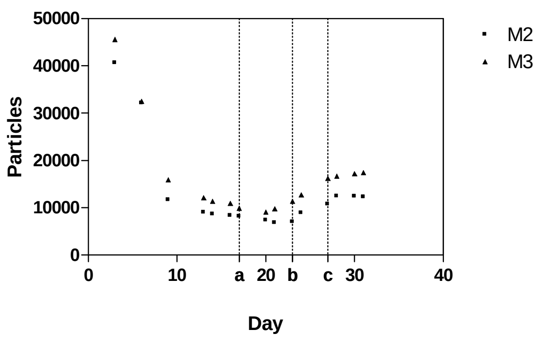
Examples of phytoplankton species. From upper left to bottom right: 1. *Asterionella japonica*; 2. *Thalassiosira rotula* (middle) and *T. nordenskioeldii*; 3. *A. japonica* and *T. rotula*; 4: *Chaetoceros debilis*; 5. *Thalassionema nitzschioides*; 6. *Phaeocystis pouchetii*


% O2 saturation
130
120
110
100
90
0
10
a
20
b
c
30
40
Day
M2
M3


pH
9.5
9.0
8.5
8.0
7.5
0
10
a
20
b
c
30
40
Day
M2
M3


Salinity (‰)
34.5
33.5
32.5
31.5
30.5
29.5
28.5
27.5
0
10
a
20
b
c
30
40
Day
M2
M3


Temperature (°C)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
10
a
20
b
c
30
40
Day
M2
M3


Particles
50000
40000
30000
20000
10000
0
0
10
a
20
b
c
30
40
Day
M2
M3