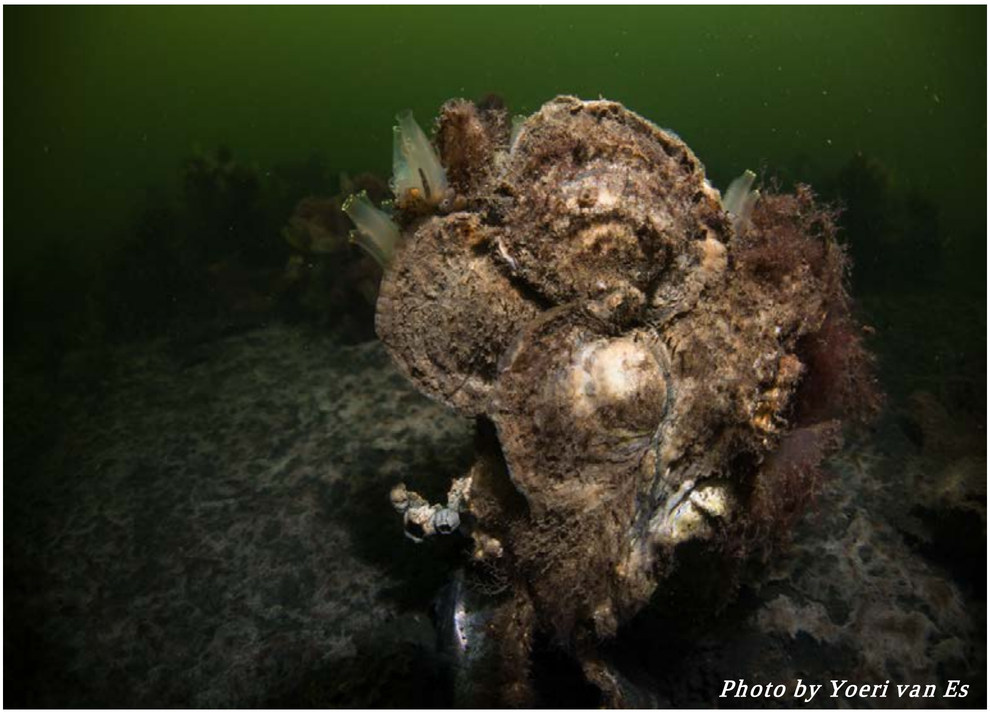

TECHNICAL WORKSHOP ON FLAT OYSTER RESTORATION

INCLUDING GUIDELINES FOR OFFSHORE PILOT PROJECTS

WORKSHOP REPORT

This report contains a summary of the presentations and discussion that took place during a Technical Workshop on Oyster Restoration, held June 2nd 2017 in Amsterdam.

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Technical Workshop on Oyster Restoration

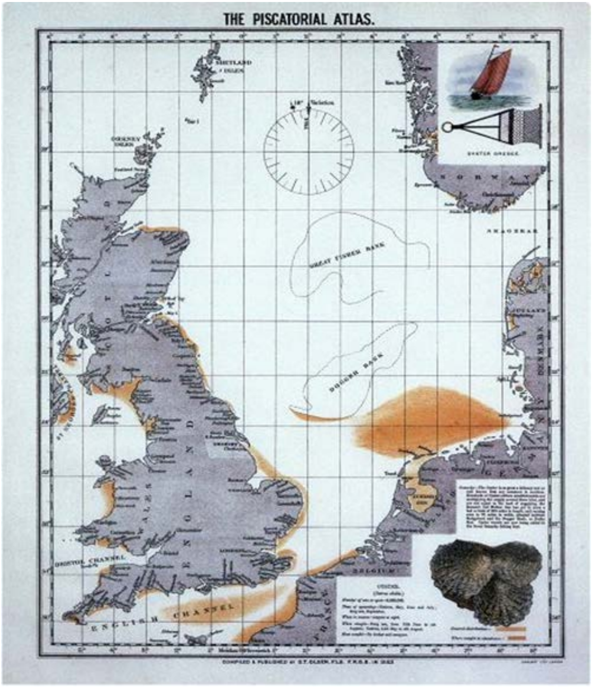
Mediamatic, Amsterdam, June 2nd 2017

Background

The Dutch national government has recently formulated policies regarding 'building with North Sea nature'[1], that is the combination of infrastructural projects in the North Sea with nature conservation, restoration or stimulation. This includes multi-user spatial collaboration, where economic use is combined with enhancing ecological functioning, for example when introducing artificial hard substrate. One concrete example of these policies can be found in 'plot decisions'[2] for new offshore wind farms. These plot decisions, which determine where and under which conditions new offshore wind farms can be built, now include an obligation for permit holders to design and build wind farms in such a way that they contribute to the conservation of naturally occurring species and habitats. The European flat oyster (*Ostrea edulis*) has been selected as an umbrella species for this obligation[3]. This is based on the presumption that native hard substrate biodiversity will benefit greatly from the establishment of flat oysters in or around wind farms and more so if it makes a wider comeback in the North Sea ecosystem. The establishment of flat oyster populations within offshore wind farms has the added benefit of providing larvae to flat oyster communities outside the wind farms including coastal areas.

Workshop overview

During the workshop, participants from Belgium, The Netherlands, Scotland, England and Germany[4] shared insights on the historic distribution of European flat oysters in their respective countries, and provided updates on the various projects that they are involved with that aim to restore native flat oyster populations. Discussions focused on common obstacles and how to overcome these. In the afternoon, a representative from a Dutch offshore wind farm operator provided an overview of the technical lay-out and daily operations of a typical North Sea wind farm, so as to allow for a better assessment of wind farm's suitability for oyster restoration projects. At the end of the afternoon, participants agreed on a set of guidelines to inform the site selection and pilot design process for pilot projects aiming to restore native flat oyster populations in offshore locations, such as North Sea wind farms.



This map from Olsen's Piscatorial Atlas (1883) shows the historic distribution of flat oysters in the North Sea and UK waters

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[1] See for example: Ministry of Infrastructure and the Environment, *Beleidsnota Noordzee 2016-2021*, p. 29 and the *Programme of Measures* developed under the MSFD, p. 54 and p. 117.
[2] In Dutch: Kavelbesluiten.
[3] W. Lengkeek et al., 'Eco-friendly design of scour protection: potential enhancement of ecological functioning in offshore wind farms', *Bureau Waardenburg report nr. 17-001*, 2017.
[4] For a full list of participants, see Annex I.

Presentation summaries

Insights from the Netherlands

Dr. Pauline Kamermans & Dr. Tom van der Have

In the Dutch part of the North Sea individual flat oysters (*Ostrea edulis*) have been found to be present on artificial hard substrates, such as shipwrecks and wind turbine foundations. Until recently it was thought that there were no oyster reefs remaining on soft sediments. Recently however, a small flat oyster reef was discovered close to shore. This reef consists of a mixture of mussels (*Mytilus edulis*), Pacific oysters (*Crassostrea gigas*) and the flat oysters (*Ostrea edulis*). Preliminary research indicates that the occurrence of the oyster reef at this specific location is most likely a result of larvae outflow from the Grevelingen, which was formerly a part of the Rhine estuary but has been converted into a saline lake as a result of coastal defence works. This lake is host to an extensive wild population of flat oysters, as well as several oyster farms. The newly discovered reef shows clear differences in the spatial distribution of various species. It has been observed that Pacific oysters tend to settle mainly on big boulders in shallow areas, while European flat oysters settle on mussel or oyster shells and are found in deeper parts of the reef on soft sediments.

Testing Survival, Growth, Reproduction and Recruitment in the Dutch Voordelta. Source: Wageningen Marine Research.

While research into the factors leading to successful settlement of native flat oysters in the coastal zone is ongoing, the Dutch government has commissioned research into the suitability of all current and planned offshore wind farms for oyster restoration. These areas are of major interest as possible locations for large-scale restoration of European flat oysters. The Dutch government is aiming at multiple-use of the space within wind farms and has identified ecological enhancement as one of the possible uses in this regard.[5] A feasibility study showed that several current and planned wind farm locations on the Dutch Continental Shelf have potential for oyster survival and oyster reef restoration.[6] According to the method used, wind farms Buitengaats and Zee-energie have the highest potential for oyster restoration, followed by Luchterduinen and Borssele.

In order to assess the suitability of the wind farm areas, the authors of the feasibility study determined the influence of locally occurring abiotic factors on the Survival, Growth, Recruitment and Reproduction (SGRR) on native flat oysters.

Survival can be affected by highly local differences in shear stress and sediment. This means that within a wind farm, there can be areas that are more or less suitable for oyster survival, which makes it vital to conduct a detailed analysis of any proposed restoration sites. Areas where native flat oysters are known to have occurred historically are typified by low bottom shear stress.

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[5] Ministry of Economic Affairs, *Natuurambitie Grote Wateren 2050 en verder*, p. 57.

[6] A. Smaal et al., Flat oysters on offshore wind farms, *Wageningen Marine Research rapport C052/17*, 2017.

Growth is dependent on levels of oxygen, phytoplankton and salinity. These are not limiting factors in any of the current and planned offshore wind farms.

Recruitment is the process of the addition of new recruits to the reproductive population. This can only take place if larvae find suitable substrate to settle on in the vicinity of their spawning area and survive up to the moment they are able to reproduce for the first time. To determine the feasibility of successful recruitment within the different wind farms, the distribution of larvae was modelled for a 10-day, by treating them as non-moving particles in existing water flow models. It was found that larvae would tend to remain within the wind farm if they spawn in Borssele, Buitengaats or Zee-energie. If they were to spawn in Hollandse Kust Zuid or Luchterduinen, they could end up outside the wind farm due to higher flow conditions.

Recruitment within wind farms, therefore, poses a significant challenge, because of the need for older (female) specimens to provide a source of larvae and suitable (clean) substrate. It seems that the window of opportunity for oyster settlement is very limited, because they have a short amount of time as viable larvae and need to find a "clean"/not-overgrown hard substrate. Which makes the right seasonal timing in restoration efforts essential.

The authors identified several knowledge gaps in their report. It is not yet known what size a source population needs to be to create a viable reef, nor how to determine the optimal timing for their introduction to maximise recruitment success. It is also yet to be determined whether the source population should be derived from a Bonamia free or a Bonamia tolerant population[7].

[7] Bonamia is an infectious disease (protist), which can infect larvae and older individuals. It has the highest impact (mortality) when oysters start to reproduce as females after 3-4 years. In Bonamia-tolerant populations the survival rate is substantial enough for a sustainable population. However, it is not possible to use this population as a Bonamia-free source. A Bonamia-free (or naive) population is highly susceptible to introduction of Bonamia, with high mortality as a result. This was the case when Bonamia was introduced in Europe in the seventies and many oyster farms and natural populations suffered high mortalities.

Insights from Belgium

Dr. Francis Kerckhof

Oyster reefs were present off the Belgian coast until the second half of the 19th century. After that they were fished to near extinction by English oyster trawlers. A search of the historical archives of the city of Oostende showed that this happened between 1868 and 1873.[8]

At that same time, oyster trawlers fully depleted the flat oyster population in the English Channel. This is unsurprising, seeing that records indicate that hauls of 20,000 oysters per ship were commonplace. There was great demand for oysters, especially in England, where the large oysters were sold cheaply and the smaller ones were sold as delicacies for the upper class. It was still a commonly held belief then that fishing activities could not exhaust the sea.[9]

In the early decades of the 20th century Professor Gilson undertook extensive expeditions to explore the flora and fauna of the Belgian marine waters. Whereas in 1900 he still describes the presence of oysters and the remainders of oyster beds, there are no reports of any remaining oysters after 1933. In later decades, solitary oysters were sporadically found in Belgian waters, but no traces of successful settlement were found until 2010 when flat oyster spat was found on a steel buoy and on a wreck.

Recent research showed that on the Hinderbanks, where oysters were present on coarse sediments, the habitat is still present and accommodates a high biodiversity. The continued presence of bottom trawling fishing activities in the area however causes regular disturbance of the seafloor and leads to the removal of suitable substrate for oyster settlement.

For future restoration projects in the North Sea to be successful, it is advised to incorporate the various international projects into a network of areas that are unaffected by bottom trawling, so that they may positively affect each other. Moreover, female oysters that are more than 15 years old are crucial for the reproduction and should not be removed.

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[8] F. Kerckhof, J.W.P. Coolen, B. Rumes and S. Degraer (under review). 'Recent findings of wild European flat oysters *Ostrea edulis* (Linnaeus, 1758) in Belgian and Dutch offshore waters: New perspectives for offshore oyster reef restoration in the southern North Sea', *Aquatic Conservation: Marine and Freshwater Ecosystems*.

[9] E.J.L.M. van Beneden, 'Question de la réglementation: rapport de M. Van Beneden', *Rapport de la Commission chargée de faire une enquête sur la situation de la pêche maritime en Belgique*. pp. XXXIII-XLII, 1866.

Insights from Scotland

Dr. Bill Sanderson

Historic records and archaeological data suggest that since the last ice age European flat oysters were present in the the Dornach Firth estuary in North Scotland. Unfortunately, oyster reefs have now been absent for the last 100 years due to overharvesting.

The Glenmorangie whisky company, which has its distilleries near the bay and uses it to discharge a small part of its production water, aims to restore these oysters and had decided to fund a major restoration project in the estuary: the Dornach Environmental Enhancement Project (DEEP).

The main aim of DEEP is to restore 40 hectares of oyster reefs. Preliminary trials have shown that current water conditions still allow for survival of flat oysters in the estuary. Cages with flat oysters that were placed in the water in March 2017 showed a survival rate of nearly 100% after two months.

Preliminary trials showed a near 100% survival rate for oysters in the Dornoch firth after two months. Source: Heriot Watt University

As a next phase of the project, an oyster hatchery will be built near the distillery in order to provide enough oysters for the planned restoration efforts. The hatchery will start with oysters that are sourced from Loch Ryan in the West of Scotland and have not been infected with the Bonamia virus.

One of the main research subjects besides Survival, Growth, Recruitment and Reproduction (SGRR) is the concept of Blue Carbon. Shellfish such as oysters bound together, modify the habitat and bury large amount organic carbon in sediments.[10] Horse mussels for example are found to bury an average of 0,492 mg of carbon a day. The Blue Carbon concept can act as a climate mitigation method and could be an interesting way for companies to decrease their carbon footprint.

[10] W. Sanderson & E.I.S. Rees, 'Mussel reefs in the Irish Sea', *Global Marine Environment 6 (2008).*

Insights from England

Dr. Joanne Preston

Oyster fishing has a long history in the Solent[11], the strait separating the English mainland from the Isle of Wight, and its associated harbours. The depletion of stocks led to a closed fishery season in 2013 and 2014. In 2015, some harbours were briefly opened for a 2 week oyster fishing season, followed by a full season in 2016 and 2017. The current flat oyster population in the Solent is Bonamia tolerant.

Unfortunately, the population is still in decline and oyster densities are low, not only due to fishing efforts but also due to predation, capital dredging projects and competition by the slipper limpet (*Crepidula fornicata*). Hydrodynamic modelling predicts that larval distribution is limited with larvae tending to stay within or near their harbour of origin. The focus now is on stimulating recruitment by introducing hanging structures containing adult oysters housed in microreefs[12] in the water column to increase the larvae output and recruitment to the seabed. The floating cage system also helps to prevent predation of broodstock by whelks or sponges and protects it from fishing activities. Large-scale restoration on the seabed is still challenging due to continued fishing activities in the area, but privately owned estuaries have been identified for seabed restoration in 2017 and 2018.

Restoration efforts in the Solent started with a pilot study in 2015 to test broodstock cages suspended from floating structures. This was successful, in terms of survival, growth, and reproduction. However, survival rates differed between locations as a result of possible local toxic algal blooms. Plankton tows and larval counts demonstrated oyster cages provided a significant larvae output, with over 100 larvae per m^3 of water being counted during the 2016 spawning season

The second phase of the project is now underway to trial a modified broodstock cage system deployed at six locations across the Solent. These cage systems are attached to marinas and pontoons and contain a total of 9000 mature broodstock oysters. High and low density stocked cages are being monitored for SGRR, disease and associated biodiversity. Preliminary results show that the new cage structures are successful in protecting the oysters against risk factors, with survival rates over 91% in all six locations after one year. Larval densities and settlement rates are also being monitored.

Broodstock is placed in cages that allow for quick and easy monitoring. Source: University of Portsmouth

The cage design appears to be an effective restoration aquaculture method for increasing larval supply to an area. However, seabed surveys conducted in fished harbours in the Solent during 2017 recorded *Crepidula fornicata* densities of >1000 /m^2 compared with very low *Ostrea edulis* densities of maximum 3/ m^2. Our preliminary results indicate that oyster populations in the Solent are negatively impacted by overfishing, a lack of suitable substrate, competition by the invasive species *Crepidula fornicate* and variable water quality.

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[11] Solent Native Oyster (Ostrea edulis) Restoration – Literature Review & Feasibility Study. Report 2906/P/01/A. (2014). MacAlister Elliott & Partners.

[12] The microreefs were developed by Tony Legg, Jersey Sea Farms, UK.

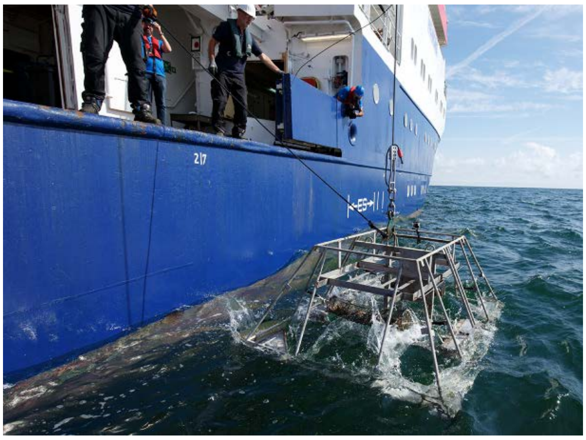
Insights from Germany

Dr. Bernadette Pogoda

While historic maps show that oyster beds were once present in a large part of the German part of the North Sea, flat oysters have not been recorded there for over 60 years.

The German Federal Agency for Nature Conservation (BfN) has now formulated the goal[13] to bring back healthy oyster reefs in the German North Sea and is contributing to this goal by funding the RESTORE project.

After a feasibility study[14] concluded that there was enough potential for oyster restoration in the German North Sea, the RESTORE project was started in 2016. This second phase of native oyster restoration aims at removing obstacles in the legal approval process for native oyster reintroduction, as well as addressing questions with regard to site selection, suitable source populations and best available technologies. This phase of the RESTORE project also includes field experiments in three locations. During the site selection process, it was shown that the Borkum Riffgrund Natura 2000 area had significant potential for oyster restoration due to its abiotic factors. This location was currently deemed unsuitable however, as bottom trawl fisheries are still allowed there. Alternative locations for the field experiments were found in the security zones of two nearby offshore wind farms and in the vicinity of Helgoland. At these locations, oysters of about 3 mm in size from a land-based hatchery are put in a lantern and hung on steel frames at a depth of about 25 m. Research at the field locations is focusing on the survival, growth and overall health status of the oysters.



Oysters are put in lanterns and attached to steel frames (landers) that can be lowered from a ship. Source: AWI

As in other projects, the limited availability of seed oysters has been flagged as an obstacle for large-scale restoration efforts. In order to overcome this obstacle, the possibility of creating a dedicated oyster hatchery on Helgoland is being considered. The seed oysters and substrate for large-scale restoration are difficult to get and the aim now is to get a hatchery on Helgoland, which can provide the oysters for restoration. The big question still is which population of oysters should be grown in the hatchery, as no oysters are present in German waters and it is not allowed to bring in "foreign" oysters.

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13 See https://www.bfn.de/17587.html

14 J. Gercken & A. Schmidt. 2014, 'Current Status of the European Oyster (Ostrea edulis) and Possibilities for Restoration in the German North Sea'.

Acknowledgments

The North Sea Foundation and the Dutch Flat Oyster Consortium would like to thank all who contributed to this workshop.

In particular, our thanks go out to:

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- All scientists who participated in the workshop and donated their time and expertise.
- The Ministry of Economic Affairs for funding and supporting this workshop
- Turing Foundation and ASN Bank for supporting the work of Stichting De Noordzee and Natuur & Milieu

Annex I: Guidelines for offshore oyster restoration projects: site selection and pilot design

Site selection

The following aspects should be taken into account when selecting a suitable location for pilot projects:

- **No Bottom Trawling**
  The absence of any form of bottom trawling is a necessary precondition for any type of restoration.

- **Moderate bottom shear stress and sediment dynamics**.
  High bottom shear stress or sediment dynamics will decrease the chances of settlement, as there is a risk of 'sandblasting' or burial of the shellfish. By contrast, if sediment dynamics are too low this will result in overly silty areas. Experience shows that flat oyster reefs can settle in areas with (moderately) high current velocities. Additional modelling and variations in pilot locations would be needed to find optimal conditions and areas.

- **Make use of currents for dispersal**
  Using current models to predict larvae dispersal, pilot locations should be selected where larvae are likely to settle in unfished areas, such as offshore wind farms. This poses a challenge, as the models used today are not sufficiently reliable to predict current patterns within the timeframe of a single spawning season.

Pilot design

The following aspects should be taken into account in the design of pilot projects: conditions/locations:

- **Creating a substantial source of larvae**
  It is recommended to make use of oysters of different age and size classes to ensure that both sexes are functionally present.

- **Offer clean substrate within dispersal range of larvae**
  During the spawning season, clean substrate should be offered for initial settlement of larvae. Shells of live oysters and empty shells (cultch) have been found to offer the best chances of successful settlement. Once a reef expands, adult oysters could form a source of clean settling substrate. It is not necessary for rocks or boulders to be present at the pilot site. The flat oyster is a soft sediment species and grows on shells or shell shards and other small hard substrate elements that are present within the sediment.

- **Ensure local variations between pilot sites**
  In order to enable research into the exact environmental factors that determine survival, growth, reproduction and recruitment, it is recommended to make use of local variations between pilot sites.

Research questions

More research is needed to answer the following priority questions before oyster restoration efforts can take place on a large scale:

- **Is it possible to predict with more accuracy when exactly oysters will spawn and when larvae will swarm?**
  Answering this question will help to determine the best time window for placing substrate for larvae to settle on.

- **What is the most suitable substrate and reef configuration?**
  Live oysters, oyster shells and shell fragments are suitable substrate for settlement, but it is unknown which type of substrate is optimal and preferred and how this preference is determined by other factors, including the behaviour of oyster larvae. In addition, it has been shown that higher reefs or reef-like structure greatly enhance the growth, settlement and recruitment of oysters. Better knowledge would greatly increase the chance of success of restoration efforts.

- **What is the most limiting factor for survival of oysters?**
  Determining the relative impact of bottom shear stress, sediment dynamics and sandblasting will help to accurately choose optimal pilot sites.

- **Should the broodstock come from a Bonamia-free or Bonamia-tolerant source population?**
  Bonamia is an infectious disease (protist), which can infect larvae and older individuals. It has the highest impact (mortality) when oysters start to reproduce as females after 3-4 years. In Bonamia-tolerant populations the survival rate is substantial enough for a sustainable population. However, it is not possible to use this population as a Bonamia-free source. A Bonamia-free (or naive) population is highly susceptible to introduction of Bonamia, with high mortality as a result. This was the case when Bonamia was introduced in Europe in the seventies and many oyster farms and natural populations suffered high mortalities.

- **How can an adequate supply of broodstock be ensured?**
  It is thought that the capacity of current (commercial) oyster producers is not sufficient to provide broodstock for the many oyster restoration projects that are currently being planned in different parts of Europe. It might be interesting to explore whether dedicated hatcheries can be set up to support restoration efforts.

Annex II: List of participants

Workshop participants:

Ms. Sytske van den Akker	Eneco
Dr. Joop Coolen	Wageningen Marine Research
Dr. Luca van Duren	Deltares
Mr. Jan Groot	PB Consultants
Mr. Luke Helmer	University of Portsmouth
Dr. Tom van der Have	Bureau Waardenburg
Prof. dr. Peter Herman	Deltares / Technical University Delft
Dr. Maarten de Jong	Ministry of Infrastructure and the Environment
Dr. Pauline Kamermans	Wageningen Marine Research
Dr. Francis Kerckhof	Royal Belgian Institute of Natural Sciences
Dr. Edo Knegtering	Ministry of Economic Affairs
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Prof. dr. Tinka Murk	Wageningen University
Dr. Bernadette Pogoda	Alfred Wegener Institut
Dr. Joanne Preston	University of Portsmouth
Ms. Emilie Reuchlin-Hugenholtz	WWF-NL
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