WIL BORST AND TIEDO VELLINGA

THE MONITORING PROGRAMME FOR THE MAASVLAKTE 2 CONSTRUCTION AT THE PORT OF ROTTERDAM

ABSTRACT

Maasvlakte 2 (MV2) is the Port of Rotterdam Authority's port extension project west of the existing Maasvlakte. The project area is 2,000 hectare gross of which 1,000 hectare is the net infrastructure. The first phase of the project is scheduled to be finished in mid-2013.

Before operations for the project could begin, a stringent Environmental Impact Assessment (EIA) was conducted to meet permitting requirements. This article focusses on the monitoring aspects and the effort the Port of Rotterdam (POR) has put into complying with the conditions of the excavation permit. The article will demonstrate that the POR went beyond what was required to satisfy what they considered their duty and rather tried to understand what was going on in the North Sea during dredging. To this end, they went beyond the responsibility of monitoring for the sake of the permit, but rather initiated more scientific research as gaps of knowledge manifested themselves.

In this article the following subjects are examined: The monitoring requirements and set-up in general, the baseline measurement for juvenile fish (2007), the seabed composition, sieve analysis and the silt component therein, and the mismatch between hatching of cockles and the algae bloom (2009-2011). Other aspects of the monitoring programme will be presented in subsequent articles.

INTRODUCTION

Maasvlakte 2 is the Port of Rotterdam (POR) Authority's port extension project west of the existing Maasvlakte. The project area is 2,000 hectare gross of which 1,000 hectare is the net infrastructure. The first phase of the project is scheduled to be finished in mid-2013. To date the project is on schedule and within budget.

Previous articles on Maasvlakte 2 (MV2) in various publications have highlighted the construction and contractual aspects. This article, the first of four, will focus on the monitoring aspects and the effort the Port of Rotterdam (POR) has put into complying with the conditions of the excavation permit. The article will demonstrate that the POR went beyond what was required; that in order to satisfy what they considered their duty to understanding what was going on in the North Sea, they initiated more scientific research as gaps of knowledge became apparent, instead of mere monitoring for the sake of a permit.

After a long preparation period (more than 15 years) the construction of MV2 finally started in September 2008. The works were tendered as a "Design & Construct" contract. The contractor PUMA (Project Organisation for Expansion of the Maasvlakte) has to comply with specifications provided by the Client, i.e., MV2 Project Organisation (PMV2) of the Port of Rotterdam.

The first m^3 of sand were dredged from the Yangtze harbour (Euromax container terminal) and deposited by pipeline on the sandy beach in front of the existing Maasvlakte. The bulk of the sand needed for the construction of MV2 however had to come from an offshore located borrow area approx. 10-15 km from the Maasvlakte (see Figure 3).

The offshore sand extraction started on January 13, 2009. Gradually over time the

Above: Maasvlakte 2 is the Port of Rotterdam Authority's port extension project west of the existing Maasvlakte. The first phase of the project will be finished by mid-2013. On the July 11, 2012 Queen Beatrix of The Netherlands initiated the closure procedure (pictured here) of the outer contour which was designed as a "soft" – that is, constructed with sand – sea defence. This event was broadcast live on Dutch national television.

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number of TSHD bringing sand to MV2 increased. The number of dredgers working for MV2 changed constantly. On average 5 TSHDs were present. The maximum number simultaneously working was 13. In total 24 different TSHDs were active from 2009 to the present.

Of the total required 220 million m³ of sand for the first phase of MV2 approximately 200 million m³ of sand was dredged offshore (July 2012) (see Figure 1).

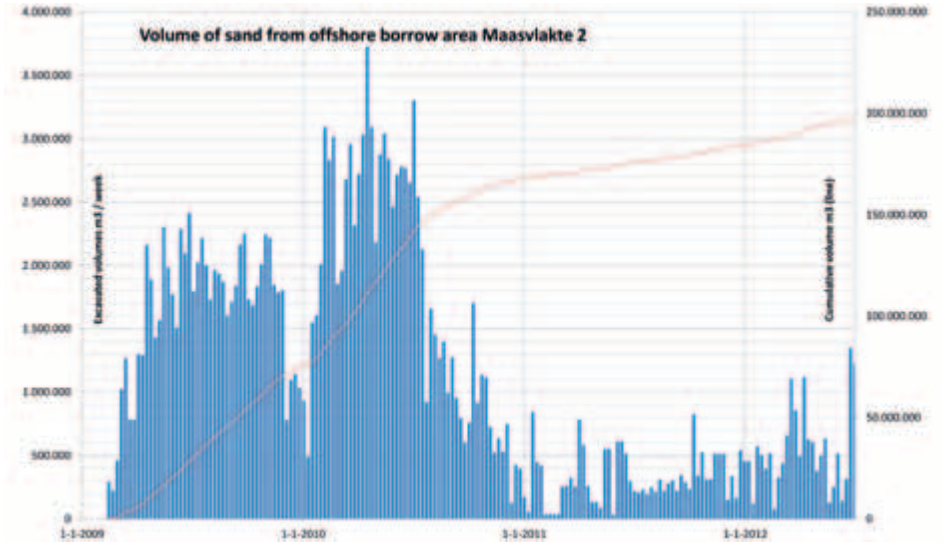

Figure 1. Volume of sand extracted during the excecution period of Maasvlakte 2.

In this article the following subjects will be presented:
- Monitoring requirements and set-up in general,
- Baseline measurement of juvenile fish (2007),
- Seabed composition, sieve analysis and the silt component therein,
- Mismatch between hatching of cockles and the algae bloom (2009 – 2011).

The following topics will be addressed in future articles:
- Benthic community along the Dutch coast (2006 – 2012)
- Silt in the water column along the Dutch coast (2007 – 2012)
- Monitoring of the current condition in the Maasgeul, the entrance to the Port (2006 to the present)
- Underwater sound of TSHD at work (source terms) (2008 – 2009)
- Verification of the EIA predictions with respect to underwater sound (2013)
- Archaeological and paleontological finds and research projects initiated (2009 to the present)

MONITORING REQUIREMENTS AND GENERAL SET-UP

The MV2 project is part of a total concept for the development of Rotterdam-Rijnmond, in which three objectives are combined. The objectives are:
- the sustainable expansion of the Rotterdam Port by construction of MV2,
- the creation of 750 hectare new green areas and recreational facilities in the greater Rotterdam Area and,
- the re-development, re-allocation and improved efficiency of the existing port.

To implement the above, the Project Mainport Rotterdam (PMR) was created in 1999, as a combined effort of the Port of Rotterdam, The Municipality of Rotterdam and some national and provincial Government agencies: The Netherlands Ministry of Transport (RWS) and Ministry of Commerce, Agriculture & Innovation (called EL&I in Dutch – Economie, Landbouw and Innovatie) and the Provincial Public Works Departments.

For MV2 alone there are 5 major permits:
- Excavation permit,
- Concession permit,
- Nature Protection Act,
- Flora & Fauna Exemption Act and
- Public Works Act (permission to work in or on the seafloor).

These are issued by two different ministries (RWS & EL&I). Each permit has its own Monitoring and Evaluation Programme (MEP) and underlying Monitoring Programme (MP). The MP provides the necessary input for answering the question to allow the evaluation of the actual effects registered through monitoring (and further analysis). The MP is delegated through the permits to POR. The evaluation remains the responsibility of the Authorities.

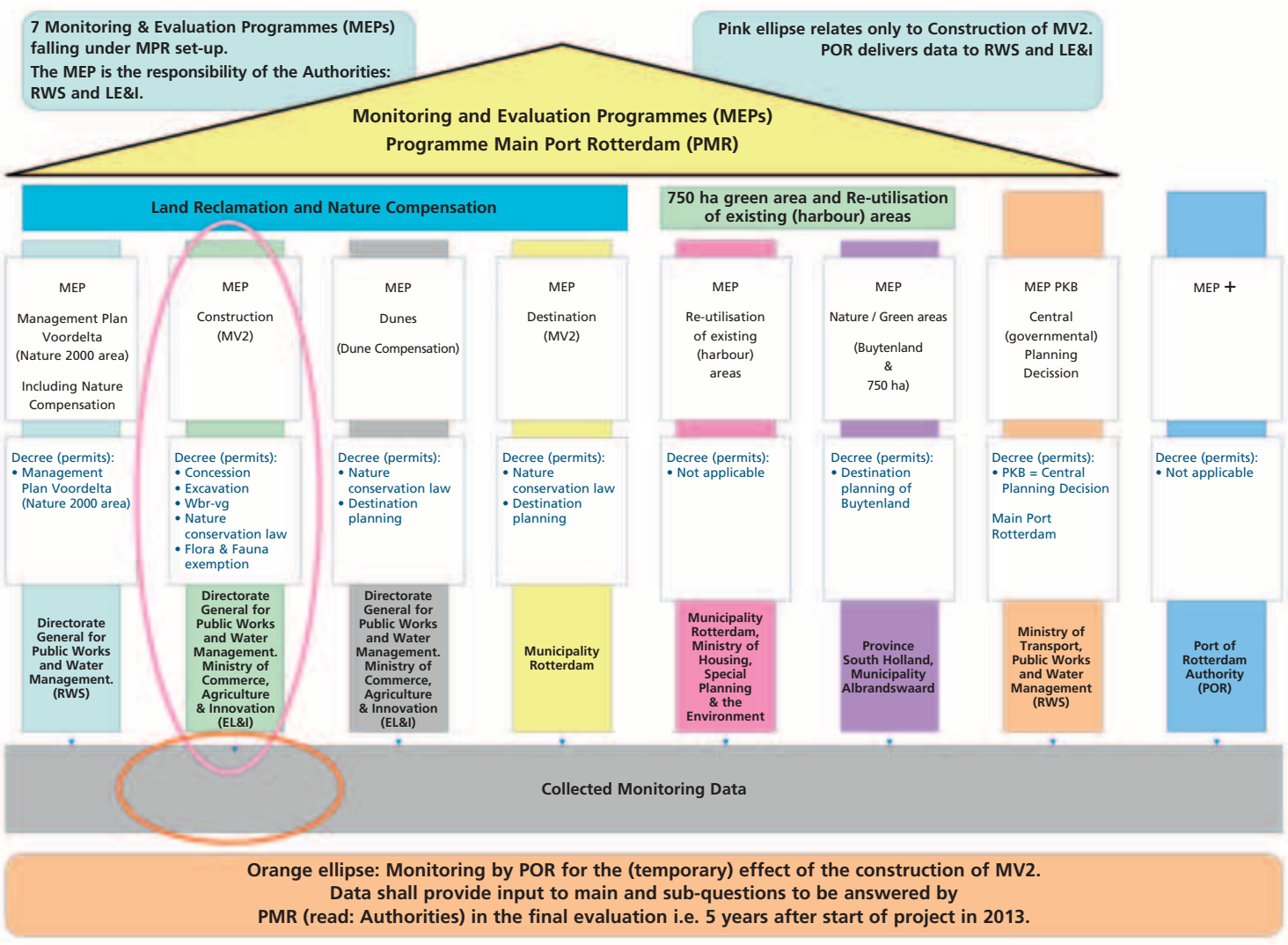

Figure 2. Organisational set-up to bring all MEPs under one umbrella as many MEPs are intertwined and provide data to more than one programme (pillar) which may have different stakeholders.

Hence, the combined and integrated approach under the PMR umbrella to safeguard uniformity and unambiguity in the evaluations (as shown in Figure 2).

The permit to excavate sand from the North Sea shows an area of approx. 90 km^2, located north and south of the Eurochannel (Figure 3). This area is based on an excavation depth of 5 metres. Till 2009 the allowable depth (permit condition) for sand extraction was 2 metres. In the EIA Construction MV2 all the effects of a deep excavation were investigated, e.g., environmental impact overall, stability of slopes, coastal defence, stagnant (anaerobic) water, benthic communities, fishing activities and so forth.

The permit allowed a maximum dredging depth of 20 metres below the existing seabed. The choice and the location(s) within the excavation area had to be made by the contractor, as different parts of the work required different sand qualities. In the end all the sand was excavated from two areas, indicated in Figure 3 by the red circle. The northern borrow area has a depth of 20 m (approx. -40 m NAP); the southern borrow area is approx. 10 m deep (-30 m NAP) (Figure 4).

The actual excavation limits and depths are shown in the bathymetric chart of mid 2012 shown in Figure 4.

In general only effects, although small, that cannot be neglected or are potentially significant require monitoring. Effect analysis is based on the BACI (Before-After–Control-Impact) assessment.

For the construction of MV2, apart from the covering up of existing sea bottom, the driving force for the possible impact is the extra silt (fine fractions) brought in suspension through the overflow of the TSHDs.

All possible effect chains have been worked out and were reported in the EIA (MER-Aanleg MV2). Leading in formulating the main questions (topics) to be addressed in the evaluation of the PMR projects, in our case the MV2 construction and presence, were the EIA, the so-called Appropriate Assessment for the effects on Nature 2000 areas and the 5 main permits. The permits contain directives for monitoring, either in a very concrete and explicit format (RWS) or in a more general sense (EL&I).

All separate projects for which monitoring is required are brought under one integrated umbrella (see Figure 2). Under this umbrella, in concert with all parties concerned, the ultimate questions to be answered in the evaluation of the impact of MV2 construction, MV2 presence and so on, have been formulated. The questions can be found in the various MEPs. Sub-questions, if relevant, have been derived from each main question.

The monitoring results will provide answers so that the main and sub-questions can be answered after a 5-year period.

- *Subject:*
  Construction MV2 – borrow area
- *Main question:*
  How will the quality of the seabed (benthic communities) develop in the borrow areas after construction of MV2 as regards to the original benthic community in and around the excavation pits?
- *Sub-questions:*
  What benthic community was present before the start of MV2?
  What are the soil properties of the top layer in and around the designated borrow areas?
  What are the quality and the variability of the original benthic community?
  What benthic community will come back (re-colonisation?)
  How long will it take before re-colonisation will take effect? What will be the quality and variability of the new community?

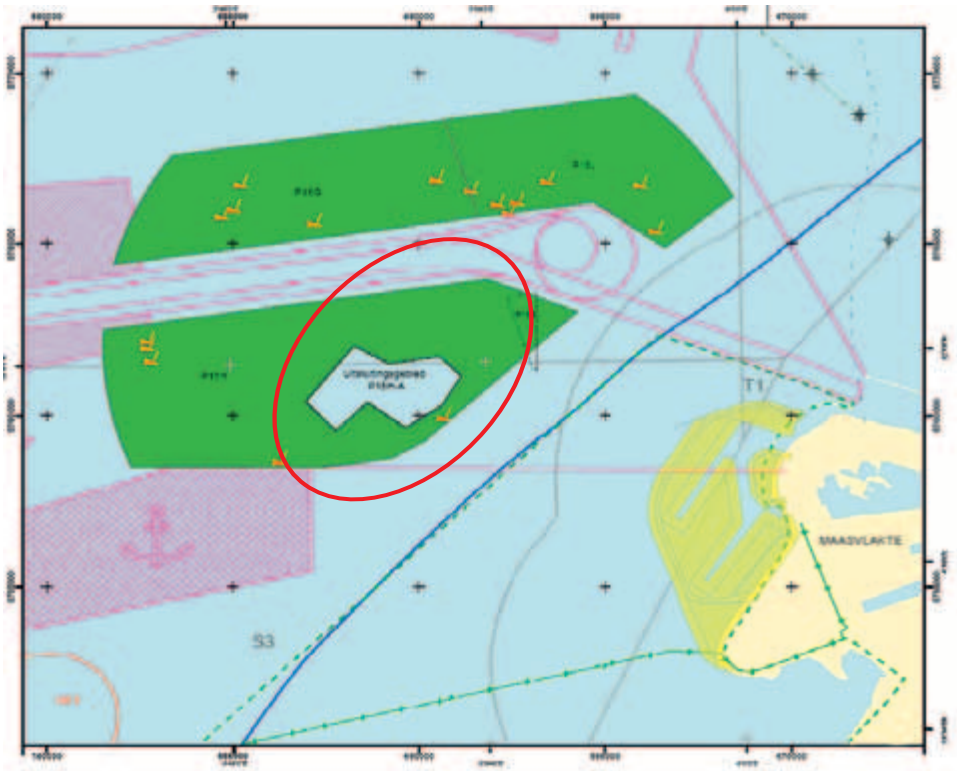

Figure 3. Drawing of the sand borrow areas north and south of the entrance channel (Euro Maasgeul) to the Port of Rotterdam (source: Permit for sand borrowing from RWS-DNZ). Sand borrow areas are indicated in green. The light blue part in the southern borrow area is excluded (clay layers).

The actual monitoring for the construction phase of MV2 will continue after 2013 as some after effects may occur, e.g., as a result of buffering of silt in the seabed being released again into the water column by storms, that is, by wave-induced water-bottom interaction (van Ledden *et al.*).

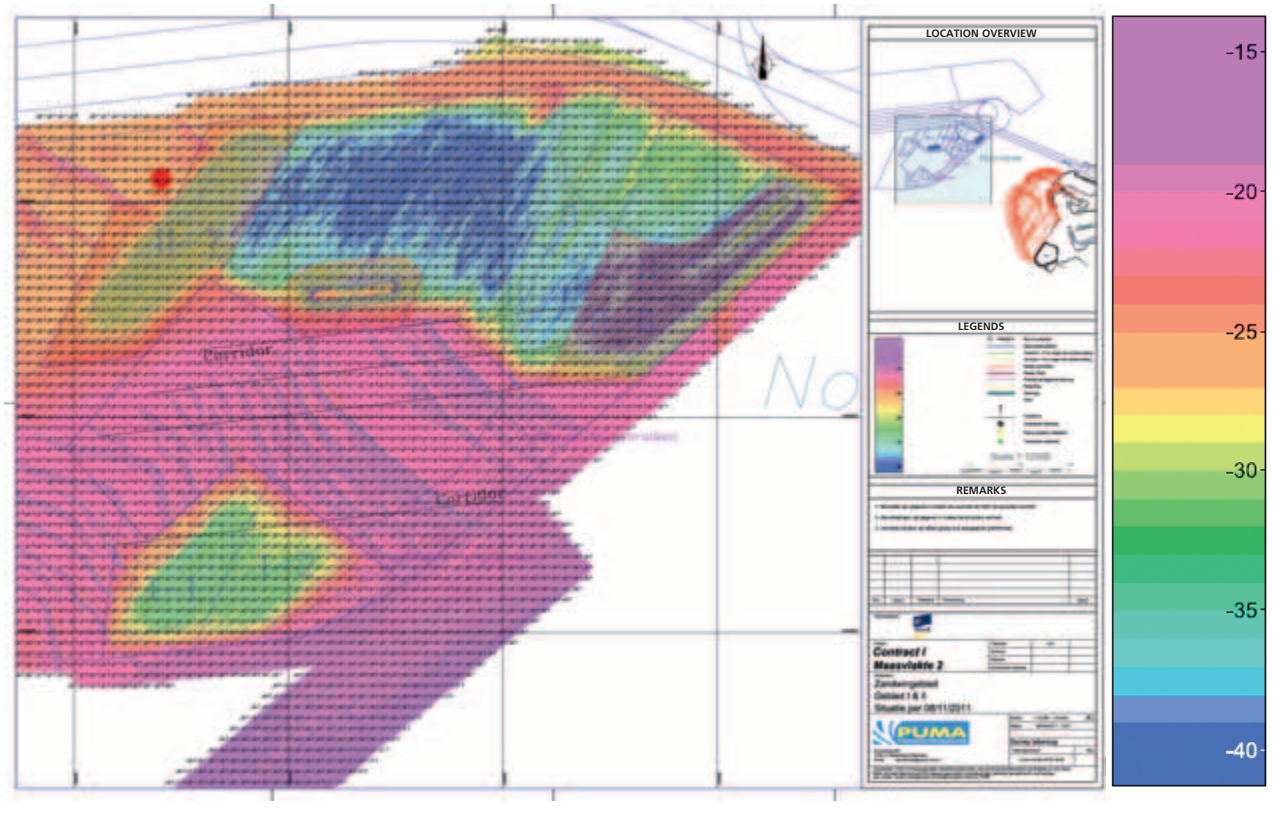

Figure 4. Bathymetric chart borrow areas MV2 mid-2012.

Table I. Overview of all the monitoring conducted by the POR.

Monitoring	Executed for and supervised by POR	Surveys carried out so far
Seabed / Bathymetry	PUMA / POR	Bathymetry of the borrow area including borders (200 m), 6 month intervals
Offshore m^3 sand	PUMA	MARS data (extracted m^3 sand), every month
Composition of sand	PUMA	Sieve analysis on board TSHD (Malvern - all trips) and 10% random selected sieved at external Laboratory, every month
Seabed composition: borrow area & Far field	NIOO	All samples from box cores, yearly
Silt in water column	POR	2007, 2009 thru 2012
Numerical model MoS^2	Deltares (& IVM)	2006, 2008 thru 2012
Mismatch algae bloom / cockle hatching	Koeman & Bijkerk	2009 & 2010
Benthic species composition / diversity: borrow area & Far Field	IMARIS (benthic sledge) NIOO (box cores)	2006, 2008 thru 2012
Underwater sound	TNO	Continuous measurement in 2008 & 2009 Measurement of 7 TSHDs (2009) Calculation of source term for 7 TSHDs (2011). Check on EIA (2012)
Archeology / drowned landscapes	Deltares / BOOR / TNO	Desk studies and field investigations (2006 – 2010) Excavation and sorting of excavated material (2011) Further analysis and descriptions of the finds in various specialist laboratories (2011 – 2012) Integration of archaeology, paleontology and the drowned landscapes studies
Paleontology	NMR, University Leiden, Naturalis Leiden, TNO	Trawling trip in the borrow area (2009 – 2011) Mechanical and hand picking searches on the outer perimeter (sandy beach) of MV2 (2010) Research projects to reconstruct the geological context of the finds Integration of archaeology, paleontology and the drowned landscapes studies
Juvenile fish	IECS (Hull, UK)	Baseline study (2007) Impact of silt on juvenile fish (Evaluation of larvae data)

In Table I an overview is presented of all the monitoring the POR is carrying out. The themes relate to the respective subjects that are extensively described in the Monitoring Programme (MP) approved by the authorities; the table column 2 indicate who carries out the surveys on behalf of POR. All the monitoring in the field and in the laboratory has been extensively supervised by specialists from POR and in some cases POR took an active role. The first three monitoring items assigned to PUMA are related to compliance with the permit conditions. They are checked by the authorities on a monthly basis and fall outside the EIA as such. The juvenile fish monitoring was no longer an issue at the time the permits were released.

Baseline measurement of juvenile fish (2007)

During the EIA it was not clear, even after consultation with external experts, whether or not juvenile fish would be affected by extra fines in the water as a result of the MV2 construction. Therefore in 2007 a baseline juvenile fish survey was carried out. This baseline fish survey was carried out in conjunction with the POR's silt survey (same area and statistically speaking the same points). The fish survey and the silt survey comprised of 100 locations, 20 sections perpendicular to the coast and approx. 5 points per section. The 100 locations are intertwined with the benthos 2008 baseline locations (statically speaking the "same"coordinates).

The juvenile fish survey consisted of catching bottom fish with a 2-m width beam trawl and pelagic juvenile fish with a plankton net. The survey was carried out in April, July and October 2007 and sailing occurred during the night as juvenile fish would be better

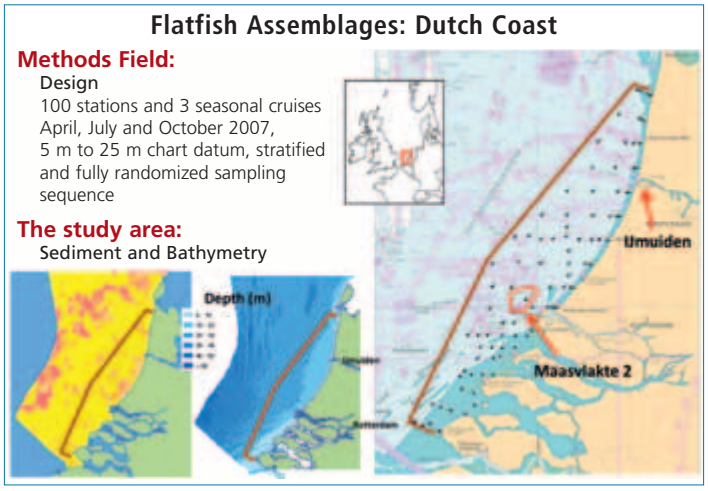

Figure 5. Flatfish and juvenile fish survey 2007 particulars.

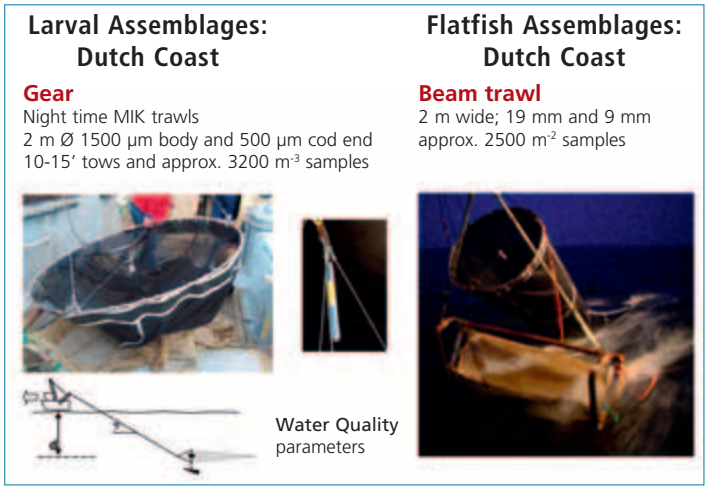

Figure 6. Methodology and net specifications of the juvenile fish survey 2007.

dispersed over the water column (Figures 5 and 6). Approx. 65,000 fish from the bottom trawl have been weighted and measured in order to establish their condition. More than 52 species were identified in the catches.

From the plankton net the juvenile fish samples were taken and deep frozen; in total 28 larval fish species were encountered (Figure 7). The idea was to compare their stomach contents in case the condition of the juvenile fish established during the construction of MV2 (effect of the extra silt from the borrow area on juvenile fish larvae) were found. The stomach content should indicate if silt particles could be the reason.

Conclusion of the juvenile fish survey of 2007

In the permits and later on when the final MEP / MP was available, the effect on juvenile fish was considered highly improbable and difficult to prove owing to the variability of the North Sea ecosystem. Hence POR was not obligated to continue monitoring juvenile fish. Silt was not a decisive factor; moreover, larval fish are particulate feeders and can distinguish between silt and plankton.

Since the juvenile fish larvae were still stored, a decision was made in 2008 to carry out a further analysis on the stomach contents of the frozen juveniles. At the same time the environmental parameter and constraints were taken into account when analysis and interpreting the results, i.e., silt in seabed, silt in water column, depth, and so on. This resulted in seasonal and spatial distributions of flatfish and juvenile fish (in 2007) in front of the Dutch coast.

A total of 28 larval fish species were encountered during the surveys with greater larval densities in April and a decreasing trend

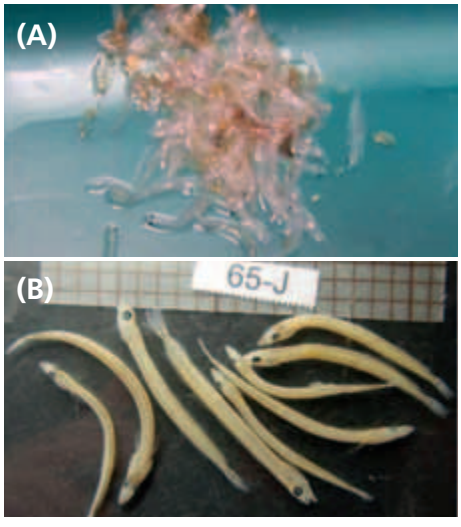

Figure 7. Photographs of fish larvae during processing. (A) fresh unsorted sample on board previous to freezing and (B) lesser sand-eel *(Ammodytes marinus)* larvae after preservation and sorting in the laboratory (2.5 mm-grid graph paper if shown for size reference).

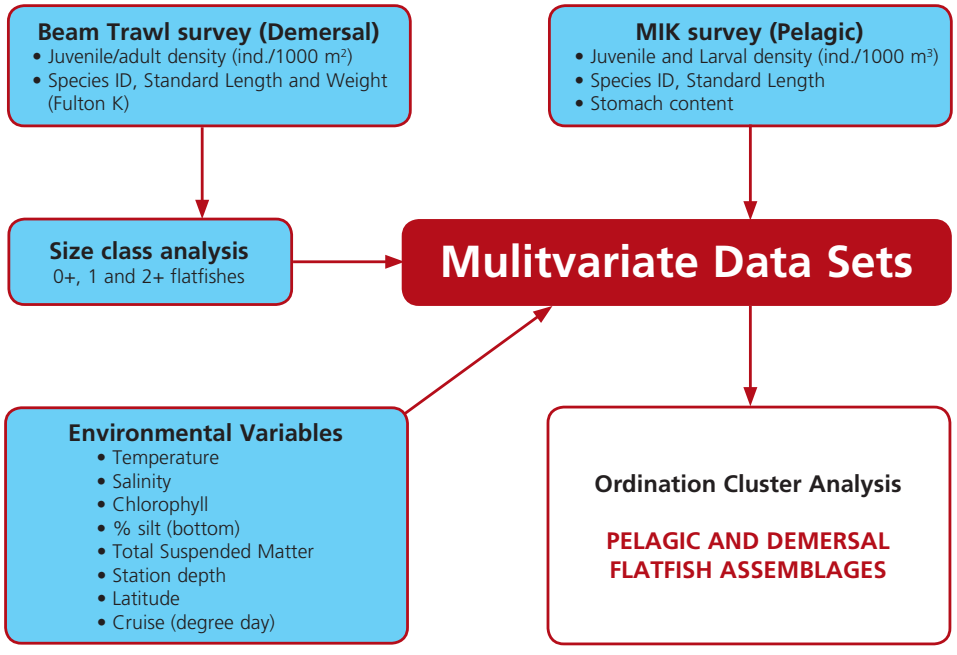

Figure 8. Analysis set-up flatfish and juvenile fish data.

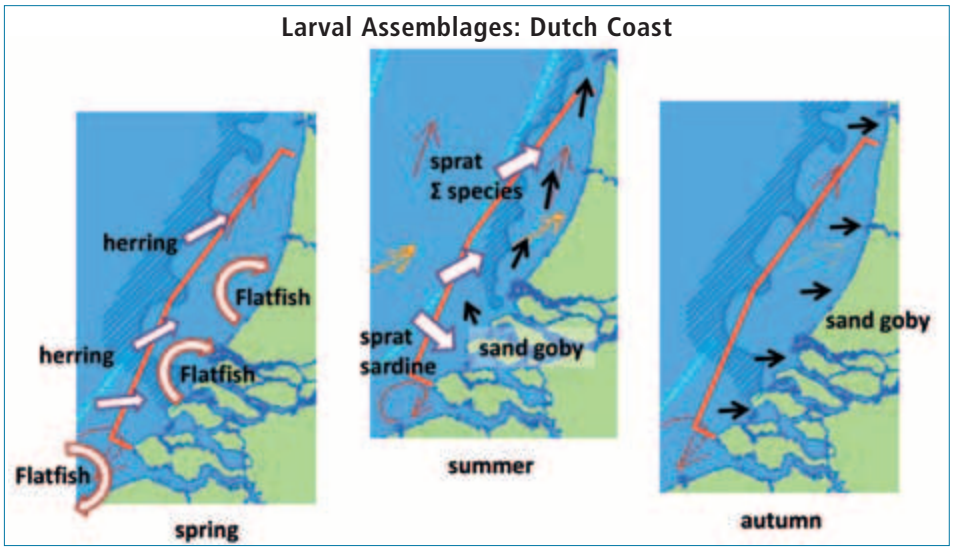

Figure 9. Larval assemblages and movements along the coast over the three seasons in 2007.

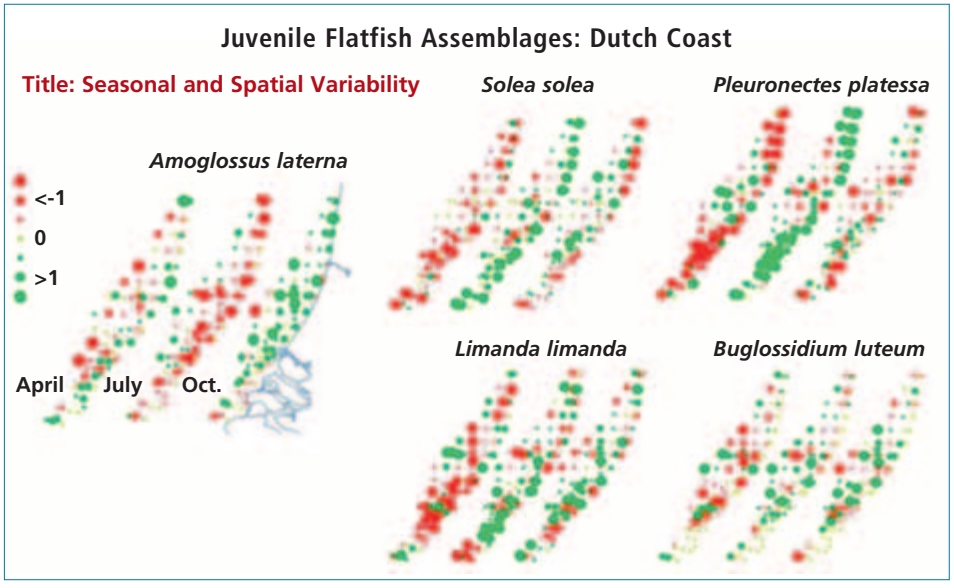

Figure 10. Seasonal and spatial variability of juvenile fish assemblage (2007).

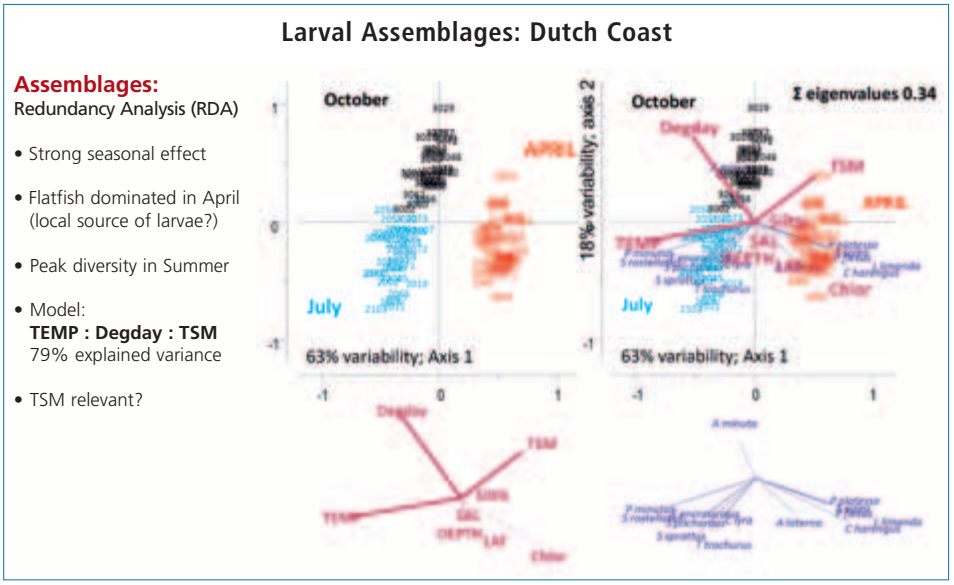

Figure 11. Example of the RDA (Redundancy Analysis) results.

towards the end of the survey period. Nineteen of these species were collected in April (11 unique species to April) grouped into 2 assemblages (cluster analyses and SIMPER), 17 species in July (4 unique) and 4 assemblages, and finally 9 species (1 unique) and 1 assemblage type in October.

Herring *(Clupea harengus)*, flounder *(Platichthys flesus)* and dab *(Limanda limanda)* dominated the catches in April. Sand goby *(Pomatoschistus minutus)*, dragonet *(Callionymus lyra)*, and sprat *(Sprattus sprattus)* dominated in July, and in October sand goby *(Pomatoschistus minutus)* was the most abundant species (Figures 8, 9 and 10).

A significant effect of month of collection on assemblage composition was found (PERMANOVA $p<0.0001$). Seasonal factors explained most of the variance (70%) but also total suspended matter (TSM) and chlorophyll-a were significantly related to the assemblage composition, although the estimated effects were minor (Redundancy Analysis, RDA). Partial RDA analysis with season and temperature as covariates (to remove seasonal effect) identified TSM and chlorophyll-a as statistically significant variables although the explained variance was low (5.4%) and presented comparatively small environmental gradients (Figure 11).

Conclusions of the Redundancy Analysis (RDA)

For larval assemblages results showed:

- Flatfish larvae dominate in the Spring
- Main predictive variables are Season and Temperature; Seasonal spawning.
- TSM and Chlorophyll may have structuring roles but with very low predictive power
- Species diversity and seasonality best chances for a predictive model

For juvenile flatfish results indicated:

- Assemblages segregate by size groups reflecting seasonal and spatial variability in usage of the nursery
- Main predictive variables are Month, Depth and Salinity; Habitat characteristics
- Larvae abundance (supply of recruits) does not explain abundance of juvenile flatfishes; flatfish assemblages probably controlled by post settlement mechanisms… or is it sampling bias?

For more details reference is made to Rafael Pérez-Domínguez *et al.*, i.e., the two reports and the presentation at the conferences (available from POR).

The study concludes that a seasonal-based model may be a useful baseline reference to describe larval fish assemblages in the area.

SEABED COMPOSITION

The seabed composition in and around the borrow area needed to be monitored. The same applied for the other (reference) areas in the North Sea, as storm conditions could cause the fine sediment fraction (silt) of the seabed to be (re)mobilised and re-suspended in the water column. There is a northward directed net residual tidal current of approximately 1.0-1.5 cm/s along the Dutch Coast.

To facilitate this monitoring aspect the box core samples provided an excellent opportunity as they covered 300 points each year. The benthic infauna was investigated by means of a Reinecke box corer of 32 cm diameter and deadweight of 200 kg (Figure 12).

Once on deck, the water above the sample is carefully siphoned off in order not to disturb the fluffy silty layer on top of the sample. Small tubes are inserted to collect sediment samples to determine the granular distribution of the sediment over the first and second layer of 5 cm thickness. After that the rest of the box core sample is treated as usual – sorted out over a sieve with a one-millimetre mesh to largely remove the sand and clayish material in the sample (Figures 12 and 13).

The sediment samples of three tubes of 1 cm diameter (or one bigger sized one) were stored in small pots and kept on ice (freeze dried). In the laboratory the samples were sieved using a particle size analyser (Malvern). For the coarse sand fraction (> 63 µm), the D50 and other specific characteristics were also assessed (Figure 13).

For each year, 2006 and 2008 thru 2012, the sediment composition of the 300 point is now available. The results are used in the analysis of the benthos (environmental variable parameter) to see if increased silt in the seabed corresponds with changes in benthic communities.

In general a slight increase in the percent (%) of fines around the borrow area has been noticed after the start of the construction works (Figure 14).

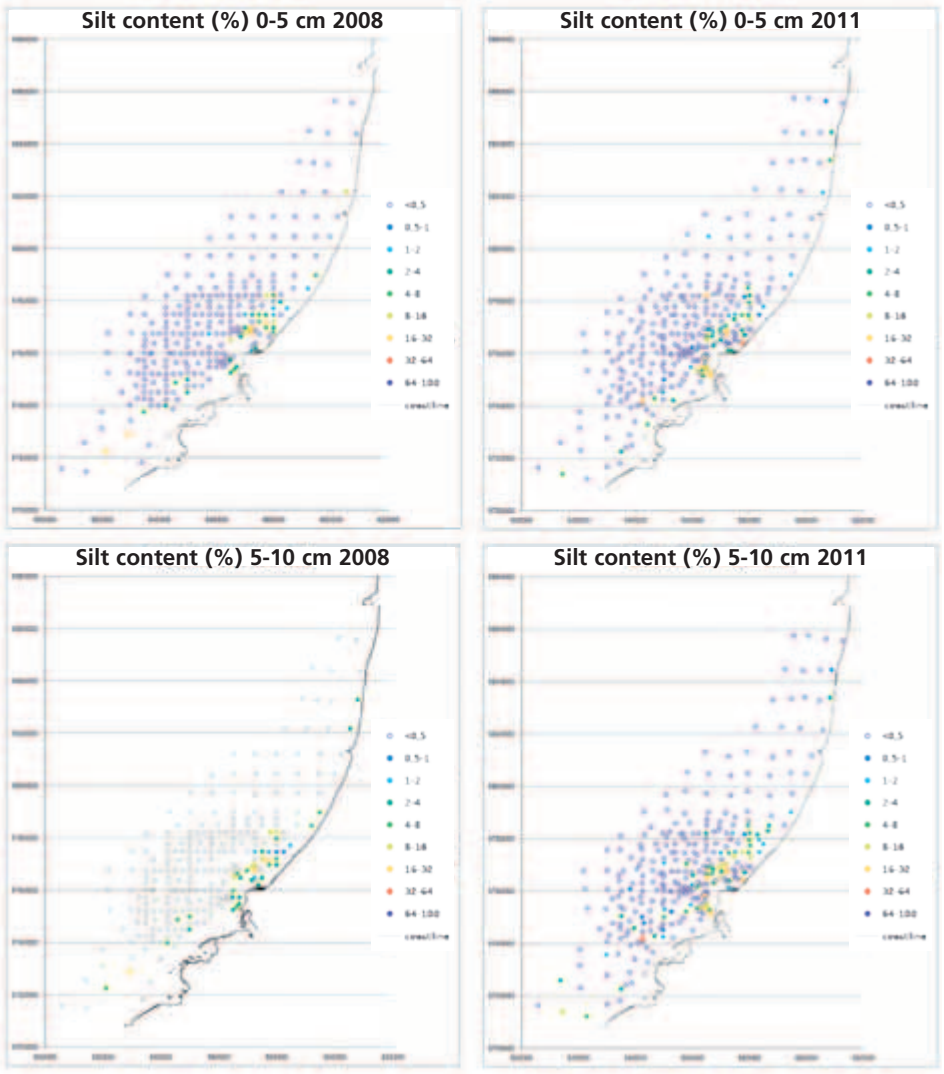

Figure 12. Baseline picture of silt (fine fraction < 63 µm) in the seabed from box core samples from the benthic surveys NIOO (300 locations) from 2008 and 2010 for the whole survey in the 0-5 cm and 5-10 cm layers in the seabed.

Figure 13. Sampling of sediment from box core.

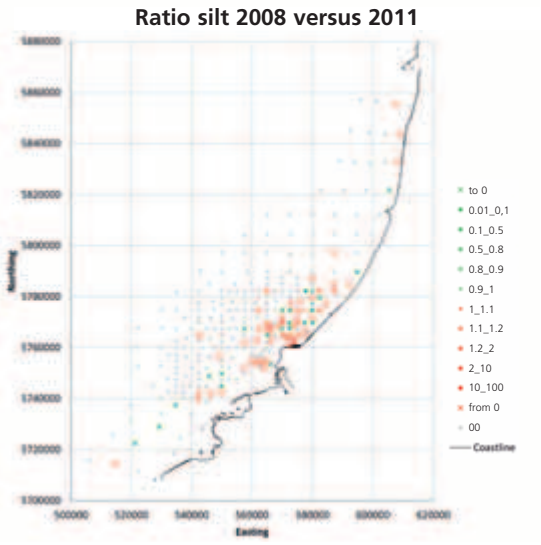

Figure 14. Increase and decrease of silt (fraction < 63 µm) in the top layer of seabed; difference between 2008 and 2011.

MISMATCH BETWEEN HATCHING OF COCKLE LARVAE AND THE ALGAE BLOOM (SPRING PEAK)

The possible effect chain through turbidity has been depicted in Figure 15. The possible mismatch between the spring peak in edible algae bloom and the effect of this on the growth of shellfish larvae and – ultimately – on the availability of food for shellfish-eating ducks, a complex chain of effects is evident. This chain is influenced by a large number of factors, such as water temperature, sunlight, the presence of silt, the ratio between salt and fresh water, and not to forget storms (waves and current action).

Algae (phytoplankton) grow – just like plants – through photosynthesis: They are dependent on the amount of light in the water. Every year, in spring, algae grow rapidly, so that suddenly a large quantity of algae is present in the sea water. This "algal peak" is also referred to as the spring bloom. It occurs because in the spring the sun is in a higher position in the sky and the longer days mean that the water warms up and more light is available for photosynthesis. As a result, algae grow faster. Growth slows down if the nutrients needed by the algae become exhausted. Some of the suspended silt released in the water column during sand extraction is transported by tide, wind, wave and currents to the Voordelta. The Voordelta is the coastal area of the Netherlands in the North Sea, protected under Natura-2000. It is located around the deltas of Haringvliet, Grevelingen, and Oosterschelde, with a total area of about 900 km².

More suspended silt in the water will make the water more turbid (less transluctancy). This reduces the amount of sunlight that can penetrate (deeper) in the water. Increased silt concentrations during sand extraction could conceivably have an effect on the annual spring algal bloom: The algae growth could be reduced and the spring bloom could occur later than normal. For some shellfish larvae, particularly the cockles, this would be bad news: They emerge from their eggs in spring and eat certain (edible) algae to grow.

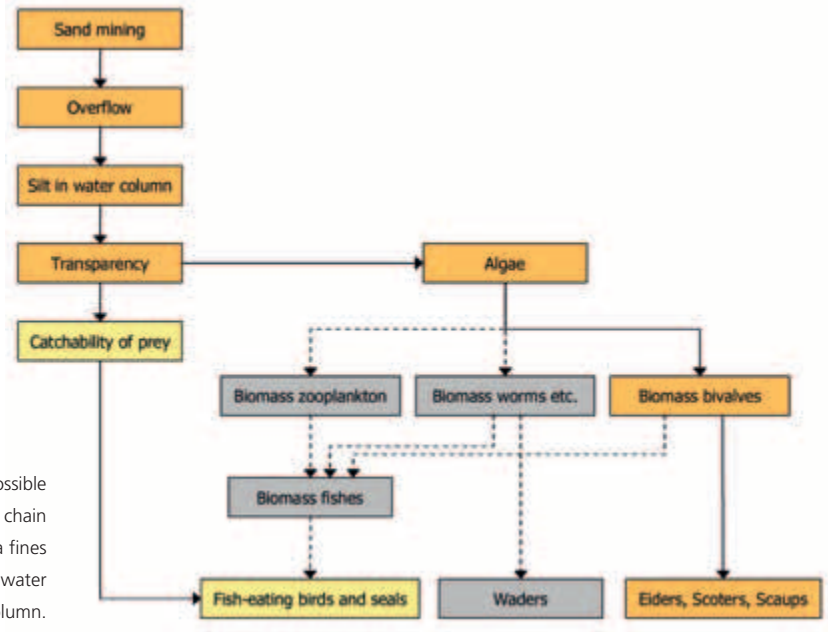

Figure 15. Possible cause-effect chain initiated by extra fines (silt) in the water column.

Under normal conditions, the cockle is the first species of shellfish to spawn, often even before the spring algal bloom. The water temperature is decisive: When the temperature rises above 12˚C, the cockles begin to spawn. The other shellfish species relevant for the study tend to spawn later. For this reason, and because the cockle is an important source of food for diving ducks, the cockle was chosen for the monitoring operation. In spring, cockle larvae float in the water and feed on the part of the hytoplankton that is edible for them; these are algae smaller than 20 µm.

If the spring peak in edible algae were to shift to after the peak in the presence of cockle larvae, this would be a mismatch, because then the two peaks would not coincide. In this situation, there could be too little food for the cockle larvae. As a result, larvae could perhaps die prematurely or be retarded in their growth before they nest on the seabed (spat fall).

If the shellfish larvae do not catch up on this possible retarded growth, the cockles on the seabed remain smaller. This could ultimately lead to less food being available for Eider ducks and Common Scoters *(Melanitta nigra)* which dive to the seabed to feed on shellfish.

A second possible effect of the increased silt concentrations is that the cockles which have settled on the bottom will grow more slowly if there is more silt in the water. Shellfish filter organic material as food from the water. In doing so, they also take in suspended silt. This is not edible and is expelled. If they take in more silt, they digest relatively less food. That could retard their growth. If these cockles have less meat weight, that could lead to a temporary decrease in the amount of food available for shellfish-eating ducks in the Voordelta because this area is the foraging area for Eider ducks and Common Scoters in autumn and winter.

Chain effects

This complicated sequence of effects begins with the water becoming more turbid because the silt concentration is too high. Hence all the work that went into the Environmental Impact Assessment (EIA) was to chart, with the aid of models, the pattern via which the silt released by the sand extraction could be distributed through the sea water.

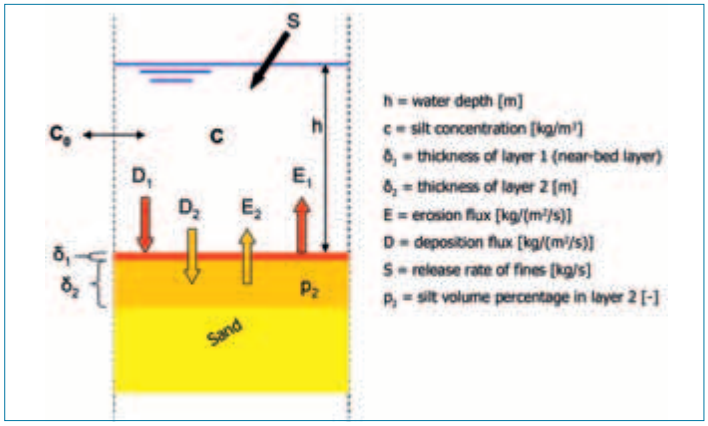

Figure 16. Water-seabed exchange model.

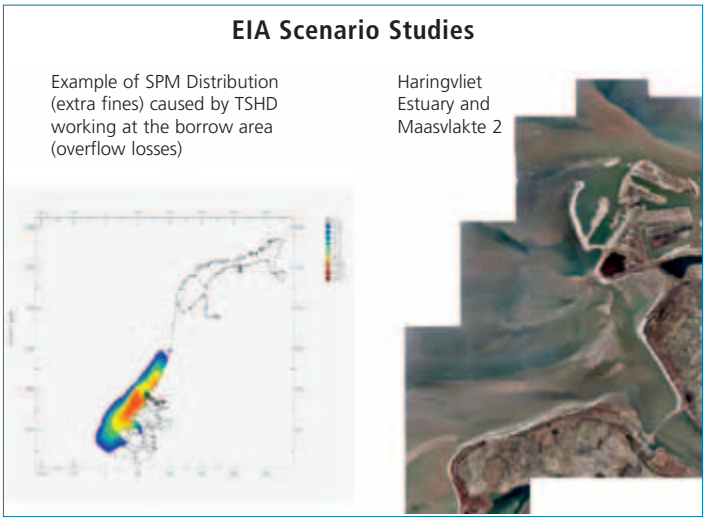

Figure 17. Example of one of the scenario computations (snapshot in time) and the Haringvliet Estuary during construction.

The EIA is based on the maximum increase in silt concentration in the worst-case scenario. The extensive monitoring programme for the silt survey, in which numerical models are also used, provided new insights into the distribution pattern of the silt released. The water-seabed exchange is amongst one of the new developments that was further explored as a result of the MV2 EIA and is now one of the "normal" tools (Figure 16).

As explained in the foregoing in EIA, temporary negative effects on the food stocks for shellfish-eating ducks were predicted on the basis of worst-case scenarios (Figure 17). This worst-case effect could have supposedly occurred in the spring of 2010 during bad weather conditions – which would naturally result in more silt in the water column – and this coincided with a large amount of sand being extracted. The increased silt concentration in the Voordelta could then rise so much during the sand extraction that the spring peak in algae concentration would occur two weeks later. This could therefore lead to a mismatch between the presence of high algae concentrations and shellfish larvae and that could ultimately mean fewer or smaller cockles being available for the shellfish-eating ducks.

It was implicitly assumed here, on the basis of available literature that shellfish (cockles) only spawn once a year – in spring. Another starting point was that shellfish (cockles), once they have suffered retarded growth, no longer catch up later in the year; supposedly, they continue to have lower biomass, leading to reduced food stocks for the shellfish-eating ducks in this area.

The monitoring of the mismatch was initially thought to be based on data from the existing measuring programmes used by RWS and the measurement data from the satellite images made from space of the North Sea (remote sensing). By using remote sensing, the algae growth can be monitored and the time of the bloom – the spring peak – can be determined.

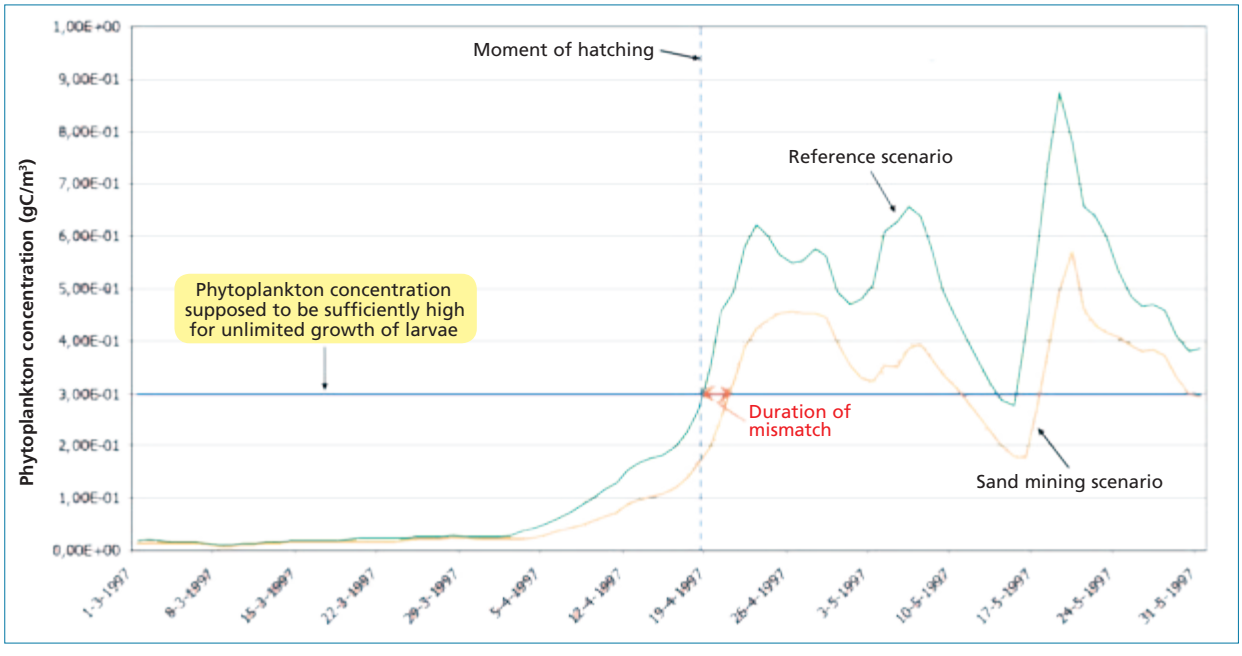

Figure 18. Mismatch depicted graphically.

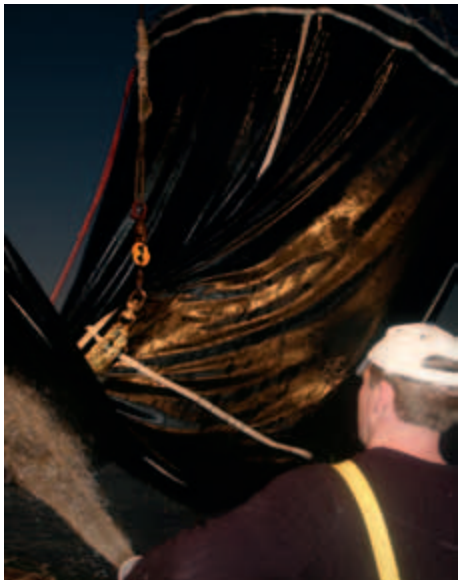

Figure 19. Clogged plankton net with Phaeocystis (working at night).

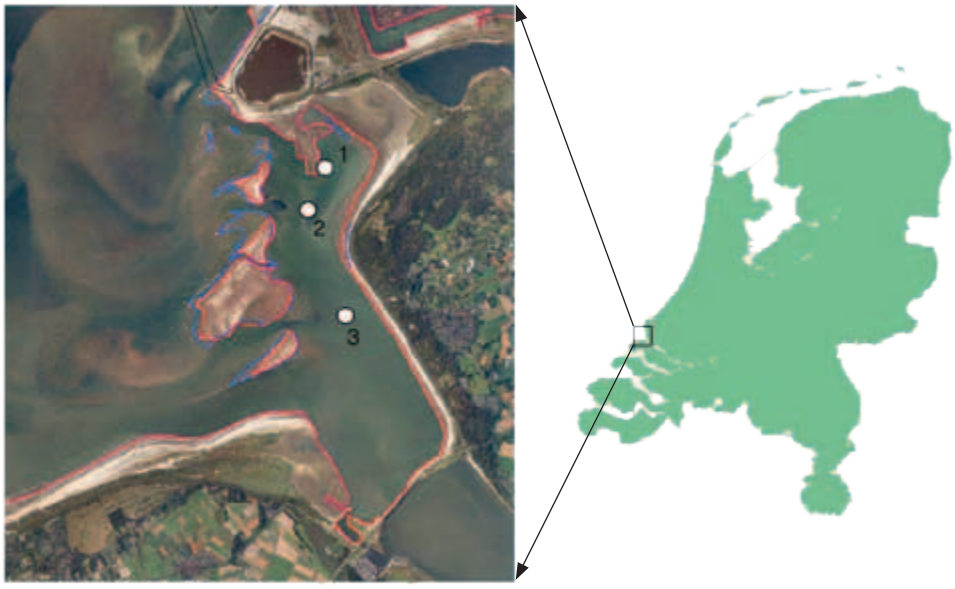

Figure 20. Haringvliet Estuary with sampling locations (1, 2, 3) for cockles.

Soon however this originally proposed measuring method was abandoned. During the spring bloom visible in the remote sensing data, the algae community consists mainly of colonies of the algae Phaeocystis.

During the juvenile fish survey a plankton net was drawn though the water at half the water depth. This very fine mesh net repeatedly was completely clogged in April 2007 survey when a Phaeocystis bloom occurred (Figure 19).

This made it clear that these particular algae are not edible for shellfish larvae in this form, owing to their size (colonies with a diameter of approximately 2 millimetres), as the shellfish larvae themselves only measure about 100-250 micrometres and their mouths are a maximum 20 µm. Determining the spring algal bloom from the remote sensing observations would therefore not give a good indication of the availability of food for shellfish larvae.

A new monitoring (and research) programme was set up based on water sampling in the Haringvliet Estuary (Figure 20). The conclusion was that the amount of food (algae) available and the quantity and size of the cockle larvae could only be determined by microscopic analysis of water samples. Also, samples of 0-year-old shellfish at various places on the seabed in order to determine the possible retarded growth were necessary. In order to gain an understanding of the possible impact on the effect chain described, water samples were taken with a high frequency at fixed points in the Haringvliet Estuary in 2009 and 2010, from the start of the growth season (spring) until into the early summer. The purpose was to determine the development of algae in combination with the development and growth of cockle larvae and their ensuing settlement on the seabed (spat fall).

Parallel to setting up the field study a TUD student (Y. van Kruchten) carried out a model study for the Port as her Master thesis. The purpose of this was to calculate, using what was known at the time, the chance of significant retarded growth occurring amongst shellfish larvae given different temperature and turbidity scenarios. The chance proved to be extremely small. The insights gained via this study were used to further streamline the planned field study.

Samples of algae, cockle larvae and cockles

In the spring of 2009 (baseline measurement) and the spring of 2010 (peak in sand extraction, April-June), water samples started to be taken just before the first larvae appeared. This was done at three locations off the coast of Voorne (in the Haringvliet Estuary) as soon as the water temperature reached about 12°C. As a mismatch of a few days could already have measurable consequences for the larvae, measurements were taken very frequently. Twice a week, samples were taken from the water column using a water sampler. The samples were always collected during the same tidal phase.

The shellfish larvae present were then filtered from the water via the sieve of plankton net.

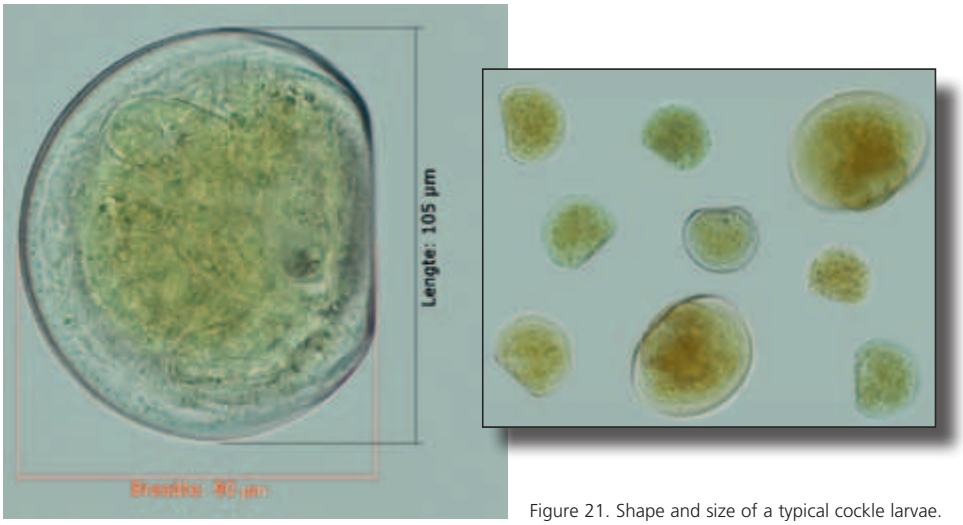

Figure 21. Shape and size of a typical cockle larvae.

Figure 22. Laboratory work on samples during determination of cockle larvae and algae.

A second sample was taken and preserved so that the phytoplankton in it could settle.

In the laboratory, the following were ascertained using a microscope:

- Density, size and species composition of the algae. Per shape and size, the number of cells was converted into biomass.
- Density and size of the cockle larvae. Their speed of growth was determined from the length of the larvae. At the same time, a number of physio-chemical parameters were measured, such as the water temperature and the conductivity (salinity) of the water in the Haringvliet Estuary. Please note that fresh water is discharged from the Haringvliet if the Rhine discharge becomes (too) high (redistribution of water).

These studies were carried out by ecological consultancy and research firm Koeman and Bijkerk and closely supervised by the POR experts. The samples were taken by ATKB (soil, water and ecology consultants) (Figure 22).

During the measurements, it came to light that an important assumption of the environmental impact assessment was incorrect. When determining the length of the larvae, it transpired that cockles did not spawn once per growth season, but several times. New cockle larvae kept appearing in the water in approximately weekly waves (cohorts). In the measurements, that was visible as the sudden appearance of large numbers of small larvae and the disappearance of the larger larvae, which had sunk to the bottom to settle there (spat fall).

By combining data from literature on the filtering and assimilation capacity of shellfish larvae with the research results, a comparison was made between the energy needs of the shellfish larvae and the amount of energy available in the edible algae fraction.

In the summer and autumn of 2009 and 2010, cockle spawn was sought on the mud flats of Voorne. To do this, the top layer of the ground (about 5 centimetres) was scraped away during low tide using a scoop. The shellfish present were sieved out. The age, shell length and biomass (fresh weight and ash-free dry weight) of these shellfish were determined. This study was carried out by the NIOO-CEME and the experts from the Port. In 2009, this study produced no results because hardly any 0-year-old shellfish were

Figure 23. Field survey to collect 0-year-old cockles in October 2010.

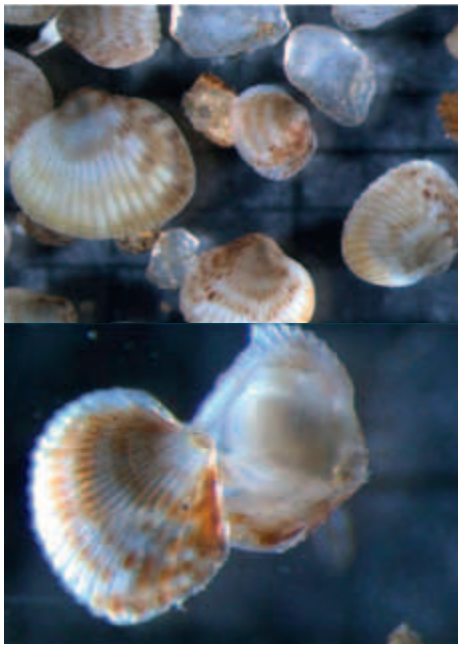

Figure 24. Photos of 0-year-old cockles from the October survey 2010.

found in the seabed. Studies were conducted again on July 15 and October 28, 2010 (Figure 23). Cockle spawn was found this time, including some cockles from the year before.

Conclusions with respect to a possible mismatch

In the period during which the effects of the sand extraction operations for MV2 would supposedly be the greatest, no mismatch occurred between the spring bloom of edible algae and the presence of shellfish larvae. The peak in the density of the edible algae fraction coincided with the appearance of the shellfish larvae (2009) or preceded it slightly (2010). In both years, the shellfish larvae did not therefore miss the algal peak, considering the fact that they were already there before the algae volume was at its highest.

The study also revealed that a mismatch cannot occur, because the cockles produce several cohorts of larvae. Cockles therefore spread the risk: At least one group of larvae is always growing under sufficiently favourable conditions. This can also be seen from the 0-year-old cockles in the Haringvliet Estuary, which reached normal size in the autumn and winter of 2010 (Figure 24). It becomes apparent from analysis of the algae composition, from the estimated amount of food ingested (from literature and the energy model) and the estimated energy needs of shellfish larvae (literature), that sufficient food was available in the water for the shellfish larvae in both 2009 and 2010. The energy needs for maximum growth were definitely not always achieved, but this is far from uncommon in natural systems. In 2009, hardly any shellfish were found on the seabed. This was presumably because the shells on the bottom had been crushed during spring storms of high intensity.

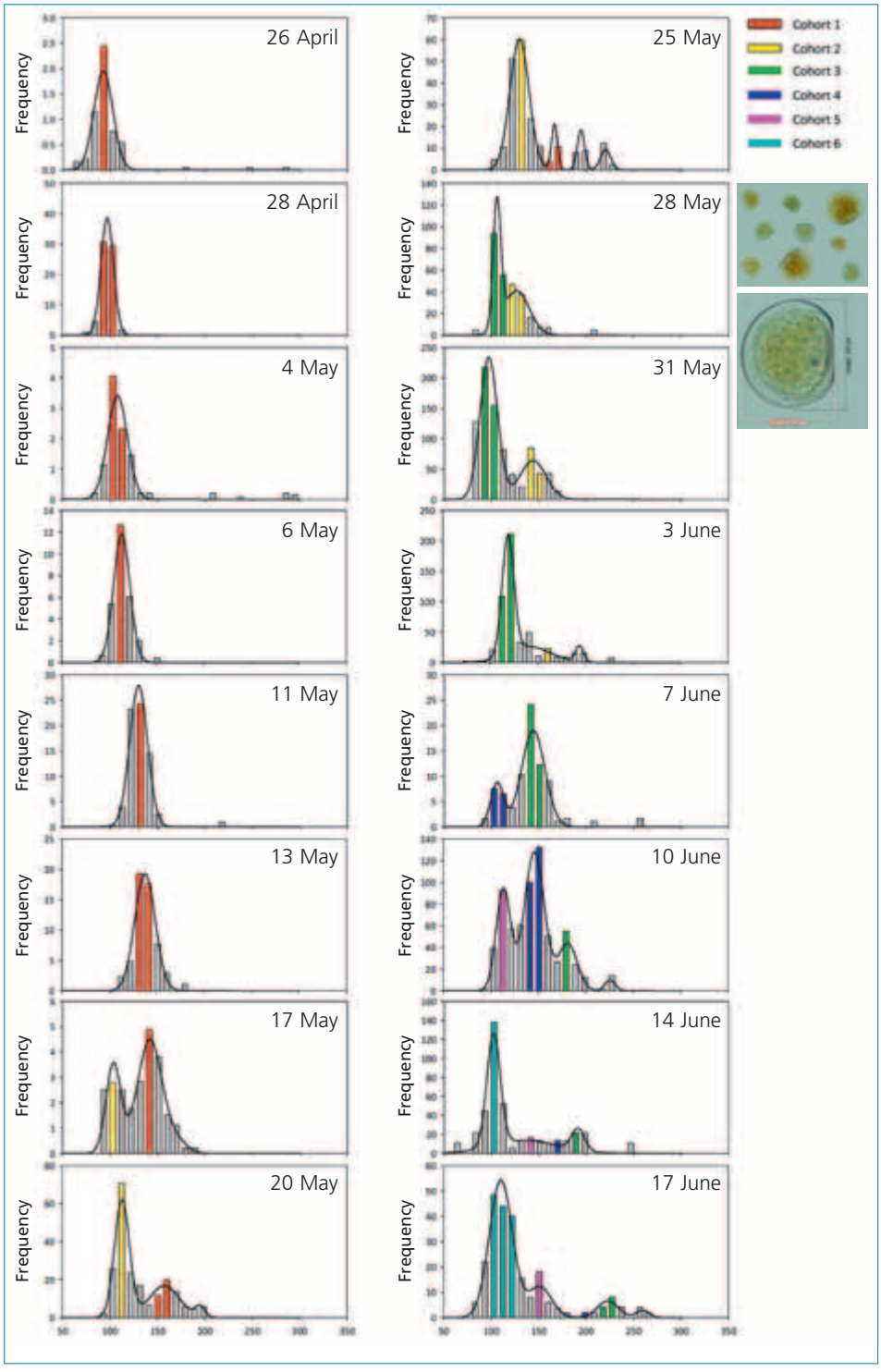

Figure 25. Distinguished cohort of cockle larvae as observed in the 2010 survey.

The length of the 0-year-old cockles from 2010 does not differ from that of other years. The length-frequency distributions from various years reveal considerable variation and show that the 2010 values fall completely within the natural variation and range.

In 2010, therefore, no effects of the sand extraction on the size of the cockles can be ascertained. This means that there is also no reason to suppose that the shellfish-eating ducks would not have enough food in the autumn and winter to come (Figure 25).

New knowledge
The studies indicate that cockles spawn several times per season. In 2009, at least two cohorts could be identified and in 2010 there were six. In 2010, the first cohort was present on the first sample date (April 26) and the last two cohorts on June 10 and June 14 respectively. Cockles are apparently insensitive to when the spring bloom occurs.

This data is confirmed by the shellfish studies done in the past. In the Haringvliet Estuary, two or more peaks in 0-year-old cockles were measured on several occasions.

Also, the natural variation in the Haringvliet is great and changeable conditions in terms of weather (wind), temperature and the ratio of fresh and salt water are not unusual. It probably does not matter too much to cockles when the greatest quantity of edible algae are available (spring peak in algae), because several cohorts are present each year.

CONCLUSIONS

Maasvlakte 2 is the Port of Rotterdam Authority's port extension project west of the existing Maasvlakte. The project area is 2,000 hectare gross of which 1,000 hectare is the net infrastructure. The first phase of the project will be finished mid-2013. To date the project is on schedule and within budget.

In this article four elements were discussed: The monitoring requirements and general set-up for the project have been defined; the baseline measurements for juvenile fish – which were established in 2007 – were evaluated; and the seabed composition, sieve analysis and the silt component therein. In addition, the potential mismatch between hatching of cockle larvae and the algae bloom in relation to the spring peak was examined.

In the set-up of the EIA Construction MV2, all the effects of a deep excavation were investigated, e.g., environmental impact overall, stability of slopes, coastal defence, stagnant (anaerobe) water, benthic communities, fishing activities and so forth. In general only effects, although small, that cannot be neglected or are potentially significant require monitoring. Effect analysis was based on the BACI (Before-After–Control-Impact) assessment.

In the permits and later on when the final MEP / MP was available, the effect on juvenile fish was considered negligible and difficult to prove owing to the variability of the North Sea ecosystem. Hence POR was not obligated to continue monitoring juvenile fish.

Regarding seabed composition, in general a slight increase in the percent (%) of fines around the borrow area has been noticed.

And finally, in the period during which the effects of the sand extraction operations for MV2 would supposedly be the greatest, no mismatch occurred between the spring bloom of edible algae and the presence of shellfish larvae.

In subsequent article(s) other topics mentioned at the start of this article – which also fall under the EIA monitoring and the MP – will be presented. Some of these are still ongoing and are needed in order to ensure a complete evaluation of the possible effects of the dredging operations and to ascertain compliance with the permit conditions.

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