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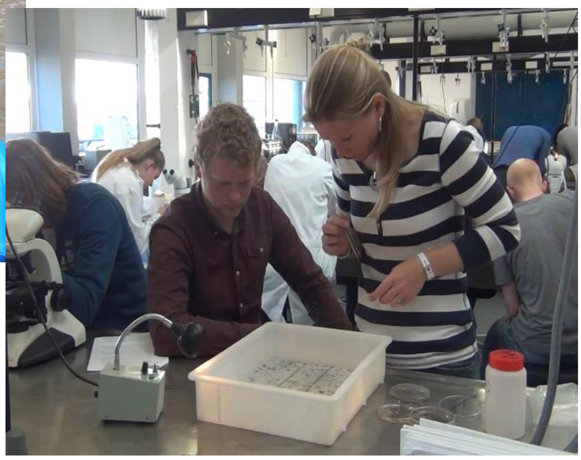
The Benthos Module

Educational module developed within the
Oesterdam project



CENTRE OF EXPERTISE DELTA TECHNOLOGY
AUGUST 2017

The Benthos Module

DEVELOPING EDUCATION WITHIN THE OESTERDAM PROJECT

CENTRE OF EXPERTISE DELTA TECHNOLOGY
AUGUST 2017

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DATE	LOCATION	VERSION AND STATUS
August 2016	Vlissingen	Final

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1 INTRODUCTION

The Oesterdam project was provided with a financial contribution of the Ministry of Education within the framework of the Centre of Expertise Delta Technology. One of the main objectives of this projects was to enhance the quality of education by providing a real case study for students and give teachers/researchers an opportunity to develop their research skills.

This project provided an excellent case study for students to work on, in total 28 student projects were realized from a 2nd year level to Master level. Furthermore a course module was developed by HZ-staff which provided large groups of students (≈250; see Appendix 1) an opportunity to study an applied coastal adaptation strategy focusing on safety and ecological restoration. This hands-on approach, and being involved with a real world project provided the students with valuable experiences that will prepare them for a future in water management.

The *Building with Nature* approach is closely related to Ecological Engineering approaches. The courses Ecological Engineering and Coastal Engineering are the most obvious ones for integrating *Building with Nature* themes within the educational programmes of the Delta Academy.

Within the course Ecological Engineering, the research group offers the 'Benthos module', within the framework of the Oesterdam project (see picture in **Error! Reference source not found.**). This Module was first offered to students in 2012, prior to the start of the Oesterdam project and the construction of the sand nourishment. The module was developed further and offered each year to the second year AET (Aquatic Ecotechnology) and civil engineering students.

The benthos module combined traditional methods of knowledge acquisition in lessons; practical, hands on experience in the field; laboratory methods that required the students to think critically, take initiative and work precisely; an independent literature research assignment to encourage students to gather existing knowledge; and verification and application of the work done through feedback. In total over four years, 134 Aquatic Eco-technology, and 118 Civil Engineering students took part in the Benthos module (See Appendix 4).

Furthermore, the benthos module was developed into a SPOC (Small Private Online Course) where students can access information and instructions related to the module. The SPOC includes seven weblectures by Tom Ysebaert, refresher information (for example, of the basics of taxonomy) and assignments. This SPOC is intended to be further developed and applied in module 8 of the new Water Management curriculum; Ecological Engineering.

This report includes various documents and resources used for the Benthos Module during the project and the plans for further development after the project has finished.

2 BENTHOS SAMPLING AND SEDIMENT ANALYSES

The Benthos module focussed on the benthic community in the soft sediment and the movement of sediment from the sand nourishment. The Oesterdam sand nourishment and the artificial oyster reefs are not only meant for coastal protection, but also for increasing nature values and increasing feeding opportunities for birds.

Sampling and analyses of benthos by students provides an indication of the development and recovery of the benthic community after the nourishment. The first sampling took place in 2011 -12, before the nourishment. The second sampling took place shortly after the nourishment, in December 2013, and the third and fourth sampling took place in spring 2014, 2015, 2016 and 2017, respectively. The second sampling was carried out within the framework of the course Water Systems Analysis, and the samplings thereafter within the framework of the course Ecological Engineering. Laboratory analyses of the samples and discussing the results only took place within the course Ecological Engineering.

The research questions for the students were: What is the relationship between presence, abundance and distribution of benthic fauna and substrate? And, how is the community developing?

Sampling and laboratory analyses were done by students, but results have been processed by researchers. This also includes a control on the benthos identification by a specialist. Therefore, researchers reported to students and not the other way around. The learning objective here is familiarizing students with steps taken in processing large data sets, as well as showing different ways of expressing “biodiversity”.

In all sampling campaigns students took more samples than they analysed themselves. The other samples went to IMARES to analyses. A sediment sample was taken for each benthos sampling point, for analysis on grain size and fraction of organic matter.

The benthos module consisted of :

- Three introduction lectures (morphology, ecology and intro on the sampling methods)
- One day of field work
- Two days of laboratory work
- Lecture in which the results are presented and discussed.
- Assignment for student groups

All parts of the module were organised and supervised by researchers from the Delta Academy who were involved in the Oesterdam project.

3 RESEARCHERS

The introduction of the project and the background information necessary to understand and take part in the module was given prior to the field work in the form of guest lectures and background information built into the existing Aquatic Ecology course. Guest lecturers varied between years but were always experts either from the HZ or external to the Delta Academy, but who were involved in the Oesterdam project (see **Error! Reference source not found.**).

The Fieldwork was coordinated by a HZ researcher and each group of students was supervised by HZ researchers or higher level students. The laboratory work was supervised by HZ researchers including a specialist in species identification and a specialist in sediment composition.

Following the practical work the data was gathered, organised and analysed before a feedback lesson in which the students learned the basics of what to do with large datasets and how to make choices in data analysis. During the feedback lesson students were also required to present their literature research of a specific benthic organism.

Table 1. Cronological list of events during the Benthos Module (exact dates varied between years).

Event type	**Title**	**Researchers involved**
Guest lecture	The Sand Hunger Problem; Sand Nourishments in the Eastern Scheldt, general concepts of morphology.	Matthijs Boersema (HZ) Eric van Zanten (RWS) Mindert de Vries (Deltares)
Lesson	Introduction to the fieldwork. Instruction film	Joao Paiva (HZ) Jan van der Vleuten (HZ) Anneke van den Brink (HZ)
Guest Lecture	The importance of Benthos; relationship with inundation time and birds in the intertidal zone of the Eastern Scheldt. Monitoring: why and what to do with the results, the situation last year.	Tom Ysebaert (WMR)
Lecture in Aquatic Ecology course	Community ecology: predation, competition and birds as indicator species	Tim van Oijen (HZ)
Fieldwork	Benthic and sediment samples taken at the Oesterdam	Jan van der Vleuten; Joao Paiva, Tim van Oijen; Eva Hartog; Carla Pesch; Anneke van den Brink; Matthijs Boersema; Edwin Paree; and various higher level students (HZ)
Lab work	Sorting and identifying benthic organisms from the samples taken in the field	Eva Hartog (HZ) Anneke van den Brink (HZ)
Lab work	Sorting, sieving and analyzing the sediment samples taken in the field	Joao Paiva (HZ)
Lesson	What to do with large datasets; feedback of data analysis; what is biodiversity? Student presentations of literature research	Jan van der Vleuten (HZ) Anneke van den Brink (HZ)

4 THE MODULE

The module began with three preparatory lessons, including guest lectures and instruction films. During the introduction lessons students were provided with a manual explaining the activities in detail (see **Error! Reference source not found.**). They were also shown an instruction film about how to take the samples.

The lessons were followed by a day of fieldwork at the Oesterdam where sediment samples were taken in various locations on and around the sand nourishment. During the field work the students worked in groups of 4-6 and took turns conducting each necessary task including using the gps, using a quadrat, digging, using the benthic core, collecting samples into sample containers and recording data on a field sheet (Figure 1 and see Appendix 3).

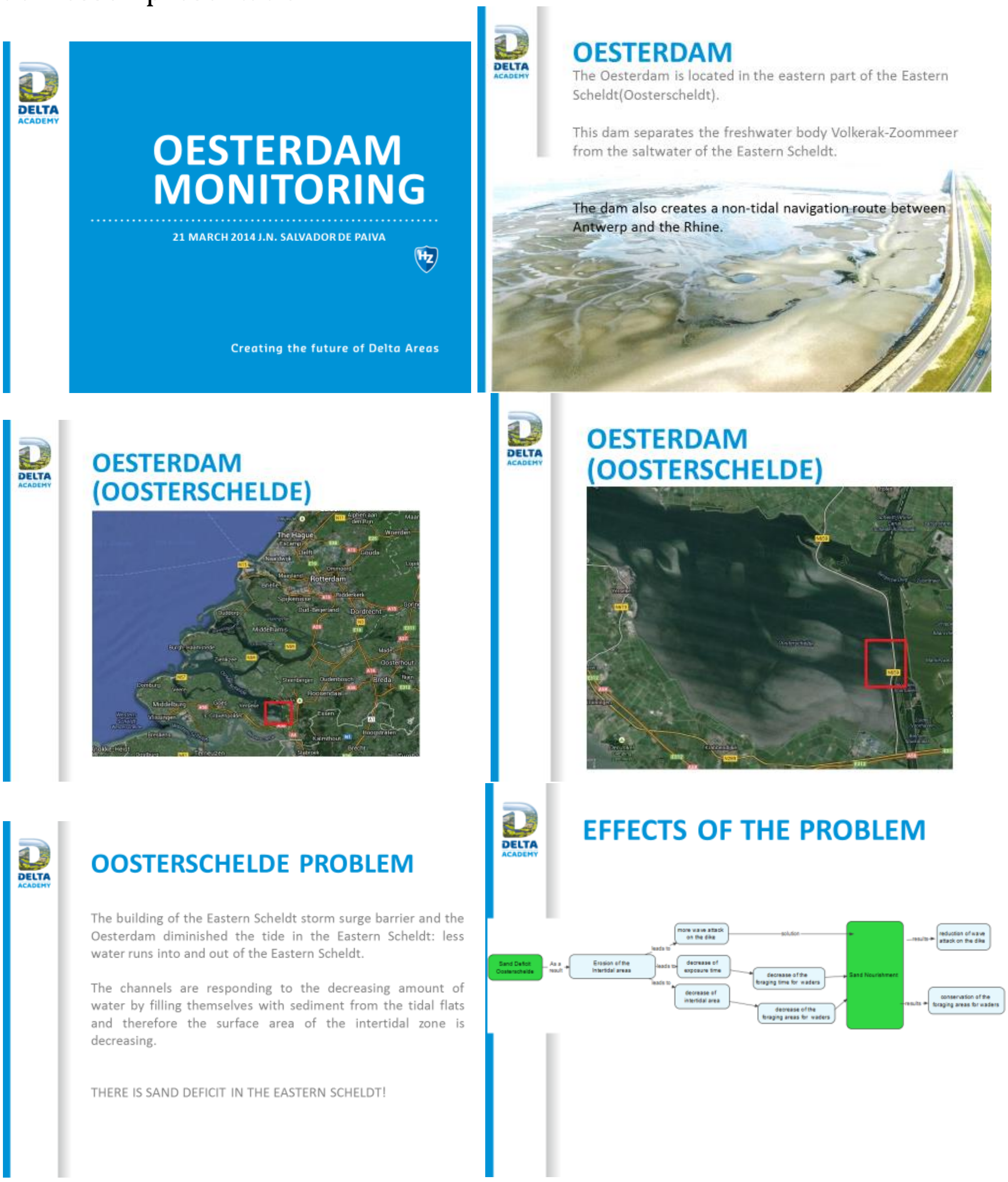
The samples taken during the fieldwork were then analysed by students for the benthic biota and the sediment grain sizes in the lab over two days under the supervision of in-house experts. In lab students worked in pairs to wash the benthic samples sort through each sample, remove all organisms, use species identification keys to identify them and record the data on a lab sheet (Figure 2 and see

Appendix 4). Students were required to use laboratory equipment such as sediment sieves and scales, as well as species identification keys. The identification of organisms was then checked by Eva Hartog before the data was given to Anneke van den Brink for further analysis. The sediment samples were dried sieved and weighed before the data was given to Joao Paiva for further analysis.

Once the data had been analysed Joao Paiva and Anneke van den Brink presented the results to the students in the feedback lesson (Appendix 5 and Appendix 7). This lesson introduced the students to appropriate ways to organising and analysing large data sets, as well as presenting the results of their work compared with the results of previous years. A film that had been shot during the practical work and later edited was also shown to the students as a reminder of the work they had done.

During the feedback lesson the students were also required to present their literature research of one common species found during the practical work in a Powerpoint presentation. The students were asked to investigate the life history and habitat preferences of their assigned species (see Appendix 6

Example of sediement SAMPLING data presented to the students during the feedback lesson presentation.



CONSEQUENCES TO THE OESTERDAM

Due to the erosion of the tidal flats in the intertidal zone, there is less wave dampening, and therefore increasing pressure on the dikes.

Moreover, the decreasing size of the intertidal area is unfavorable for birds, which forage on the tidal flats.

NATURA 2000

SAND NOURSHIMENT AT THE OESTERDAM

The Dam did not pass the 5-yearly (now 6-yearly) safety assessment. Therefore, the revetments were adjusted, along the whole dike.

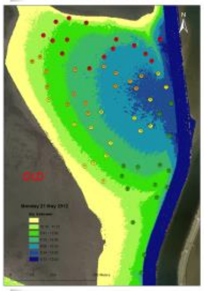
The solution also included a Sand Nourishment

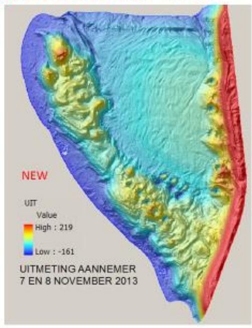
SAND NOURISHMENT

The beaches and dunes of the sandy Dutch coast protect the hinterland from flooding. Sand nourishment allows natural processes to maintain this sandy coast and 'dynamically' keep it in place.

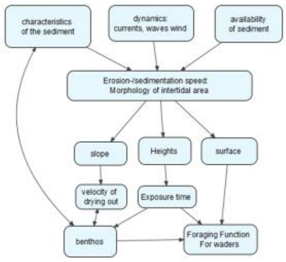
The sand for nourishment is dredged from deep waters (below the 20-metre depth contours). Water and wind distribute this sand naturally along the beach and across the dunes

SAND NOURSHIMENT AT THE OESTERDAM





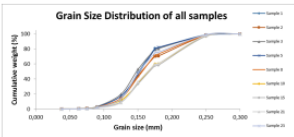
SAND NOURSHIMENT AT THE OESTERDAM



SEDIMENT ANALYSIS

SEDIMENT: ANALYZING

- Organic Material
  - $Organic\ Material\ Content = \frac{Dry\ weight - Ash\ weight}{Dry\ weight} \times 100\%$
- Sediment Grain Size
  - $\%\ of\ sediment\ retained = \frac{Weight\ of\ sediment\ remained\ on\ sieve}{Total\ weight\ of\ sediment\ used\ for\ sieving} \times 100\%$



- Median Grain Size (D50)

ORGANIC CONTENT

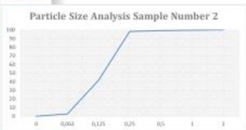
On the tidal flat:

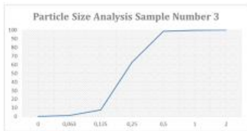
Sample	Organic content [g]	Organic Content %	min (%)	max (%)	Average (%)
SP2	0,32	1,55	0,24	1,55	0,63
SP3	0,07	0,24			
SP19	0,20	0,75			
SP23	0,06	0,66			
SP26	0,18	0,38			
SP52	0,08	0,26			
SP56	0,11	0,56			

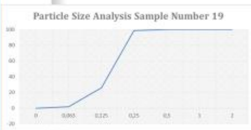
On the Nourishment:

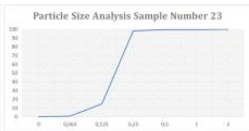
Sample	Organic content [g]	Organic Content %	min (%)	max (%)	Average (%)
SP4	0,03	0,24	0,04	0,39	0,24
SP6	0,04	0,20			
SP7	0,06	0,38			
SP9	0,01	0,04			
SP17	0,06	0,39			
SP18	0,07	0,33			
SP22	0,07	0,14			
SP32	0,03	0,13			
SP25	0,13	0,39			
SP27	0,04	0,12			

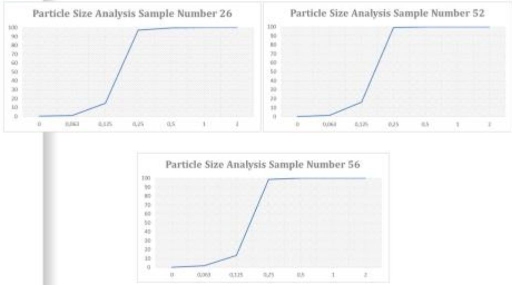
PARTICLE SIZE ANALYSIS: TIDAL FLAT



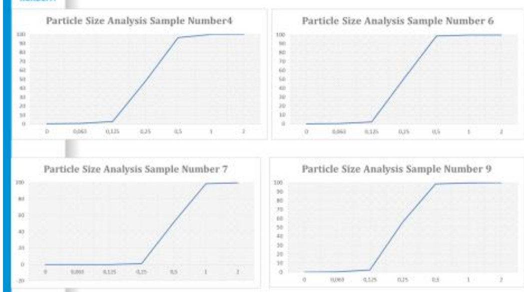


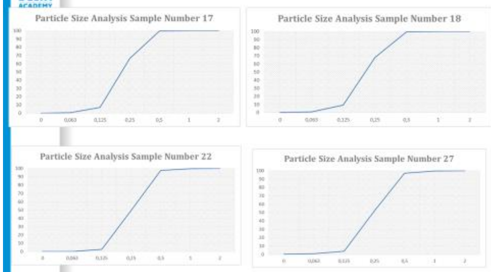


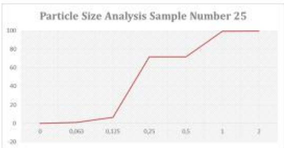




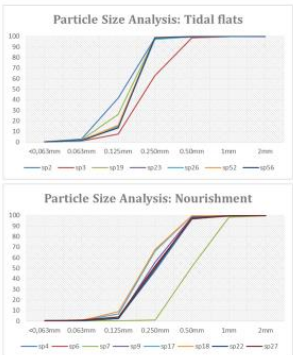
PARTICLE SIZE ANALYSIS: NOURISHMENT

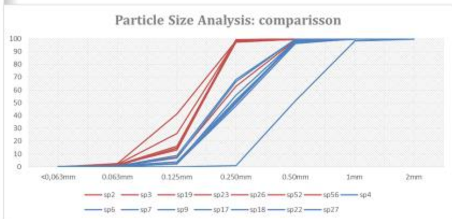






PARTICLE SIZE ANALYSIS: COMPARISSON BETWEEN THE TWO SITUATIONS





Appendix 7Appendix 5). During this assignment the students learned how the specific biology of different organisms can influence how and why they live at the Oesterdam, what influences their distribution and what effect the sand nourishment could have on their population. In this way the students made connection between different biological scales and how the sand nourishment can influence the biota on many levels.

The benthos module was worth 2.5 study credits for the student. This is approximately 28 hours work within the Ecological Engineering course. The assessment for this module comprised of the group literature assignment presented in the feedback lesson, as well as part of the exam for the course.

Figure 1 Selection of stills from one of the films of the students in the field during the Benthos Module.

Figure 2 Selection of stills from one of the films made of the students during the lab work

5 FURTHER DEVELOPMENTS OF THE MODULE

Because the Oesterdam project has come to an end and the curriculum of the water management course at the HZ has been rebuilt, the Benthos Module was rebuilt into a new course independent of the project by Carla Pesch.

The module will be offered as a SPOC (Small Private Online Course) in the last quarter of the second year (Module 8) in the Ecological Engineering course.

The SPOC includes seven weblectures by Tom Ysebaert, refresher information (for example, of the basics of taxonomy) and assignments. This SPOC is intended to be further developed and applied in module 8 of the new Water Management curriculum; Ecological Engineering.

Students can access the information and weblectures via the educational resource platform LEARN. Assignments are also given via LEARN in the form of literature research assignments as well as online debates (see Appendix 8) .

6 APPENDICES

6.1 APPENDIX 1. STUDENT NAMES FROM THE AQUATIC ECO-TECHNOLOGY COURSE ECOLOGICAL ENGINEERING WHO TOOK PART IN THE 'BENTHOS MODULE'

2013/14	**2014/15**	**2015/16**	**2016/17**
Dijk, Laurens van	Al-Nabhani, Alya	Allard, Silvan	Abbenis, Serena
Gerull, Nadja	Alvarez Luckow, Cristian	An, Yingjie	Avontuur, Stan
Goethem, Thomas van	Barker, Ross	Baars, Joshu van	Bakker, Lisa
Gremmen, Thomas	Coomans, Dirk	Bastiaansen, Tom	Benaduce Ortiz, Beatriz
Hahn, Levi	Dekker, Dennis	Bijkerk, Ella	Bergen, Michael van
Hankinson, Paul	Drenth, Pim	Boer, Xander de	Boer, Eva den
Hoenjet, Nieke	Eijkelhof, Yoeri	dos Reis, Hélen	Bonné, Yves
Hu, Tianyi	Goorden, Irene	Deitelzweig Senior, Patrick	Bortoluzzi, Pietro
Janse, Benno	Hoeder, Mike	Djojodimedjo, Andrew	Breunesse, Sara
Jeworrek, Anna	Jansen, Kas	Dong, Linyinxue	Chen, Ruby
Leuchter, Lennet	Kablau, Chico	Feng, Chanyan	Duan, Ashley
Malawauw, Rémon	Kemink, Sjoerd	Filutás, Filu	Dubbeldam, Mathijs
Mustalahti, Vesa	Koeijer, Kevin de	Gillissen, Lasse	Duren, Lars van
Pranger, Anton	Kort, Sven	Goethem, Thomas van	Elliot, Lauren
Schraaf, Maurits van der	Martens, Mireille	Gu, Yifei	Favier, Lucas
Vries, Anne de	Meerman, Chris	Guijt, Willem	Gonguet, Gabriel
	Pool, Jesse van der	Heijden, Luuk van der	Hoexum, Maeike
	Rommens, Johnny	Hogeweg, Micha	Huitema, Max
	Rooij, Ger de	Kampen, Luuk van	Huizer, Mikayla
	Scholtens, Sam	Keur, Martijn	Jin, Yujin
	Schreur, Bo	Kloet, Jonas	Jong, Loes de
	Sisselaar, Samuel	Kraa, Axel de	Kauhl, Luc
	Solé, Liliane	Leeuwen, Mark van	Koeijer, Phiel de
	Tange, Sjaak	Leijs, Thomas	Kooiman, Maurice
	Verbeeke, Gabrielle	Maljaars, Thijs	Krielen, Rein
	Visschedijk, Niek	Oosse, Sem	Lambregts, Kayleigh
	Vliet, Marjolein van	Oosterwal, Sake	Leeuwen, Dorian van
	Wokke, Menno	Peng, Tian	Mast, Ivory
	Zijlstra, Iris	Poppe, Wilco	Nolte, Dana
		Ruijs, Nijs	Parasirisakun, Ronnaklit
		Schaier, Sylvester	Peene, Kristof
		Smits, Nadine	Phuwarueangrat, Nopphakrit
		Spaans, Hedzer	Pompoes, Richard
		Speelman, Elias	Pons, Charlotte
		Stouten, Marijn	Portier, Joey
		Tanis, Remko	Rosien, Jean-Luc
		Vega Garre, Beatriz	Sande, Joris van der
		Wagenaar, Niels	Schaap, Daniel
		Wang, Jiaqi	Temmerman, Ymke
			Teng, Sean
			Thewissen, Tim
			Tran, Phat quang
			Truong, Uyen hai
			Vlieger, Owen de
			Wahl, Marie
			Wens, Justin

			Witte, Bart de
			Zhang, Chi
			Zhang, Seven
			Zhao, Randy

Student names from the Civil Engineering course Coastal Engineering who took part in the 'Benthos Module'.

2013/14	2014/15	2015/16	2016/17
Švežika, July	Bielskus, Andrius	Belzen, Dieko van	Bödges, Scott
Abrawi, Shafa al	Gorsel, Jan van	Calbo, Ian	Breda, Lars van
Ahmed Nabil Mohamed, Ahmed	Halley, Matthew	Heeren, Dennis van	De Neef, Michaël
Bijvank, Robert	Jastrumskis, Gediminas	Janse, Jurgen	Dingemanse, Dennis
Gheorghe, Teodor	Johnson, Mattaniah	Lauret, Niek	Eshuis, Olivier
Janga, Denzel	Meskenaite, Viktorija	Nieuwpoort, Bas	Grinwis, Lars
Meijer, Anthony	Nieuwenhuizen, Christian van	Noteboom, Ramon	Houte, Thijs van
Mendez Groot, Tony	Olosunde, Demi	Pijl, Michael	Jacobs, Wilmer
Munteanu, Ioana	Srisuttisaard, Phongsatorn	Rikkers, Reindert Jan	Lous, Robin
Zodila, Emil	Zhang, Brian	Splunter, Max van	Murre, David
Boeren, Gorian	Alleyne, Richard	Steur, Jesper	Neels, Jack
Bolijn, Stefan	Cilli, Silvia	Boden, Stijn	Nijskens, Bastiaan
Dekker, Michael	Cuthill, Aidan	Bulman, Tom	Poorter, Arne de
Francke, Niek	Flikweert, Dies	Dekker, Thomas	Poortvliet, Gerard
Gillissen, Joren	Keeney, Jordan	Feber, Fabian le	Slabbekoorn, Gert
Heij, Werner	Kreike, Boris	Gillissen, Kees	Tiegelaar, Femke
Hollemans, Ruben	Ngirubiu, Isaac I.	Jonge, Marijn de	Traas, Ralph
Hoogstrate, Miquel	Richards, Hilary	Kock, Joris de	Verhage, Jan
Jonge, Ries de	Rook, Sandra	Maljers, Dylan	Visser, Patrick
Kingma, Matthijs	Zimina, Mikelina	Nugteren, Jorrit	Al-Azri, Ahmed
Klooster, Marjanne van der		Rooij, Pieter de	Amor dos Santos, Geanny
Kool, Rick		Rossum, Kim van	Chidi-Njemanze, Philip
Kooman, Levi		Smits, Daniël	Dremdjieva, Boyana
Maas, Hannelore van der		Steketee, Christa	Dykmans, Georges
Maas, Jelte		Tilburg, Sjoerd van	Ellis, Sheldon
Migalski, Jos		Verhulst, Rens	Habtezghi, Alex
Musters, Kenneth			Meylemans, Celine
Peijl, Robert van der			Nooteboom, Cees
Rietveld, Jacintha			Paul, Byron
Rijckaerd, Huub			Pauls, Rihards
Thilleman, Kevin			Ramos Arboleda, Mauricio
Walhout, Korné			Ratchakom, Nat
Witte, Dennis			Razali, Tedric
			Rijke, Demi de
			Rodrigues da Silva, Adão
			Roos, Mark
			Safonova, Dasha
			Tiersen, Michiel
			Zee, Siebe van der

6.2 APPENDIX 2. THE MANUAL PROVIDED TO THE STUDENTS FOR THE BENTHOS MODULE

OESTERDAM MONITORING

LABORATORY AND FIELD WORK MANUAL

Vlissingen, April 26, 2017

Building with Nature Research Group - Delta Applied Research Center

OESTERDAM MONITORING

LABORATORY AND FIELD WORK MANUAL

In 2013 a pilot sand nourishment was constructed on the tidal flat in front of the Oesterdam. It is expected that the nourishment will affect the surrounding ecology. By monitoring characteristics of the tidal flat on a yearly basis the long term impact of the sand nourishment on safety anfd surrounding ecology can be investigated. The monitoring is executed by HZ students of the Delta Academy. This project is coordinated by the Building with Nature Research Group.

Hartog, Eva;

Salvador de Paiva, João;

Van den Brink, Anneke;

Vlissingen, April 26, 2017

6.2.1 THE OESTERDAM

6.2.1.1 MONITORING THE DEVELOPMENT OF A PILOT NOURISHMENT

6.2.1.1.1 Introduction

Coastal erosion represents a serious problem to many coastlines around the globe, and is expected to become even a more serious problem in the next decades due to on-going human-induced changes in estuarine landscapes combined with an accelerated sea-level rise. Efforts to protect coastal areas consist of hard (e.g. dikes) or soft engineering methods (e.g. sand nourishment). In the Oosterschelde tidal inlet dikes need to be reinforced from time to time to meet safety criteria's. The safety provided by a dike is not only based on the height and material of the construction itself, but also on the presence of tidal flats in front of the dikes. Tidal flats can contribute to the safety of dikes by attenuating wave action in front of them. Since the construction of the Delta works the Oosterschelde tidal inlet is an erosion dominated system. With the construction of the Delta works tidal prism and tidal currents were reduced and due to that tidal channels became oversized with respect to the tidal current. As a result the sediment from the tidal flats is deposited in the oversized channels and the natural dynamic cycle of accretion and erosion changed into a continuous erosion process. When the tidal flats in front of dikes disappear, higher dikes are needed to meet safety criteria's (Figure 1).

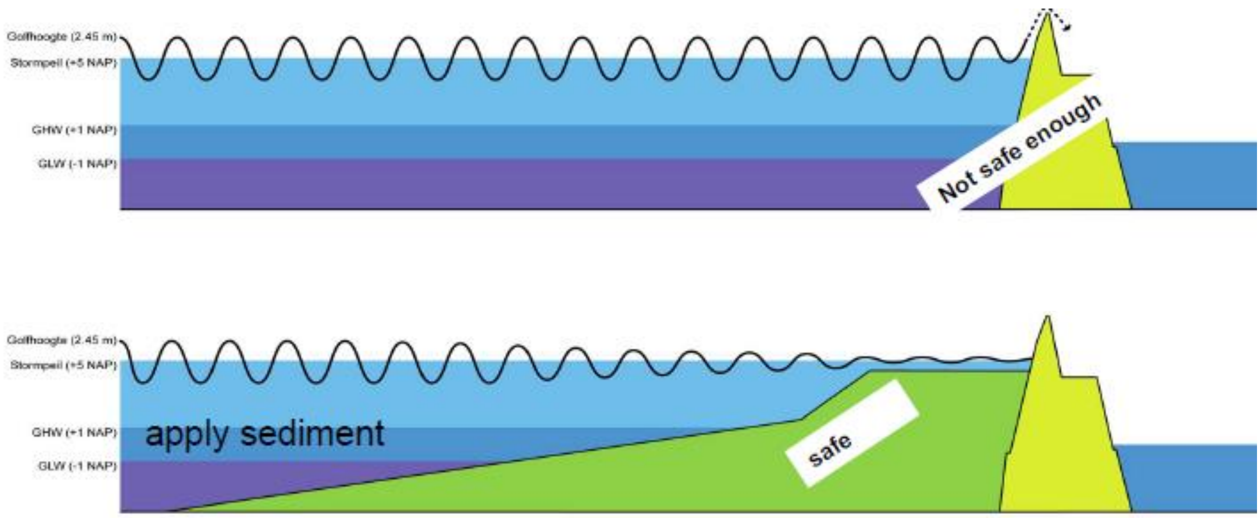


Figure 3. Situation with and without a tidal flat in front of a dike. Tidal flats attenuate waves reducing the forces of waves on the dikes.

Slowing down or even stopping the erosion process of tidal flats in front of dikes ca reduce maintenance costs of the dikes and preserve important ecosystems. To preserve a tidal flat in front of the Oesterdam and reduce the maintenance costs a pilot nourishment was constructed in 2013. Around 300.000 m^3 of sand was used on the edge of the tidal flat, and near the dike, Figure 2. It is expected that under influence of waves and currents sediment from the nourishment will move northwards, resulting in a gradual increase in elevation of the area on the eastside of the nourishment. It is also expected that the nourishment will have an impact on the local benthic community, sediment composition, sediment transport and height of the tidal flat. To monitor the effect of the nourishment on these characteristics we need to measure all these characteristics on regular basis at the nourishment and its surroundings.

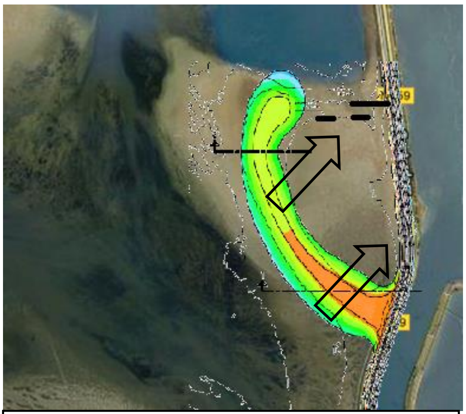


Figure 4. Proposed sand nourishmenton the intertidal flat in front of the Oesterdam. Waves and currents are expected to distribute the sediment northwards over the tidal flat (arrows).

6.2.1.1.2 Natura 2000: the importance of the benthos

Natura 2000 is the centrepiece of the EU nature & biodiversity policy. It covers an EU-wide network of protected natural areas and is intended to insure the long-term survival of Europe's most valuable and threatened species and habitats. While these specified areas are protected, the policy does not completely restrict human activity, instead it focuses on the ecological and economical sustainable management of the areas.

Natura 2000 applies to the area around the Oesterdam primarily as a feeding habitat for birds. The area is used as a feeding ground by birds such as the Pied Avocet (kluut), the Common Ringed Plover (Bontbekplevier), the Kentish Plover (Strandplevier), the Sandwich Tern (Grote stern), the Common Tern (Visdief), the Arctic Tern (Noordse stern) and the Little Tern (Dwergstern). These birds feed on the benthos living on and in the sediment, primarily eating worms, shellfish, gastropods and small crustaceans. The presence of these benthic organisms is essential to the habitat suitability for the birds that either stay for a breeding season or use the area as a resting place during their migrations.

The addition of new sand around the Oesterdam has buried and killed much of the benthic life and greatly reduced the food available for feeding birds. It is expected that the benthic organisms will recolonize the newly added sediment, but exactly how long and in what way this will happen is not yet known. Our sampling over time will show us the rate of recovery of the habitat from a bare lifeless sediment to a rich feeding ground for visiting birds.

6.2.1.2 **METHODS**

In groups we will investigate sediment characteristics of the area; spatial distribution of the benthic community; height of the tidal flat; and the current sediment transport. In the coming years we will do the same measurements with other students. By comparing this year's measurements with next year's monitoring we will show the effects of the nourishment on these characteristics. By monitoring these characteristics of the tidal flat on a yearly basis the long term impact of a sand nourishment can be investigated.

6.2.1.2.1 Benthic community/sediment characteristics

For the benthic community and sediment characteristics we need to answer the question: is there a relation between the presence, abundance and distribution of benthic animals and the substratum? In order to get an idea about the presence, abundance and distribution of benthic animals on the tidal flat in front of the Oesterdam, samples are taken of the benthic community. Sediment samples will be taken on the same locations as well. This way the two variables can be related to each other. Repeating this monitoring on a yearly basis shows the response of the benthic community to the sand nourishment and allows calculating the colonization rate.

To sample the benthic community we will take sediment cores at each sample location. These cores will be sieved in the field after which all organisms will be persevered in a jar and brought to the lab for determination. Besides taking sediment cores lugworm (*Arenicola marina*) abundance will be monitored by counting the number of heaps of digested sand in a 50 x 50 quadrant.

To sample the sediment characteristics we take three samples. One will be used to determine the chlorophyll-a content of the sediment (we won't do this), two will be taken to determine the sediment organic matter content and particle size distribution of which one will be stored to analyse with the Malvern (we will not do this). To determine the organic matter and particle distribution samples will be placed in the oven at 103 degrees. After drying we take the sample which will be weighed and ashed at 550 degrees for 2 hours. The weight loss is the amount of organic matter. After that we will analyze the particle distribution of the sediment.

6.2.1.2.2 Height / sediment compactness

When constructing the sand nourishment, bulldozers will drive over the tidal flat compacting the sediment. It is unknown if this has an effect on the recruitment of the benthic community. To monitor the effect of the bulldozers we will also measure the compactness of the sediment.

6.2.1.2.3 Sediment transport

The sand nourishment is developed such that sediment of the nourishment will be transported northwards elevating the whole area. This is based on knowledge of water flows. In this subtopic we question if the sediment really is transported northwards. To test this we will construct so called mini sand nourishments during low tide. Mini sand nourishments are round sand nourishments with a radius of 0,5/1 m. Tidal and non-tidal currents and waves will displace the mini sand nourishments and reveal the overall transport of sediments. The construction of mini sand nourishments is an easy and efficient method to study the sediment drift on tidal flats. After some tidal cycles, not only the direction of sediment drift, but also the magnitude can be measured.

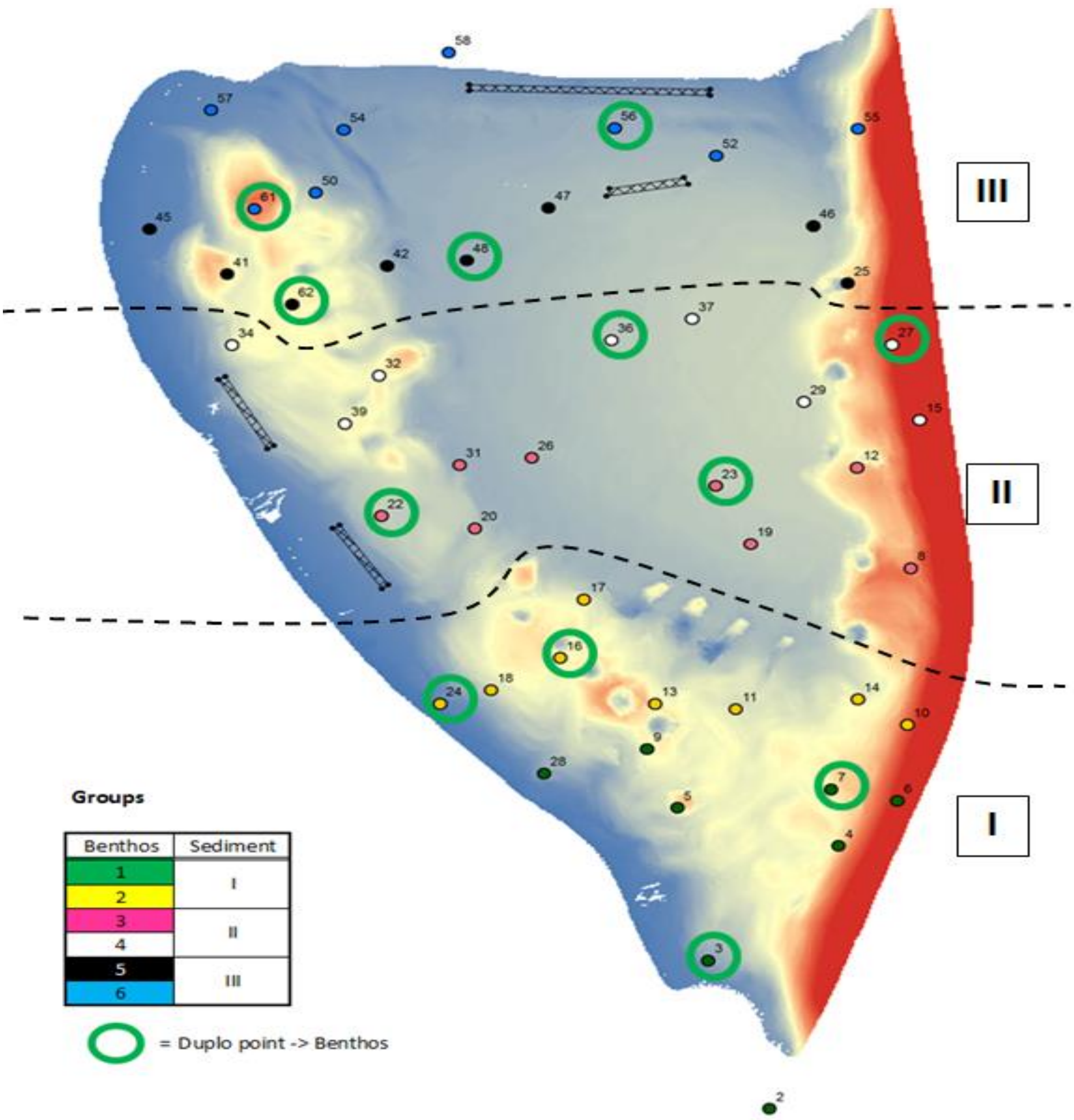
The centre of the mini sand nourishments will be marked by bamboos and their coordinates measured with a gps. Sand from the top layer of the tidal flat will be used to build the sand nourishments as this maintains visible for a couple of days. The same amount of sediment (two "Slikkarren" per sand nourishment) will be used for all mini sand nourishments to be able to compare different mini sand nourishments with each other. It is important to form a perfect circle to get a good impression of the changes. For that purpose we used a stick with a ½-1/4 meter line, which can be used to draw a circle. The sediment has to be dispersed symmetrically around the bamboo to a height of about 20cm with the highest point in the centre. After a certain period the nourishment have changed visibly depending on the local hydrodynamics. To measure these changes, a one meter circle is drawn around the bamboo as a reference. After that, the new shape of the nourishment can be drawn. To measure the direction of the sediment flux, a wind rose with the marks at N, NE, E, SE, S, SW, W and NW will be drawn on the sand nourishment. For every direction the distance between the bamboo and the edge of the new shape will be measured. Additionally, it is useful to indicate in which direction the highest point of the nourishment can be found. The construction of the mini sand nourishment will take place on Monday. On Wednesday we will come back to monitor the development of the nin sand nourishments with part of the group, the rest of the students will help with sorting the Benthic samples in the lab.

Groups

Monday (8:00-14:00 in the field)			
Group	**Topic**	**students**	**Supervisor**
1	Benthic; sediment	**4**	
2	Benthic; sediment	**4**	EVA
3	Benthic; sediment	**4**	
4	Benthic; sediment	**4**	
5	Benthic; sediment	**4**	TIM
6	Benthic; sediment	**4**	JAN
Tuesday (09:00 – 12:15 Ecolab)			
According to Schedule	Determination benthos		
Thursday (09:00 – 17:00 Ecolab)			
According to Schedule	Determination benthos		

6.2.1.3 **FIELD WORK**

Group 1 to 6



ID	X	Y	Group
2	73847,717	386062,520	1
3	73782,798	386253,700	1
4	73921,306	386401,376	1
5	73750,289	386450,663	1
6	73983,346	386459,774	1
7	73913,324	386474,618	1
9	73718,225	386526,520	1
28	73608,921	386494,997	1
10	73993,910	386557,833	2
11	73812,342	386577,921	2
13	73726,688	386584,903	2
14	73941,530	386590,611	2
16	73626,253	386643,988	2
17	73651,248	386719,449	2
18	73552,778	386602,482	2
24	73498,737	386584,803	2
8	73997,754	386759,589	3
12	73940,435	386889,604	3
19	73827,808	386790,884	3
20	73535,635	386811,175	3
22	73436,465	386827,181	3
23	73790,826	386865,686	3
26	73596,011	386901,974	3
31	73519,474	386892,760	3
15	74007,132	386950,877	4
27	73977,627	387048,088	4
29	73884,314	386974,249	4
32	73434,255	387008,388	4
34	73278,480	387047,387	4
36	73680,556	387053,688	4
37	73766,009	387081,306	4
39	73397,830	386946,220	4
25	73930,657	387127,273	5
41	73273,105	387138,749	5
42	73442,607	387149,668	5
45	73190,542	387197,117	5
46	73894,108	387201,215	5
47	73613,863	387224,424	5
48	73526,925	387156,728	5
62	73342	387100	5
50	73367,114	387244,173	6
52	73791,237	387291,554	6
54	73396,464	387325,109	6
55	73941,634	387326,230	6
56	73683,860	387327,317	6
57	73256,130	387350,322	6
58	73507,969	387424,690	6
61	73302	387223	6

Field measurements Oesterdam

6 Benthos groups of 7/8 students:

- Lug worms count (10 quadrants)
  Are Lug worms present? Yes/No. Throw the quadrant (50*50 cm) ten times at a random place. At each place you count the number of lugworm heaps in the quadrant and note the number down on the Sample card.
- Environmental picture:
  First, take 1 picture of the sample card of the sample point. This way we know where the pictures are taken. Then take 4 environmental pictures in different wind directions. At last take 1 picture from a height of 1 m of undisturbed soil within a representative quadrant (50*50 cm). That is 6 pictures at each site.
- Benthos
  Take 3 cores till the mark and sieve the sand in water. Collect the residue (the benthic organisms and shells in the sieve) from the sieve. Put the residue in the jar labelled "Benthos Oesterdam NIOZ" for the sample point where you are. IF YOU ARE AT A MEASURING POINT WITH A GREEN CIRCLE, REPEAT THIS SAMPLING. Put the second sample residue in the jar labelled "Benthos Oesterdam HZ"
- Crabs, shrimps and cockles
  Throw the quadrant (50*50 cm) at a random place at the sampling site. Put the top 5 cm of the sediment within the quadrant in the net. Sieve it in the water and put the residue in the provided jar (labelled Crabs e.g.). Repeat this at one other location at the same sampling site and put the residue in the **same jar**.
- Grain size and organic content
  First take 1 sediment sample of the top 3 cm with the bigger syringe (spuitje). Put this sample in the small jar.
- Chlorophyll
  Take 3 times the top 1 cm of sediment with the small syringe (spuitje). Put all three samples in the small bag, labelled for the sample point and store the bag in the larger freezing bag with the freezer pack.

6.2.1.4 **LAB WORK**

6.2.1.4.1 Analysis of Benthic Samples

6.2.1.4.1.1 PREPARATION

1. Before the analysis, each sample should be stained with a solution of Rose bengal. This dye binds specifically to proteins, which produces a clear contrast between the living animal material and the dead residue collected in the samples.

Bengal Rose (already preperated):
Create a solution with a ratio of 1 gram Bengal rose (powder) in 100 ml of 96% Ethanol. From this solution add a SMALL dash to the sample so that the liquid is a clear, pink color. Carefully tilt the sample several times, so that the dye spreads evenly over the whole sample. Ensure that sand and silt on the bottom also becomes suspended. Leave the sample to rest for at least 1 hour to give it time to attach to the animal material.

2. In the wet area in the Ecolab, sift the sample above a bucket containing a frame using two stainless steel sieves of 1 mm and 0.5 mm fitted one on top of the other.
3. Sorting will be done on a table in the Ecolab in photography trays or possibly using a microscope.
4. Each sample processed will have a unique sample number. This should be listed on a specifically designated data sheet provided in the lab.
   On the form record:
   - The sample number
   - The date of collection
   - Your name
   - The date the sample is analysed

   For an explanation of how the samples will be analysed, see: Methods, Analysis and Sorting
5. Keep the completed data sheet in the sample during the analysis and, after the analysis is complete, return it, along with the sample to the supervisors.

6.2.1.4.2

6.2.1.4.2.1 METHODS: SORTING

Rinsing

1. Before you start the analysis, complete the data sheet using the sample number of the container.
2. Rinse the sample in the wet area of the eco-lab, above the bucket in the sink. Put the sample through two sieves of 1mm and 0.5mm assembled one on top of the other (1mm sieve on top, 0.5mm sieve on the bottom). Gently pour the contents of the sample container into the sieves and rinse them with tap water, so that the finer material falls through the meshes.
3. *Divide large samples into two or more portions and rinse each separately. Do not add too much of a sample to the sieves at one time, as you will risk it*

clogging and overflowing which would mean animals may be lost from the sample.

4. Finally, properly clean the sample containers (inside and outside) and any text is removed with acetone in the fume cupboard.
5. Make sure that you know which sample number corresponds to the sample at all times!!!

Sorting the samples

1. Sort the sample into sieve groups; the first group from the 1mm sieve and the second from the 0.5mm sieve . For each sieve group, place a small amount of sediment in a photography tray and spread it evenly over the tray. Add a thin layer of water. Do not overfill the tray or it will become too cluttered.
2. NOTE : There may be animals stuck in the mesh of the sieve, so inspect the sieve carefully and make sure nothing left!
3. Place the photography tray on a table in the Ecolab provided with light and extraction.
4. On the base of the tray there will be lines/stripes, use these to keep track of where you are up to in the sample. Inspect the sample line by line and carefully remove all the 'coloured' organisms from the sample with a set of 'blunt' tweezers. (NOTE: there may also be unstained organisms present in the sample). Search through the sample until no more organisms are found (do this at least twice) and then let one of the supervisors check it before it is disposed of in the appropriate bucket.
5. This way you can carefully inspect your whole sample so that everything is sorted out from the sieve.

Sorting the organisms

1. Once the organisms are removed from the sediment in the photography tray they can be sorted into different groups.
2. The lines on the bottom of the tray will help you to systematically search through the organisms, giving you a clearly defined path to work so that you do not miss a spot.
3. Remove all the organisms from the tray with a 'blunt' tweezers place them in a petri dish with distilled water.
4. You can already distinguish the organisms between Polychaetes (worms) , Crustaceans (crabs, shrimp, amphipods etc) and Molluscs (snails and bivalves). Place these into separate petri dishes but do not use unnecessarily large petri dishes for a sample.
5. Handle the material carefully , so that no organisms break or get crushed.
6. Write the sample number and sample date on ALL petri dishes
7. Once you have finished sorting a sample, seal the petri dishes are with a lid and keep it ready for the species determination.

METHODS: SPECIES DETERMINATION

Species Determination

It is assumed here that all samples are already stained and sorts so that the samples consist only of 'live' material.

1. Use a microscope with light source, tweezers and possibly a needle. Put it in a suitable place on a table in the Ecolab .
2. Work from petri dish to petri dish in the same sample so that you finish one sample completely before you start another. Do not mix up samples!
3. If the sorting of the species went well, there is already a small distinction between Polychaetes (worms) , Crustaceans (crabs, shrimp, amphipods etc) and Molluscs (snails and bivalves). These can now be developed further and counted.
4. Polychaetes (worms) are difficult to distinguish from each other. This can only be done by looking at the fine details, however the obvious different species can be distinguished from each other. Using the literature, try and identify the species. Ask the supervisors for help and always let them check that you have the correct species! Count only the heads of the specimens and record this information on the data sheet.
5. Small crustaceans (shrimp, amphipods etc) are sometimes difficult to distinguish from each other. This can only be done by looking at the fine details, however the obvious different species can be distinguished from each other. Using the literature, try and identify the species. Ask the supervisors for help and always let them check that you have the correct species! Count only the heads of the specimens and record this information on the data sheet.
6. Decapoda/Brachyura (crabs) can be identified by the shape of their carapace (shell) and bij the shape off the legs. Check the literature or ask for help from the supervisors. Once you have identified the species, count only the heads/mouths and fill in the details on the data sheet.
7. Gastropoda (snails) such as mudsnails , periwinkles and slipper shells can be distinguished from one another and count only the mouths (of the shells) , note this information on the data sheet.
8. Bivalves (clams and cockles) can be distinguished from the molluscs. Try to identify these further using the literature (let the supervisors check that you have it correct!). Make a count of all the locks and record this information on the data sheet.
9. Once the entire sample is processed , counted and recorded , it can be in its entirety, including data sheet, handed to the supervisors before you start on a new sample.

Quality Assurance

<u>1. NOTE Each data sheet must be correctly and fully completed for each sample!</u>

<u>2. NOTE Each jar/petri dish must be properly labeled showing where it comes from.</u>

<u>3. Record all data at all times on the data sheet and let the supervisors check everything!</u>

6.3 APPENDIX 3 FIELD SHEET FOR STUDENTS TO RECORD DATA IN THE FIELD

Sample point	
Time	
Group Number	
Group leader:	

Benthos

Core samples	Check if taken
Core 1	
Core 2	
Core 3	

Worms	Number per quadrant
Quadrant 1	
Quadrant 2	
Quadrant 3	
Quadrant 4	
Quadrant 5	
Quadrant 6	
Quadrant 7	
Quadrant 8	
Quadrant 9	
Quadrant 10	

Crabs etc.	Check if taken
Quadrant 1	
Quadrant 2	

Sediment

Chlorophyll Small seringe	Check if taken
Core 1	
Core 2	
Core 3	

3 cm Grain size NIOZ Big seringe 3 cm	Check if taken
Core 1	

Exceptional notes:

Describe sample surrounding: close to an oyster reef, or other features
Describe the sand: colour, sand or silt, structure, are there organisms
Is there a layer of water on top of the sediment?
Are there weeds present? Yes/No
Note the depth at which an oxidation layer (black layer) starts (in cm)
Are there marks of worm diggers?
What is the predominant direction of the ripples in the sand? ||||--> North? South? East? West?

6.4 APPENDIX 4 LAB SHEET FOR STUDENTS TO RECORD NUMBER AND SPECIES OF BENTHIC INFAUNA FOUND IN THE SAMPLES

Sample ID		**Name Analyst**	
Sample Date		**Date**	
Number of jars			

Anthrazoa	**Amount**		
Actinaria sp.			
Other			

Bivalve	**Amount**		
Cerastoderma edule			
Crassostrea gigas			
Ensis sp.			
Macoma balthica			
Mya arenaria			
Mytilus edulis			
Scrobicularia plana			
Tellina sp.			
Other			

Crustaceans	**Amount**		
Crangon crangon			
Gammaridea			
Prawn			
Other			

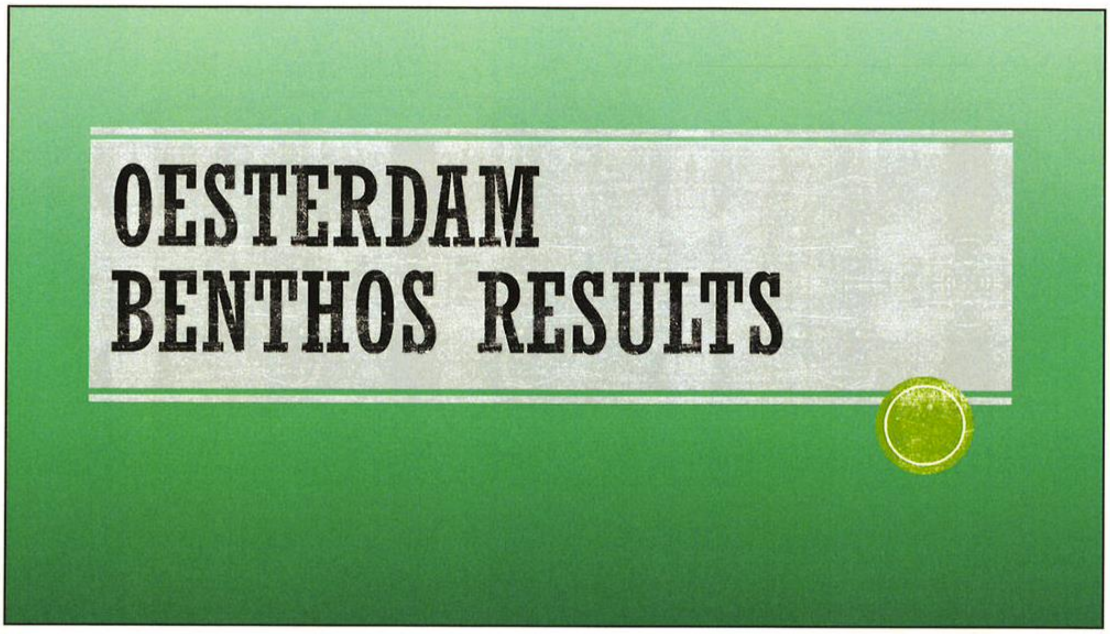
Decapoda	**Amount**		
Carcinus maenas			
Diogenes pugilator			
Pagurus berhardes			
Hemigrapsus takanoi			
Hemigrapsus sanquineus			
Other			

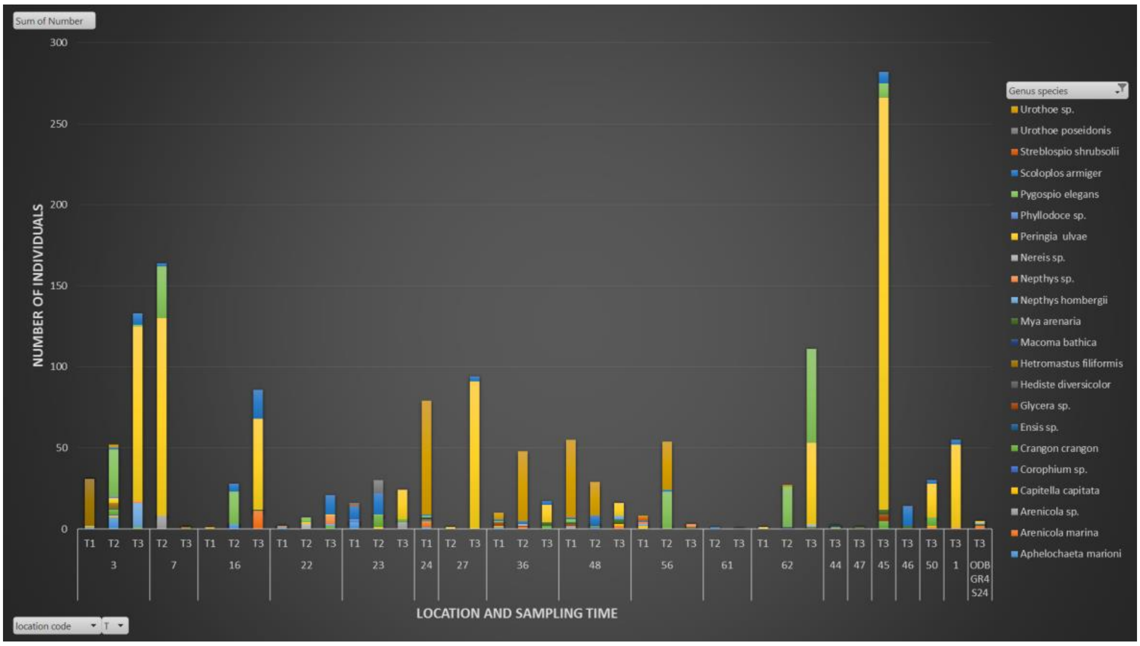
Echinodermata	**Amount**		
Astereas rubens			
Other			

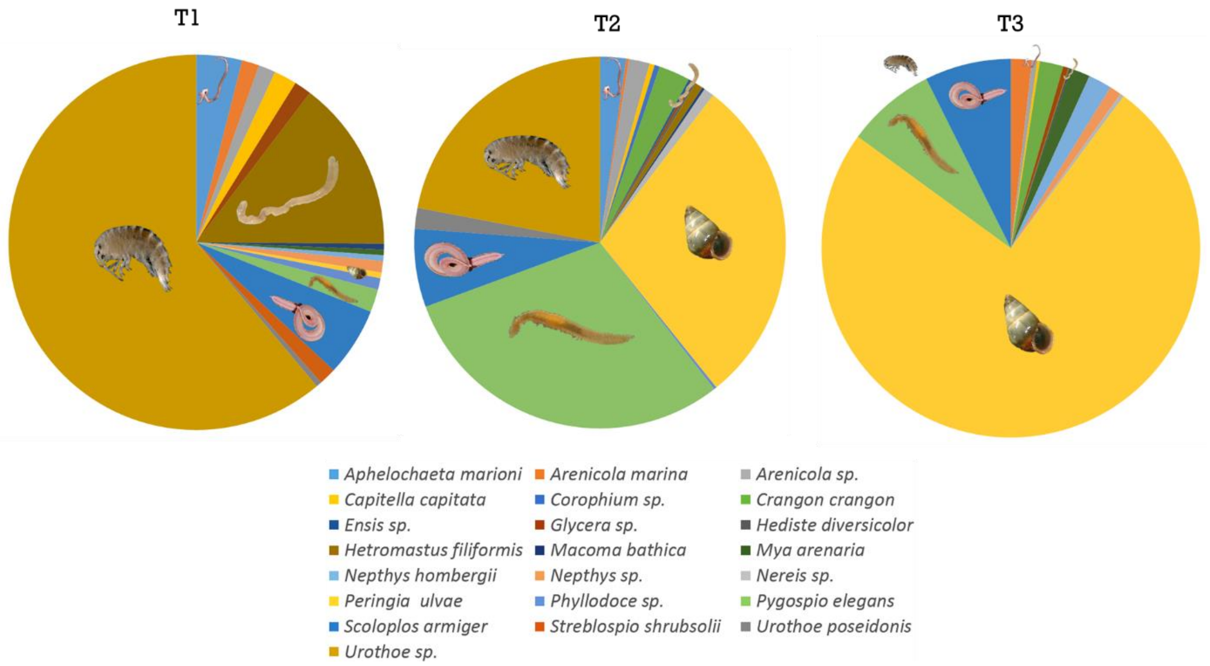
Gastropoda	**Amount**		
Crepidula fornicata			
Hydrobia ulva			
Littorina littorea			
Other			

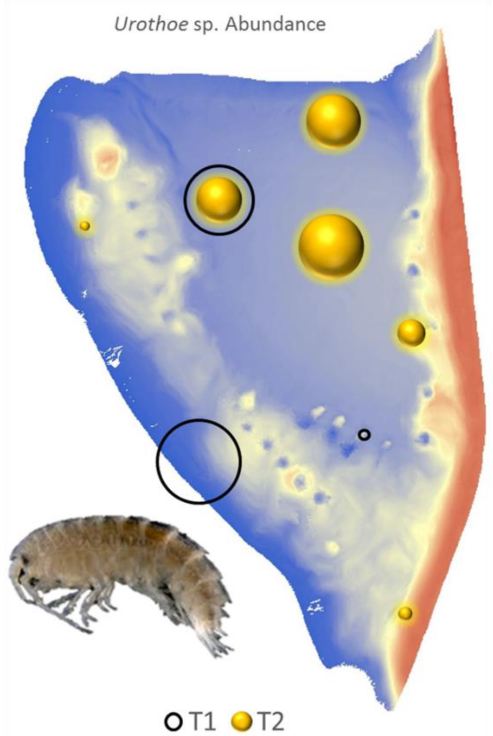
Polychaeta	**Amount**		
Arenicola sp.			
Arenicola defodiens			
Arenicola marina			
Capitella capitata			
Hetromastus filiformis			
Nepthys sp.			
Nepthys caeca			
Nepthys hombergii			
Nepthys longosetosa			
Nereis sp.			
Nereis cirrosa			
Nereis diversicolor			
Nereis virens			
Oligochaeta			
Scoloplos armiger			
Other			

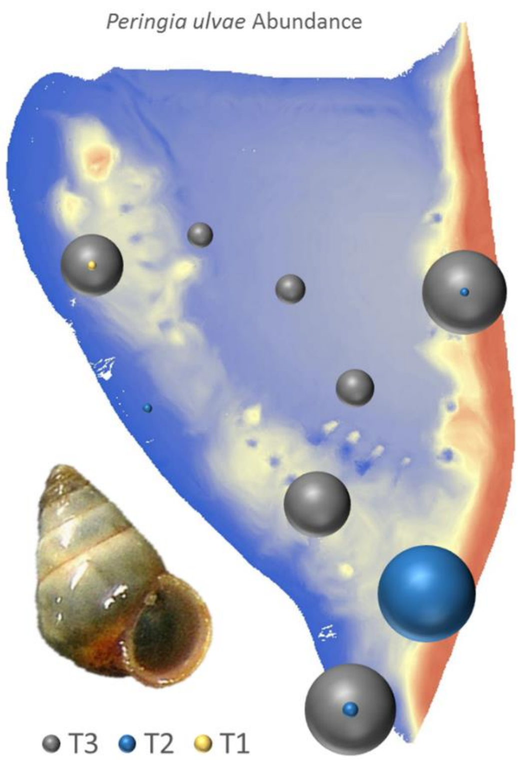
6.5 APPENDIX 5 EXAMPLE OF BENTHIC SAMPLING DATA PRESENTED TO THE STUDENTS DURING THE FEEDBACK LESSON PRESENTATION.

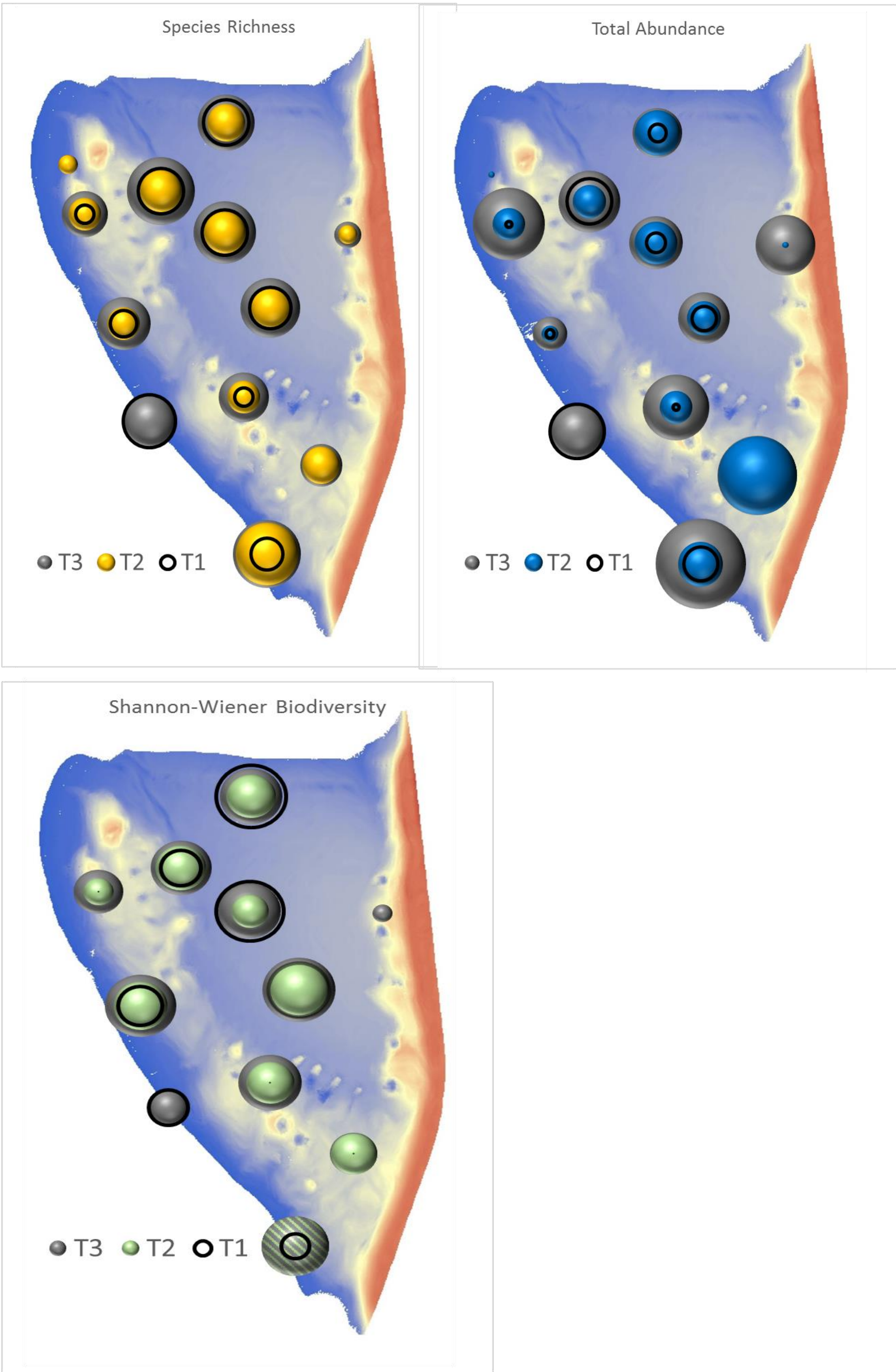




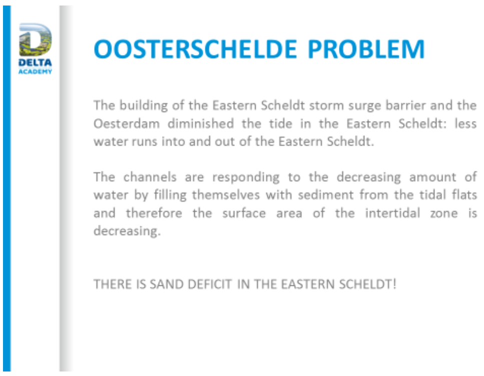

T1
T2
T3
Aphelochaeta marioni
Arenicola marina
Arenicola sp.
Capitella capitata
Corophium sp.
Crangon crangon
Ensis sp.
Glycera sp.
Hediste diversicolor
Hetromastus filiformis
Macoma bathica
Mya arenaria
Nepthys hombergii
Nepthys sp.
Nereis sp.
Peringia ulvae
Phyllodoce sp.
Pygospio elegans
Scoloplos armiger
Streblospio shrubsolii
Urothoe poseidonis
Urothoe sp.

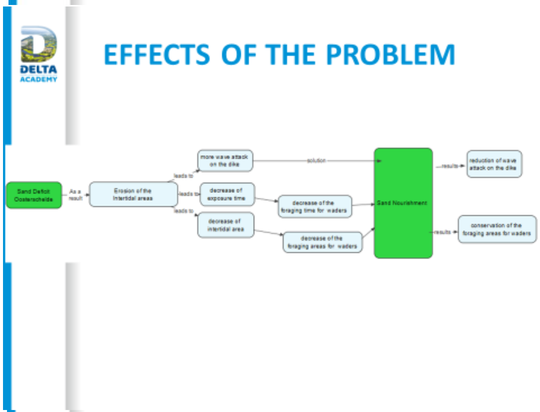

Urothoe sp. Abundance
T1
T2

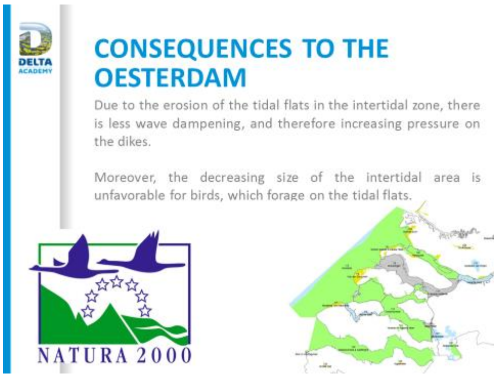

Peringia ulvae Abundance
T3
T2
T1

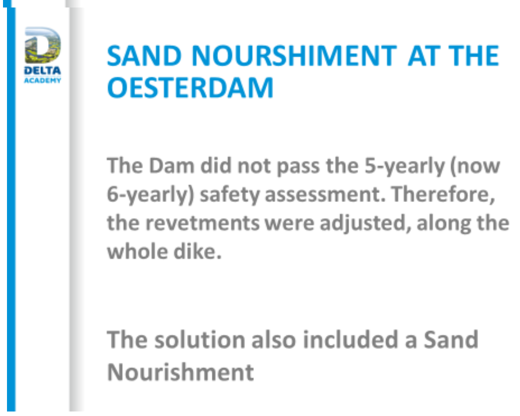

Species Richness
T3 T2 T1
Total Abundance
T3 T2 T1
Shannon-Wiener Biodiversity
T3 T2 T1

6.6 APPENDIX 6 EXAMPLE OF SEDIEMENT SAMPLING DATA PRESENTED TO THE STUDENTS DURING THE FEEDBACK LESSON PRESENTATION.







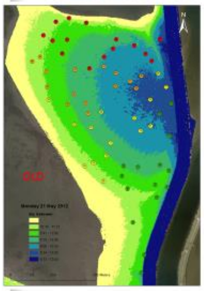


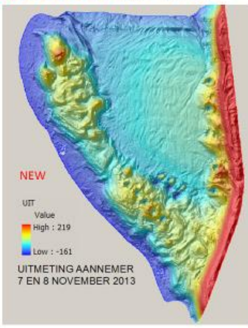
SAND NOURISHMENT

The beaches and dunes of the sandy Dutch coast protect the hinterland from flooding. Sand nourishment allows natural processes to maintain this sandy coast and 'dynamically' keep it in place.

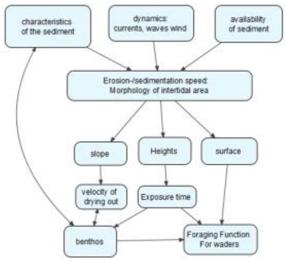
The sand for nourishment is dredged from deep waters (below the 20-metre depth contours). Water and wind distribute this sand naturally along the beach and across the dunes

SAND NOURSHIMENT AT THE OESTERDAM





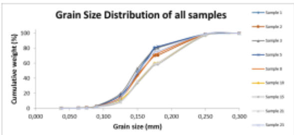
SAND NOURSHIMENT AT THE OESTERDAM



SEDIMENT ANALYSIS

SEDIMENT: ANALYZING

- Organic Material
  - $Organic\ Material\ Content = \frac{Dry\ weight - Ash\ weight}{Dry\ weight} \times 100\%$
- Sediment Grain Size
  - $\%\ of\ sediment\ retained = \frac{Weight\ of\ sediment\ remained\ on\ sieve}{Total\ weight\ of\ sediment\ used\ for\ sieving} \times 100\%$



- Median Grain Size (D50)

ORGANIC CONTENT

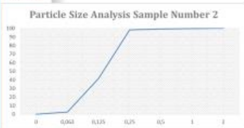
On the tidal flat:

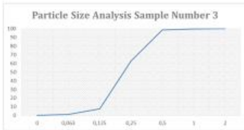
Sample	Organic content [g]	Organic Content %	min (%)	max (%)	Average (%)
SP2	0,32	1,55	0,24	1,55	0,63
SP3	0,07	0,24			
SP19	0,20	0,75			
SP23	0,06	0,66			
SP26	0,18	0,38			
SP52	0,08	0,26			
SP56	0,11	0,56			

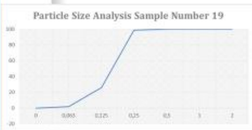
On the Nourishment:

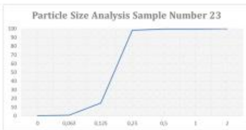
Sample	Organic content [g]	Organic Content %	min (%)	max (%)	Average (%)
SP4	0,03	0,24	0,04	0,39	0,24
SP6	0,04	0,20			
SP7	0,06	0,38			
SP9	0,01	0,04			
SP17	0,06	0,39			
SP18	0,07	0,33			
SP22	0,07	0,14			
SP32	0,03	0,13			
SP25	0,13	0,39			
SP27	0,04	0,12			

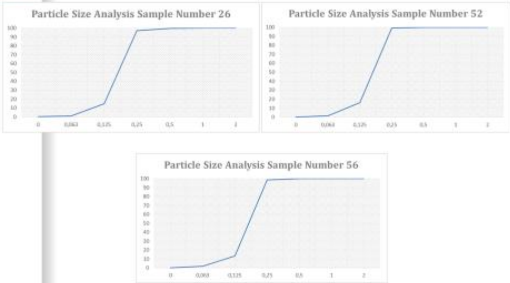
PARTICLE SIZE ANALYSIS: TIDAL FLAT



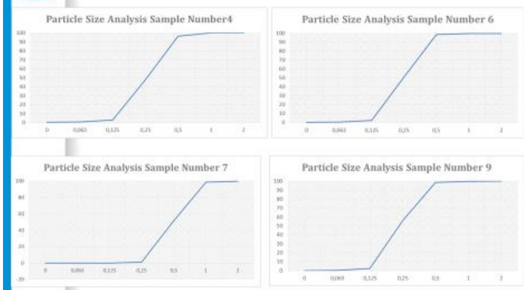


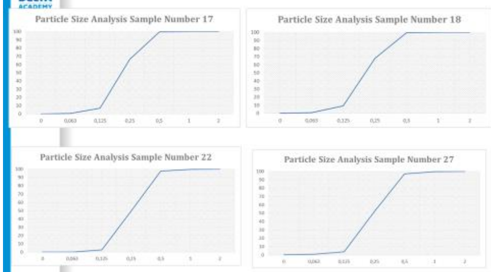




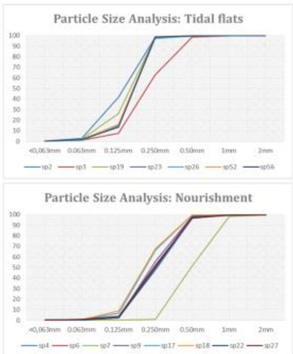


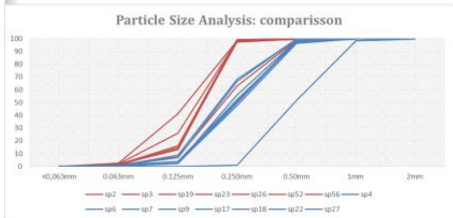
PARTICLE SIZE ANALYSIS: NOURISHMENT





PARTICLE SIZE ANALYSIS: COMPARISSON BETWEEN THE TWO SITUATIONS





6.7 APPENDIX 7 LITERATURE RESEARCH ASSIGNMENT GIVEN TOT HE STUDENTS TO PRESENT IN THE FEEDBACK LESSON

ASSIGNMENT IN THE BENTHOS-SAMPLING MODULE, ECOLOGICAL ENGINEERING, 2017

During the feedback lecture

PRESENTATION OF INDIVIDUAL BENTHIC SPECIES

Group	**Species**
1	*Urothoe* sp.
2	*Hetromastus filiformis*
3	*Arenicola marina*
4	*Peringia ulvae*
5	*Pygospio elegans*
6	*Mya arenaria*

All the different benthic organisms at the Oesterdam make up the benthic community. Each species has its own unique morphology (physical structure and characteristics), life history strategy (patterns of growth and reproduction) and ecological niche (habitat, distribution, food source, community interactions).
To understand how the community functions and how each species relates to the others in the community it is important to understand each individual species.

You will be given the name of one of six benthic species commonly found at the Oesterdam. Make a 5 minute PowerPoint presentation (4-5 slides) to describe how the species fits into the benthic community including:

- General morphology (main physical characteristics and what they are used for)
- Life history (life stages and reproduction strategy)
- Distribution (where it is found, how is disperses, at what life stage it disperses, what factors can influence its dispersal)
- How it relates to the other species in the community (what it eats, what eats it, what it competes with, and what it competes for).

You will be judged on:

- How in depth your information is
- How well your story flows between subjects
- How well you present (voice, eye contact, familiarity with the material)
- That everyone in the group takes part
- How well you answer questions after your presentation

6.8 APPENDIX 8 SCREEN SHOT OF THE LEARN PLATFROM WHERE THE BENTHOS MODULE WILL BE OFFERED AS A SPOC