Eco-engineered coastal defense integrated with sustainable aquatic food production in Bangladesh (ECOBAS)

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Summary

The objective of the ECOBAS project is to provide the coastal people of Bangladesh with an alternative approach for adaptation to coastal erosion and flooding. By using the concept of “eco-engineering” the natural resistance of shellfish reefs against hydrodynamic forces reduces human vulnerability to coastal erosion and flooding, and delivers a source of aquatic food. ECOBAS stands for ECO-engineered Coastal Defence Integrated with Sustainable Aquatic Food Production in BAngladeSh, and was executed by a multidisciplinary team of Dutch and Bangladesh research institutes. This report summarizes the outcomes of this study. It is not an in-depth report where scientific outcomes are discussed, but a summary for the funding agencies. The ECOBAS project was funded by Partners for Water. Also the Embassy of the Kingdom of the Netherlands financed extra monitoring activities in the second phase of the project which enabled generation of more data and a broader understanding of the research.

In the first phase of the ECOBAS project, the suitability of the Bangladeshi coast for oyster reef development was investigated through a habitat suitability analysis and field visits. Subsequently, to acquire practical information about oyster settlement and growth, different substrates (i.e. dead oyster shells, living oysters, window pane shells and stones) were tested in a field experiment at Kutubdia and Moheshkali Island in 2012. Substrates were fixed in bamboo mattresses and placed on the intertidal mudflats of two sites. This experiment provided data on spat settlement, growth and survival of oysters. However, the reefs made of bamboo frames have proven vulnerable to destruction by hydrodynamic forces, in particular in the monsoon season, and also smothering of fine sediments and silt on the substrates, suffocating the oysters. In addition, ECOBAS partners organised a cook workshop in 2013 and developed a cook book “Cook the Ocean Bangladesh style” in order to enhance interest in sea food preparation and home consumption.
In the second phase, a new reef structure was constructed on the south-east coast of Kutubdia Island made out of a concrete structure. The structure mimics the dimensions of a full grown oyster reef in such a way that effects on local hydromorpholgy can be evaluated. At the same time the structure offers a suitable substrate for oyster settlement, as it is sufficiently elevated above the surface. By monitoring biological and hydromorphological parameters the feasibility of application of such a reef in reducing sediment/coastal erosion (or promoting shoreline accretion) and its role in supplying aquatic foods was investigated. A model was used to predict long term development (growth, biomass) and determine harvestability of edible oysters over a period of 30 years. Furthermore, a Social Cost Benefit Analysis (SCBA) addressed the economic potential of the reef in a socio-economic context.

Results indicate that the reef structure can facilitate accretion on the lee side of the reef by influencing the wave climate. By doing so growth of mangrove saplings and saltmarsh vegetation might be enhanced. The reef has an indirect effect on coastal protection, because by dissipation of wave energy the earthen embankment is expected to be less affected by erosion. After placement in April 2013, oyster larvae successfully started settling on the reef. Settlement increased rapidly a year after the reef was installed. Modelled results show that with a growth speed of 2 cm per year the reef will be able to keep up with sea level rise. Also 5,6 kg live oysters m^2/year can be harvested while still maintaining a vital reef.
The outcomes of the SCBA indicate that use of ecosystem engineers (i.e. oyster reefs and mangroves) in combination with an earthen embankment provide comparatively high coastal defence benefits and improved adaptability to climate change. Also, oyster reefs and mangroves promote a wide range of ecosystem goods and services that can support local livelihoods including food security.

The main successes of ECOBAS are (i) the novelty of the concept, (ii) the interest it has generated among stakeholders and in the media, (iii) the successful application for continued research (i.e. Nuffic fellowship at PhD level), (iv) active involvement and participation of local community, and (v) the

cooperation and adequate flow of information between all consortium partners. The main complications were the extreme environmental conditions in the south-east coast of Bangladesh (i.e. varying water salinity, and sediment loads and dynamics), resulting in a more time-consuming experimental phase. Also, data collection proved more challenging because sufficient and modern monitoring equipment was not always at hand and logistics support was limited. Therefore, ECOBAS provided a first, but important step towards application of the concept, and at the same time it is realized that further steps are needed to value the full potential of ECOBAS. This can be achieved through further joint collaboration, education of students and young professionals, and scaling-up of the pilot experiments.

For a next phase we propose to put emphasis on up-scaling and further optimizing of the ECOBAS project and also implementing the concept of eco-engineering for risk reduction and climate change adaptation along the coast of Bangladesh. The aim is to broaden the approach, and to provide insight in the conditions under which coastal ecosystems can be valuable for coastal protection. With this information these systems can be designed (restore or develop) in such a way that ecosystem services are maximised. In this approach we incorporate natural ecosystems in the designs for coastal risk reduction. We specifically consider the whole foreshore in which, depending on the settings, we include tidal flats, biogenic reefs (e.g. oyster reefs), salt marshes and mangroves, as a protective zone in front of the (earthen) embankments. Such hybrid approaches will better reduce risks and hazards and at the same time support many valuable additional ecosystem services, including food production.

Introduction

The low-lying, densely populated coastal areas of Bangladesh are under threat due to increasing risk of storm-flooding and sea level rise (Karim & Mimura, 2013). Loss of land due to erosion is a chronic problem in many coastal areas and offshore islands (Maminul et al., 2014). Traditional engineering with hardened or earthen embankments often fails and is non-resilient, expensive and often sub-optimal with respect to other functions (as providing a source of food, income and other ecosystem services).

The ECOBAS project (Eco-engineered Coastal defence integrated with sustainable aquatic food production in Bangladesh) aims to provide the Bengal authorities with an alternative approach for coastal protection and climate change adaptation, by using the concept of "eco-engineering" (box 1), utilizing reef structures with oysters to combat coastal erosion and at the same time to provide a source of aquatic food and stabilize the tidal flat for enhancing marshes and mangrove habitats (Figure 1).

Textbox 1: Eco-engineering

The concept of "eco-engineering" aims at the design of sustainable systems in concert and consistent with ecological principles that integrates human activities with the natural environment to the benefit of both (Mitsch & Jørgensen, 2003). The construction or restoration of coastal ecosystems like shellfish reefs, coral reefs, salt marshes, mangroves and dune vegetation, in combination with existing coastal defence structures, will enhance the protection of coastal areas and communities against erosion and flooding.

Oysters are shellfish and grow naturally to form three-dimensional reef structures that influence tidal flow, wave action and sediment dynamics in coastal ecosystems and, in doing so, modify patterns of sediment deposition, consolidation, and stabilization (Walles et al., 2014). These organisms and their conspicuous habitats are therefore called "ecosystem engineers" (Jones et al. 1994; Jones et al., 1997). The concept of ecosystem-engineering offers promising possibilities for shoreline protection and coastal defence (Temmerman et al., 2013; Cheong et al., 2013).

Within ECOBAS the Dutch and Bangladesh experts worked together to investigate the technical and economic feasibility of this alternative approach for coastal adaptation in two areas (Kutubdia Island and Moheshkhali Island), in the south east of Bangladesh. Since the climate conditions of Bangladesh are more extreme than in the Netherlands, the pilot project should deliver valuable information on the ecological, technical and socio-economic constraints in tropical and sub-tropical conditions. The approach and techniques can be applied in other deltas in the tropics such as Vietnam and Mozambique. Furthermore, ECOBAS also provides valuable knowledge to further enhance existing "building with nature concepts" in temperate regions and more specifically in the Oosterschelde in the Netherlands where pilot research on the role of oyster reefs in tidal flat stabilisation has been executed (Walles et al., 2014). This report summarizes the outcomes of ECOBAS. It is not an in-depth report where scientific outcomes are discussed, but a summary for the funding agencies. The ECOBAS project was funded by Partners for Water. Also the Embassy of the Kingdom of the Netherlands (EKN) provided extra finance in the second phase of the project. The financial contribution of EKN enabled extra monitoring activity in 2013-2014. Therefore is was possible to monitor oyster growth for a longer period and develop a deeper understanding of the hydro-morphological processes that was used to develop a hydro-morphological model.

financed extra monitoring activities in the second phase of the project which enabled generation of more data and a broader understanding of the research.

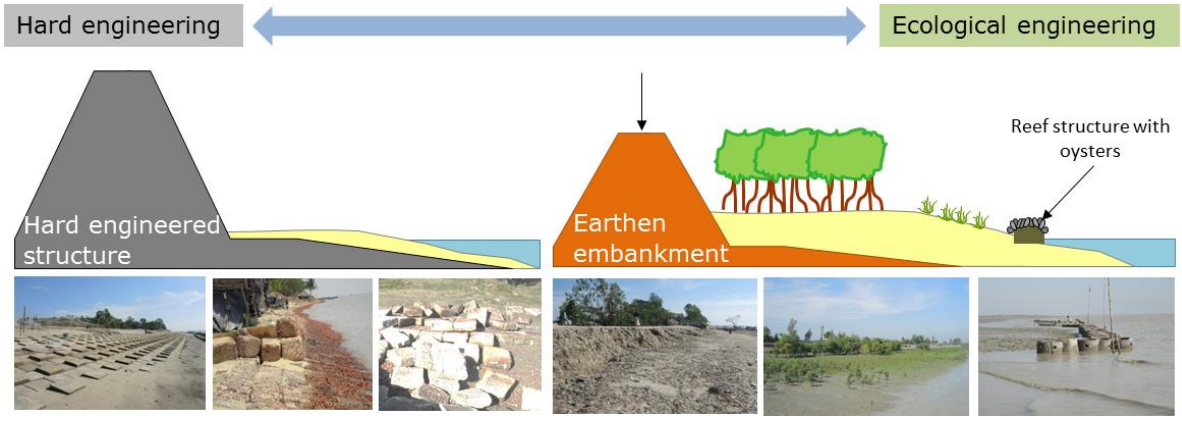

Figure 1. The concept of eco-engineering in Bangladesh. Hard engineered structures are replaced by a hybrid concept in which coastal ecosystems like oyster reefs, salt marshes and mangroves form a 'first' zone of defence, protecting the 'second' line of defence (i.e. earthen embankment) behind it (Source: IMARES).

The ECOBAS project iwas implemented by IMARES (Institute for Marine Resources & Ecosystem Studies, LEI (Agricultural Economics Institute), both are part of Wageningen UR; Royal HaskoningDHV, and the Institute of Marine Science and Fisheries of the Chittagong University Bangladesh. The project was funded by Partners for Water and the Embassy of the Kingdom of the Netherlands in Bangladesh and started in January 2012 and is completed in December 2014.

Approach and main activities

The project investigated the technical, sociological and economic feasibility of eco-engineered coastal defence along the south east coast of Bangladesh, through: Phase 1 (2012) involving small-scale ecological field trials, socio-economic (field) studies and morphodynamics analysis, including hydro-dynamic modelling; Phase 2 (2013- 2014) with construction and testing of a pilot oyster reef at Kutubdia Island, mathematical modelling and dissemination of results.

Main project activities 2012:

- Identifying suitable sites for oyster development based on habitat suitability analysis;
- Testing phase: Design and monitoring of a small-scale ecological field experiment to study the settlement and survival of oysters on different substrates (stones, oyster shells, live oyster and window pane shells) at two locations (Kutubdia and Moheskhali) and at different heights above the tidal flat;
- Data collection for a cost-benefit analysis of the eco-engineered shellfish & mangrove coastal defence structures;
- Investigation of the effects of an oyster reef on hydrodynamics and sediment dynamics;
- Supply chain and market analysis of bivalves
- Capacity building and stakeholder involvement, active involvement of the community of Kutubdia in the project;
- Strengthening collaboration efforts among partners through joint Dutch-Bangladesh project meetings & workshops.

Main project activities 2013:

- Pilot phase: Completion (April 2013) of a reef structure mimicking a full-grown, long-living oyster reef, by constructing a concrete reef made out of 69 concrete rings, 45 meters long and situated 215 meter out of the earthen embankment on Kutubdia Island (Figure 2). This concrete reef structure mimics the dimensions of a full grown reef in a way effects on local hydro-morphology can be monitored. At the same time the structure offers a suitable substrate for oyster settlement.
- Start monthly monitoring program: spat settlement, growth, sedimentation, sediment composition, environmental parameters.

- Joint Dutch-Bangladesh project meeting

Main project activities 2014:

- Continuation monthly monitoring program on the concrete reef structure at Kutubdia Island.
- Analysis and interpretation of monitoring data.
- Construction and application of a predictive model for oyster reef development using Dynamic Energy Budget modelling
- Completion of seafood cooking camp and publication of a cook book.
- Joint Dutch-Bangladesh project meeting
- Presentation of ECOBAS results at the international conference “Delta’s in times of climate change” (Rotterdam, The Netherlands, 24-26 September 20014)
- Presentation of project results at the India-EU MARECLIM III workshop “Coastal zone management and impact on society” (Kerala, India, 6-9 October 2014)
- Presentation of results at the final ECOBAS conference (Dhaka, Bangladesh, 26 November 2014).

Figure 2. Location of the reef structure at south-east Kutubdia island (Source: Chittagong University).

The original proposal did not include a testing phase. However, given the particular prevailing environmental conditions in Bangladesh and the scarcity of information on oyster habitat requirements, initially we decided to conduct a number of small-scale field experiments (phase 1). Consequently, the total duration of the project needed to be extended for one more year, to December 2014.

The effect of a full grown oyster reef on shoreline stabilisation and food production cannot be demonstrated during the life span of ECOBAS project. These effects can be simulated using a conceptual model. As the predictive capacity of this model depends to a large extend on the data collected in the field, a rather intensive monitoring program is required. The original proposal included only limited time and funds for monitoring and data collection. Therefore, additional financial resources have been requested from the Dutch Embassy in Dhaka. The embassy agreed to fund the additional field works and maintenance costs of the reef.

Summary of results

Phase I Field experiments: substrate, oyster settlement and growth

In the first phase of the ECOBAS project a field experiment was executed in the period of April-November 2012 at Kutubdia and Moheshkahli islands. Based on the habitat suitability analysis these islands were identified being suitable for oyster settlement and growth. The most common oyster species in this area of Bangladesh is *Crassostrea madrasensis* (Preston).
The experiment was carried out using structures made of bamboo (Figure 3) in which four different substrates were placed: stones, oyster shells, live oysters and windowpane (*Placuna* sp.) shells. The bamboo mattresses were placed directly onto the mudflat and 25 cm above the mudflat, to investigate the possible effect of smothering of the substrates by mud and silt.

Figure 3. Left: Bangladesh and the location of Kutubdia and Moheshkahli Island. Right: Field experiment with bamboo mattresses containing four different substrates (stones, oyster shells, live oyster and window pane shells) to test settlement of oysters and growth. The picture was taken at Kutubdia Island in April 2012 during the construction phase (Source: Chittagong University).

The main findings of the field experiments were:

- Window pane shells, live oysters, oyster shells and stones were suitable substrates for natural spatfall and growth of *Crassostrea madrasensis* with window pane shells being the most successful (Figure 4).
- Environmental conditions (salinity, pH, temperature, TSS etc.) were favourable for growth of oysters;
- Sedimentation and smothering with sediment was the main threat for oysters during monsoon period; the structures directly onto the mudflat suffered more from suffocation with silt and mud compared to the structures placed 25 cm above.
- Bamboo as a reef structure has not proven strong enough to withstand the high water dynamics in the monsoon period, therefore demolition of some of the structures appeared during the monsoon period.
- A more solid substrate with high vertical relief (to prevent smothering of the structure by mud) was recommended as reef structure.

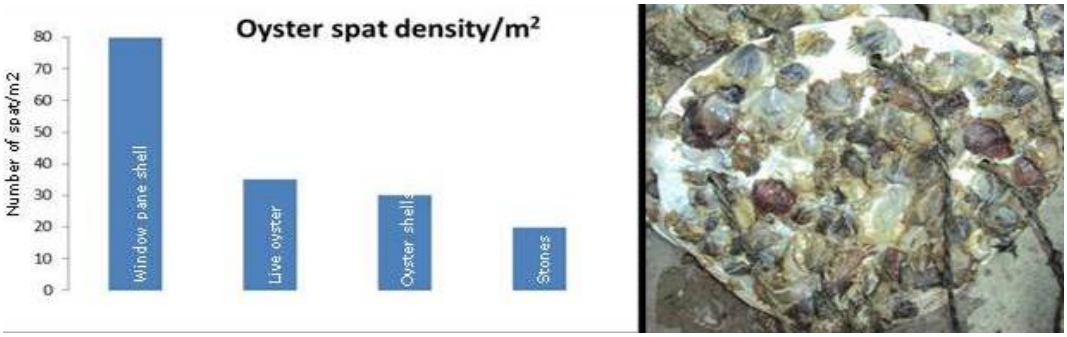

Figure 4. Left: Number of oyster spat (Crassostrea madrasensis) on different substrates on the bamboo reef (April-November 2012). Right: oyster spat settlement on a window pane shell. The movement of the substrates within the bamboo mattresses probably influenced the settlement of oysters negatively, especially for shells and stones (Photo by Chittagong University).

Phase II Pilot reef structure for coastal defence and food production

In the second phase of the project (April 2013 - November 2014) an experimental oyster reef was constructed at south-east Kutubdia Island. The reef consisted of 69 concrete rings placed next to each other covering 45m and was situated 215 meter of the coast near the low tide level. The concrete reef was elevated around 50-75 cm above the sediment level and can serve as suitable substrate for oyster spat settlement. This concrete reef structure mimics the dimensions of a full grown reef in a way that effects on local hydromorpholgy can be monitored. By monitoring biological and hydromorphological parameters the feasibility of the application of such a reef in reducing coastal erosion and providing an aquatic food source to humans was investigated. Furthermore, a Social Cost Benefit analysis (SCB) addressed economic potential of the reef in a socio-economic context. In the text below the major outcomes of this phase are discussed.

Hydromorphological aspects

The Kutubdia channel is bordered by a wide mud flat with a very gentle slope of approximately 1 degree. The tidal range is approximately 4 m with a seasonal variation in Mean Tide Level of 50-80 cm. During the monsoon season the wave climate can be very rough as a consequence of summer storms. The wave climate at the pilot site was determined by extrapolating offshore waves. For this, a 12-year data set collected from a data point ca. 300 km offshore from the pilot site was used. The south west appears to be the dominant wave direction offshore and a maximum wave height of 8.5 m was measured. Next, the offshore waves were translated to nearshore waves in order to get a feeling about the expected wave conditions around the oyster reef. The translation was done by a 2D Wave modelling tool, called SWAN. The highest wave of 8.24 m is expected to reduce to only 0.78 m at the pilot site. Larger waves can be expected as local wind waves are generated in the channel.

To obtain more information on the morphology and especially on changes in time, beach profiling is a suitable method. In this project simple equipment was used for shore profiling that is particularly suitable on mud flats with difficult and limited working conditions (Chowdhury et al., 2014). Two vertical poles and a flexible tube in between form a manometer, traditionally called a U-tube. The tube is filled with liquid and forms the reference for determining the elevation difference between two places. This method involves establishing a line of sight: a straight line perpendicular to the shore marked by erecting bamboo poles (Figure 5). This method for shore profiling was published by Chowdhury et al. (2014).

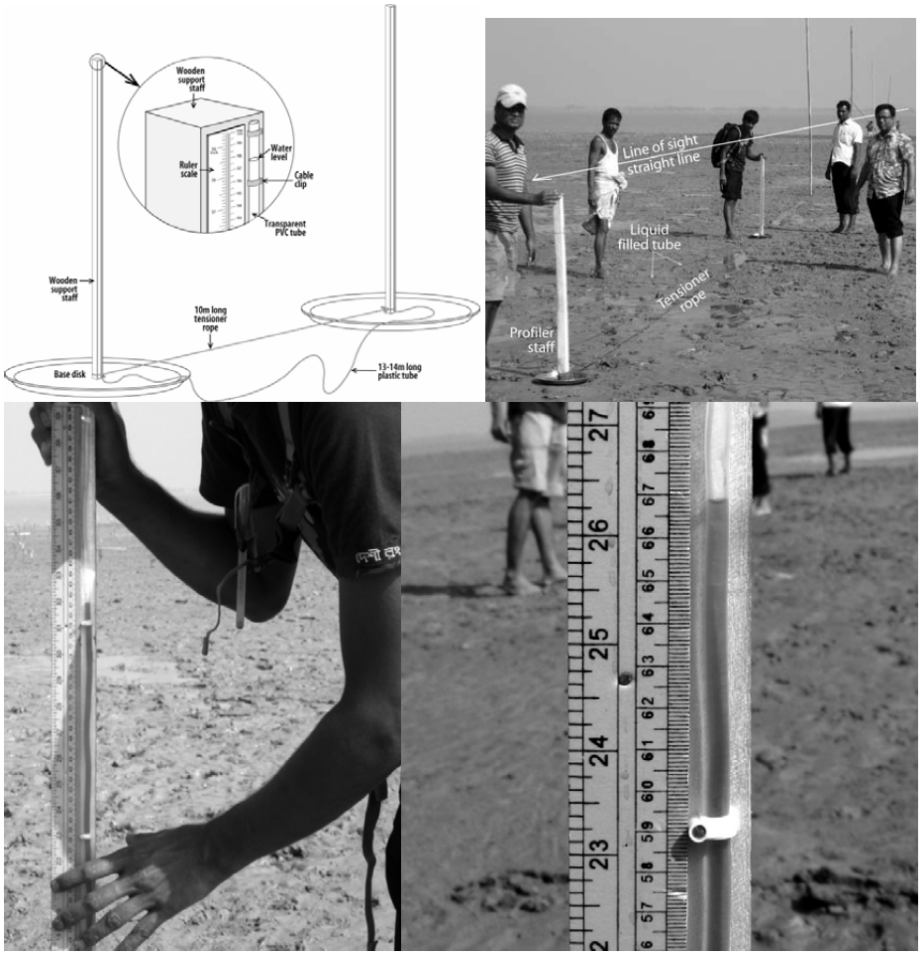

Figure 5. Beach profiling method on mud flat of Kutubdia Island. Top left: mud flat profiler assembly. Top right: profiling the shore along an established line of sight. Bottom left: taking instrument readings. Bottom right: the graduated ruler scale (Photos by Chittagong University).

Although a method was chosen that was suitable for this type of environment, surveys are always very sensitive to any kind of errors. Furthermore, in complex situations, such as present at Kutubdia Island, long time series are needed to be able to draw conscientious conclusions. Therefore, at this stage, it is hard to use these measurements for interpreting the behaviour of the system and recognizing a certain trend. Though, accretion as an effect of the oyster reef is confirmed by other aspects. Firstly, deposition of sediment in a region behind (i.e. lee side) the reef is observed clearly during upcoming tide (Figure 6). Moreover, the retention of this deposit is observed, even during the monsoon period. Lastly, measurements of sediment layer thickness indicate that accretion takes place on the lee side of the reef

Figure 6. Visible accretion behind the reef (Photo by IMARES).

From a hydro-morphological perspective, the main findings are:

- Oyster reefs result in accretion of sediment on the lee side of the reef;
- As a result of the accretion behind the oyster reef, salt marshes and mangrove development can be enhanced;
- Effects of the reef are indirect. Due to the accretion behind the reef a more extended foreshore is created. As a result, wave damping occurs and the primary defense (i.e. the earthen embankment) is less affected.

Remarks:

- During high water levels the foreshore is not protected by the reef, since the waves do not 'feel' the reef in this case, hence, there is no wave energy dissipation.
- Since wave measurements are lacking, the direct effect of the reef on wave attenuation could not be determined. It is recommended to improve this study with wave measurements and use them to validate the SWAN wave model.

Ecological aspects

The reef made out of concrete rings provided substrate for the oyster larvae to settle. Development of oysters on the reef is strongly determined by recruitment of oysters larvae but also by shell production (growth of newly settled oysters) (Walles et al., 2015). To ensure sufficient supply of oyster larvae in the water column the concrete reef was placed close to a natural adult population of oysters (Figure 7). After placement of the concrete reef, settlement of oyster larvae and growth of the oysters was measured every month. The first six months from April-November 2013 only few larvae settled on the reef but from January 2014 the amount of oysters on the reef started increasing followed by a fast exponential increase from June to August 2014 (Figure 8). It was also observed that the reef facilitates increased biodiversity by providing substrate and shelter for numerous marine species like anemones, crabs, juvenile fish, barnacles, microalgae, snails etc. Besides, as mentioned before, there are indications that the presence of the reef positively influences growth of salt marsh vegetation and survival of mangrove saplings.

Figure 7. Presence of adult oysters (Crassostrea madrasensis) on the nearby jetty pillars at Kutubdia pilot site (Photos by Chittagong University).

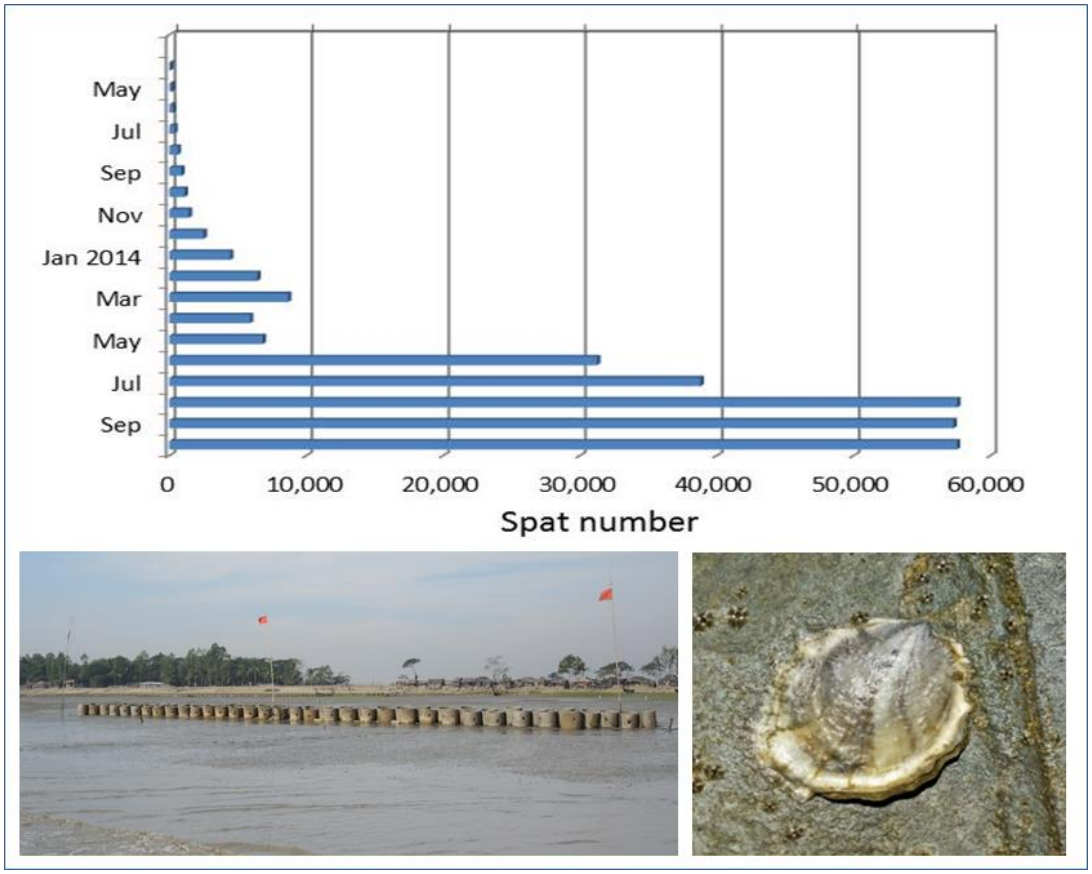

Figure 8. Top: Number of oyster spat (Crassostrea madrasensis) that settled on the concrete reef structure at Kutubdia Island in the period of April 2013 to September 2014. Bottom left: concrete reef structure. Bottom right: young Crassostrea madrasensis oyster on the reef (November 2013) (Photos by Chittagong University).

Modelling oyster reef development on the concrete structure

DEB modelling (Dynamic Energy Budget, (Kooijman, 2010)) calculated an average reef growth of 2 cm/year, and a harvestable oyster biomass of 5,6 kg/m^2/year for a period of 30 years (Figure 9). The harvestable biomass indicates the amount of live oysters that can be harvested while at the same time maintaining a vital reef structure. Importantly, the growth rate of oysters on the reef is sufficient to keep up with sea level rise. The model is partly based on monitoring data and partly on assumptions.

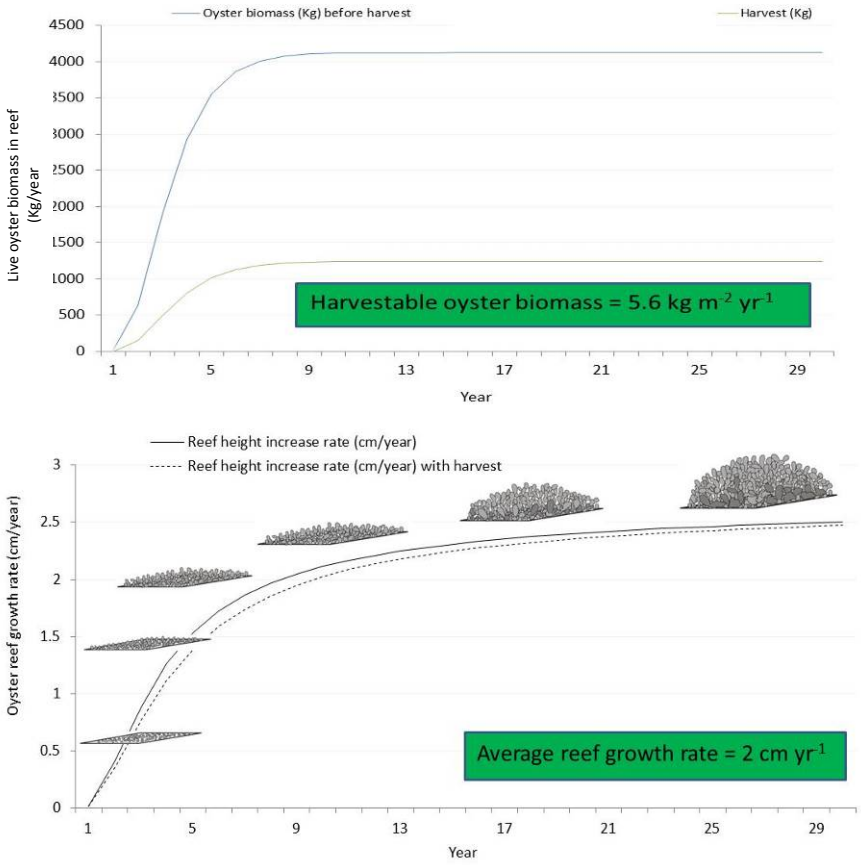

Figure 9. Modelling results using DEB. Top: development of oyster biomass over 30 years and harvestable oyster biomass. Bottom: reef height development over 30 years.

Supply chain and market analysis

The supply chain and market analysis showed that trade in bivalves between developing countries and major markets (e.g. EU, US, Japan) is not as developed as trade in other seafood products. Importing countries (also within the South-East Asian region) enforce strict regulations on bivalves, because of public health concerns. At this moment Bangladesh is unable to meet these requirements. As a consequence, the current export potential of mollusc (incl. oysters) from Bangladesh is limited.
Within Bangladesh, the mollusc meat is predominantly consumed by the Rakhine people. There is reportedly an informal trade between the Rakhine living in Bangladesh and Myanmar. The Rakhine people consider mollusc meat as special (stir fried and as a soup ingredient) and people are willing to pay more for mollusc meat (200-300 TAKA/kg for blood cockle meat, 200 TAKA/kg for large oysters and 120-160 TAKA/kg for other species) compared to poultry (100 TAKA/kg). The oyster meat is mainly sold within the community. If there is a surplus, this is sold to neighbouring Rakhine communities. As mollusc products have to be consumed the same day, they are sold door-to-door instead of at a market. Hotels and/or restaurants currently do not buy mollusc meat. Access to other inland Rakhine communities (to sell the surplus) is an important criteria for pilot site selection. Shells are sold for decoration purposes at tourist markets in Cox's Bazaar at a price of 130-150 TAKA/kg or as an ingredient for poultry feed or lime production at a price of 100 TAKA/kg.

Community involvement

Involvement of the local community of island people (

Figure 10) has already been manifested in the preparation phase. Through early involvement and cooperation the pilot was embraced by the local people.

Figure 10. Local children of Kutubdia at the reef site (Photo by IMARES).

Social Cost Benefit Analysis

The Social Cost Benefit Analysis(SCBA) aims to describe benefits of eco-engineering in monetary terms compared to traditional engineering using earthen embankments. In the SCBA five different coastal defence structures for Kutubdia Island were evaluated, to get an indication of their costs and benefits and to determine knowledge gaps. It is assumed that all these five alternatives for coastal defence provide equal safety (flood protection):

1. Earthen embankment (EE): the current coastal defence structure (reference situation)
2. Earthen embankment with shoulders of concrete (EE+SH)
3. Earthen embankment with oyster reef structure (EE+RS)
4. Earthen embankment with Mangroves (EE+Mang)
5. Earthen embankment with oyster reef structure, and Mangroves (EE+RS+Mang)

In a SCBA all effects are taken into account (positive & negative):

- Effects with money transfer (e.g. investments costs) and without money transfer (e.g. ecosystem services)
- Costs and benefits in future are valued as Net Present Value (NPV) using a discount rate, to compare costs and benefits. Total costs consist of investment costs and operations and maintenance costs. The benefits are partly qualitative (adaptation to sea level rise and ecosystem goods and services like crab harvesting) and partly monetary (value oyster harvest).

if the benefits exceed the costs a measure is potentially attractive.

In the current situation the Earthen Embankment is rebuilt after a storm. This happens with a frequency of four times every five year (Figure 11). A reef structure in combination with mangroves will reduce

wave energy and erosion and enhance deposition. Thus, as can be seen in Figure 11, the reef structure will increase the lifetime of the earthen embankment and reduce the related costs (Figure 12).

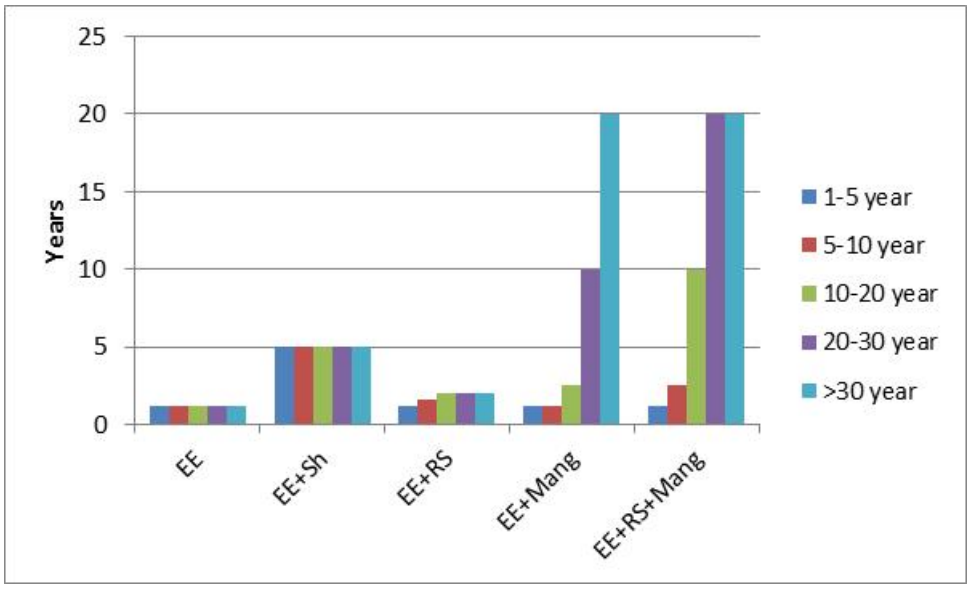

Figure 11. Lifetime of the earthen embankment in different periods (after start).

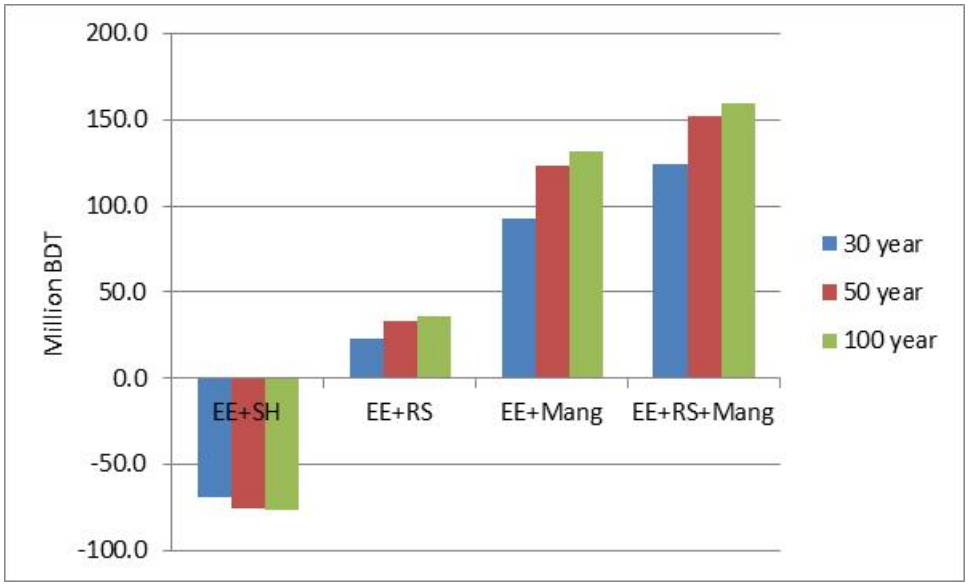

Figure 12. Social cost benefit balance of the four alternatives, compared with the current situation (EE) for different SCBA time horizons (30,50 and 100 years), using a 7.5% discount rate. BDT = Bangladeshi Taka.

Major outcomes of the SCBA:

- The combination of Earthen Embankments with oyster reef structures and mangroves has the highest benefits (compared to the current situation).
- If benefits which are not yet valued in monetary units (e.g. crab, wood, honey) are included, Earthen Embankments with oyster reef structures and Mangroves have an even higher cost benefit balance.
- Earthen Embankments with oyster reef structures and mangroves provide more climate adaptation possibilities than the other measures analysed.

The reduction in maintenance and reconstruction costs and the subsequent change in lifetime of earthen embankment determines for a large part the results of the SCBA analysis.

Popularizing sea food

In 2013 ECOBAS partners organised a cook workshop and developed a cook book “Cook the Ocean Bangladesh style” in order to enhance interest in sea food preparation and home consumption(Figure 13).

Figure 13. Left: sea food cooking workshop. Right: a cook book that was developed by ECOBAS partners to popularize sea food in Bangladesh.

ECOBAS meetings

During the ECOBAS project several meetings were organised and conferences were attended:

- Joint Dutch-Bangladesh project meeting & workshop on 14-15 November 2012, in Chittagong, Bangladesh.
- Joint Dutch-Bangladesh project meeting on 22-23 November 2013 in Chittagong, Bangladesh. The mission report is included in Appendix A.
- Joint Dutch-Bangladesh project meeting on 23rd of September 2014 in Yerseke, the Netherlands
- Presentation of ECOBAS results at conference “Delta’s in times of climate change”, 24-25 September, Rotterdam
- Presentation of project results at the India-EU MARECLIM III workshop “Coastal zone management and impact on society” (Kerala, India, 6-9 October 2014)
- Presentation of results at the ECOBAS conference 26th of November 2014, BRAC Centre, Dhaka, Bangladesh. Over 40 participants were present with people from government agencies, enterprises, research institutes and universities. Chief guest was the Minister of Water Resources (Figure 14). Special guest was Prof. Dr. Iftekhar Uddin Chowdhury, Pro-Vice Chancellor of the University of Chittagong. The powerpoint presentations of this meeting are can be found on the following website: http://www.wageningenur.nl/nl/nieuws/Oesters-en-mangroves-beschermen-Bangladesh-tegen-overstromingen.htm.

Figure 14. ECOBAS conference on 26th of November in Dhaka: chief guest, Barrister Anisul Islam Mahmud, Minister of Water Resources, Government of the People's Republic of Bangladesh gives his speech (Photo by Chittagong University).

Public outreach

The ECOBAS project received considerable attention in the media and tried to disseminate its findings to a broader public by actively communicating our concept and project results to the media. This has resulted in considerable press coverage (Volkskrant, technical media, Bangladeshi newspapers, Bangladeshi radio and TV). In December 2014 the major TV channel of Bangladesh, Channel i, broadcasted a thirty minute talk show on eco-engineering including interviews with several researchers (please refer to https://www.youtube.com/watch?v=qZt0S9Esgcs) and ECOBAS was an item on the Channel I news in November. To better explain the concept a short animation was produced by the project team in cooperation with animation experts to better explain the concept. This animation on eco-engineering in Bangladesh has already received over 777 hits (as on 16/02/2015) in Youtube (https://www.youtube.com/watch?v=9lq8SeiDUEA).

Future perspective

The general interest in the eco-engineering or building with nature concept for sustainable coastal defence has increased considerable the last few years (e.g. Cheong et al. 2013, Temmerman et al. 2013). The ECOBAS project achieved to promote successfully the concept in Bangladesh. On the final conference in November 2014, the Minister of Water Resources responded very enthusiastically to the concept on eco-engineering and also advocated further development of these concepts in Bangladesh. Also the Embassy of the Netherlands expressed its interest and is sincerely willing to support future initiatives. Besides, meetings with potential interested clients for up-scaling, such as the Bangladesh Water Development Board, Blue Gold program, CEGIS, IWM, DUET etc., resulted in general in positive reactions. So far, however, this has not resulted in concrete assignments for up-scaling.
IMARES-Wageningen UR together with the University of Chittagong will continue further research on oyster reefs for coastal defence in Bangladesh. For this purpose we applied for and were awarded a Nuffic fellowship, enabling one of the Bangladeshi researchers to work for 4 more years on this subject as part of a PhD project. One of the aims of the PhD project is further monitoring the ECOBAS experimental site on Kutubdia Island.

In a next phase, we recommend to put emphasis on further optimizing and implementing the concept of eco-engineering for risk reduction and climate change adaptation along the coast of Bangladesh. The aim is realize the full impact of ECOBAS, to broaden the approach, and to provide insight in the conditions

under which coastal ecosystems can be valuable for coastal protection and to design (restore or develop) these systems in such a way that ecosystem services are maximised. In this approach a natural ecosystem approach in the designs for coastal risk reduction is suggested. The whole foreshore should be taken into consideration, in which, depending on the settings, tidal flats, biogenic reefs (e.g. oyster reefs), salt marshes and mangroves should be included, as a protective zone in front of the (earthen) embankments. Such hybrid approaches will better reduce risks and hazards and at the same time support many valuable additional ecosystem services. One of these ecosystem services is food security provided by these ecosystems. As shown by the ECOBAS project, coastal ecosystems like reef structures can provide a food source to the local community. In addition, mangroves are important nursery grounds and feeding areas for many fish and crustaceans (Laegdsgaard & Johnson, 1995).
Activities foreseen include:

- to build operational frameworks, using an eco-engineering approach, for coastal defence planning and implementation in Bangladesh which operate across the natural and social sciences;
- identify where along the coast of Bangladesh ecosystems can contribute to risk reduction and identify which ecosystems are most promising (depending on the local settings);
- set up of large demonstration project(s) in which the approach is further being tested, monitored and evaluated;
- organize stakeholder involvement and participation of local community
- effective valuation of the ecosystem services delivered by the eco-engineering approach compared to traditional engineering, including cost-benefit analysis.

Cooperation between project partners and international partners

The cooperation between all consortium partners has been productive. The project benefitted from the multidisciplinary composition of the consortium. During the project the collaboration between Dutch and Bangladeshi partners has strengthened substantially and it is the intention of all partners to continue this relationship by looking jointly for new research opportunities.

Innovation

The concept of eco-engineering for coastal adaptation is definitely new and innovative, not only in Bangladesh but also in other regions worldwide, as was for instance experienced during the EU-India workshop in India. The concept is increasingly emerging in high-ranked journals and publications, but needs further implementation and understanding through real-world applications and examples.
Coastal ecosystems provide many benefits to humans, and ECOBAS is one of the first projects where coastal protection and food production (in an experimental way) were combined. Sustainable aquaculture provides an important complimentary source of food security, human nutrition and poverty alleviation in many rural areas worldwide, and ECOBAS showed that coastal ecosystems like oyster reefs can provide such benefits. Especially in Bangladesh not many people are familiar with oysters, and cooking of oysters for home consumption. Therefore, the project initiated a number of cooking classes and published a cook book for local sea food.

Evaluation

The main successes are the novelty of the ECOBAS concept, the interest it has generated among stakeholders and in the media, the successful application for continued research (Nuffic fellowship), and the cooperation between all consortium partners. Tough there were also complications and challenges during this project and some outcomes were different than expected. For example the extreme environmental conditions in the south east of Bangladesh (varying water salinity and sediment loads and dynamics), resulted in a more time-consuming testing phase. Also, data collection proved more challenging because sufficient monitoring equipment was not always at hand and logistics limited. Even with extra monitoring provided by EKN the oysters did not reach consumable size in 2014. Concerning the market value of oysters analysis showed that the market for oysters is not as well developed as for

other sea food products. This could be stimulated by promoting oyster harvest with the Rakhine people. Also the calcareous shell material and meat could be used for several goals (e.g. fish feed).
For the Dutch side, an important lesson is that concepts like the one proposed here (i.e. eco-engineering for coastal adaptation) are exportable to other countries like Bangladesh, but the implementation requires tailor-made techniques and solutions, based on a thorough understanding of the local and regional socio-ecological conditions. This requires substantial efforts that cannot be achieved within the frame of a 3 year project. Therefore, ECOBAS provided a first step towards application of the concept, but further steps are needed. This can be achieved through further joint collaboration, education of students and young professionals, and scaling-up of the pilot experiments.

Contribution to Partners for Water programme

The PvW financial support has been essential for the implementation of the ECOBAS project. This project gave the opportunity to bring innovations and experiences from the Netherlands to Bangladesh and test the concept of eco-engineering in a different environmental and socio-economical setting with local experts. Also, it was possible to develop a close cooperation with local partners and give broad exposure to the innovation of eco-engineering. This may benefit possible business opportunities in the future.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Appendices

Appendix A: Mission report November 2013

ECOBAS

Eco-engineering for Coastal Defence and Food Production in Bangladesh

19-25 November 2013

Mission report Marijn Tangelder & Tom Ysebaert (IMARES)

Introduction

The objective of the ECOBAS project is to provide the coastal people of Bangladesh with an alternative technique for climate change adaptation, by using the natural resistance of shellfish reefs against hydrodynamic forces, in order to reduce human vulnerability to coastal erosion and flooding, as well as to deliver a source of aquatic food. ECOBAS stands for Eco-engineered Coastal Defense Integrated with Sustainable Aquatic Food Production.

In the first phase of the ECOBAS project, reefs made of bamboo were installed at Kutubdia and Moheshkali Island in 2012. These bamboo mattresses contained four different substrates (dead oyster shells, living oysters, window pane shells and stones). This experiment provided data on spat settlement, growth and survival of oysters. However, the reefs made of bamboo frames have proven vulnerable to destruction by hydrodynamic forces, in particular in the monsoon season, and smothering of fine sediments and silt on the substrates, suffocating the oysters.

In the second phase of the project a new reef was installed on the south-east coast of Kutubdia Island made out of a concrete structure. Community involvement of island people was started in the preparation phase. The concrete reef is elevated above the sediment level that can serve as suitable substrate for oyster spat settlement. By monitoring biological and hydromorphological parameters the feasibility of application of such a reef in reduction of coastal erosion is investigated. Furthermore, a Social Cost Benefit analysis (SCB) will address economic potential of the reef in a socio-economic context.

This report describes the findings of the mission with Bangladeshi and Dutch partners from 19-25 November 2013.

Objectives

The objectives of this mission were:

Visit the reef site at Kutubdia island and mangrove plantation areas near Chittagong

Project workshop:

Discuss monitoring data collected so far

Discuss monitoring plan for 2014

Discuss overall framework of ECOBAS and conceptual model for oyster reef development aimed at coastal protection and aquatic food production

Discuss Social Cost Benefit analysis

Meeting with Mr. Martin Bos (NL embassy, Dhaka) on project progress (IMARES participants only)

Meeting with Mw. Catharien Terwisscha, (Wageningen project office, Dhaka) (IMARES participants only)

Activities

Mission participants that were present during (part of) the programme:

University of Chittagong:

Prof. Sayed Chowdhury, Dr. Shahadat Hossain, Dr. Sharif Sharifuzzaman,

Students: Mr. Avijit Talukder, Mohammed Shah Nawaz Chowdhury, Mr. Royhamur Islam Rasel (Chittagong University).

Wageningen UR: Prof. Dr. Tom Ysebaert and Ms. Marijn Tangelder (IMARES), Mr. Arie van Duijn (LEI), Mr. Mohammad Asadi (student).

Table of activities:

Date	Activity	Joining
20-11	- Visit to reef site at Kutubdia Island	Whole team, excluding Arie van Duijn
21-11	- Visit mangrove plantation sites near Chittagong - Workshop preparation	Whole team

22-11	Internal workshop in Chittagong - Presentation of Bangladeshi counterparts and plenary discussion on monitoring results - Presentation of Dutch counterparts and plenary discussion: experience with oyster reef pilot in the Netherlands, framework for ecological engineering in Bangladesh, conceptual model oyster reef, social cost benefit analysis - Student research on eco-physiology by Mr. Mohammad Asadi	Whole tea
23-11	Internal workshop - Continuation of model discussion and social cost-benefit analysis - Monitoring plan for 2014	Whole team
24-11 morning	Meeting with Mr. Martin Bos Embassy of the Kingdom of the Netherlands, Dhaka	Tom Ysebaert and Marijn Tangelder
24-11 afternoon	Meeting with Mw. Catharien Terwisscha Wageningen project office, Dhaka	Tom Ysebaert and Marijn Tangelder

Field trip to Kutubdia Island

In April 2013 the concrete reef, made out of 69 concrete rings, was installed. The reef is 45 meters long and situated 215 meter out of the earthen embankment on Kutubdia Island on the tidal flat (see Progress report, 2013 and figure 1). Mission participants have visited the reef on 20th of November 2013. Due to low spring tide in the morning the reef was fully exposed.

Figure 1. Situation of the concrete reef on Kutubdia Island.

The reef is located in front of an earthen embankment (Figure 2, 5). On the embankment some houses of island people are located. During monsoon storms severe erosion of the earthen embankment took place which was not repaired yet by the time of visiting. Around 100 meter to the south the embankment is protected by a newly constructed concrete shoulder.

Figure 2. The concrete reef on Kutubdia Island. Photo taken on 20 November 2013.

General ideas developed during the visit: In the close proximity of the reef a mangrove plantation area is present (Figure 1). The mangrove saplings were planted a few years back. This is a government project supported by local people to reduce erosion of the tidal flat. The saplings were still relatively small but were rooted well in the tidal flat. Between the mangrove zone and the concrete reef a zone of salt marsh vegetation (probably *Spartina* sp.) is present. The presence of the reef could enhance salt marsh and mangrove development. Altogether they could form a cascading protection zone (reef – salt marsh – mangrove) to minimize erosion of the earthen embankment. It is important to consider the oyster reef in this broader context. This was discussed during the workshop.
The reef itself was still well in place and seemed to have survived the monsoon season in good order. Also there were no signs of substantial scouring around the bed level of the rings. Inside the rings sediment accumulates, but will not accumulate above the openings in the rings. On the inner side of the rings more oysters were present than on the outer side. The oysters that were visible are estimated to be around 1-5 cm long (Figure 3). Recruitment of new larvae is still expected (November).
Besides oysters, also other species were present on the surface of the reef (non-target species) (Figure 3). Barnacles were abundantly present on the inner as well as the outer side of the concrete rings. Also sea anemones and zones with green algae cover were seen. The abundant occurrence of barnacles might prevent settlement of oyster larvae.

Figure 3. A settled oyster on the inner side of one of the concrete rings (left); fouling with barnacles on the rings (middle); inspection of the reef (right). Photos taken on 20 November 2013.

During flood the effect of the reef on sedimentation/erosion processes became clearly visible (Figure 4). Behind the reef (i.e. the lee side of the reef), a sedimentation area is present that stretches out over several 10s of meters. This area is clearly elevated compared to the area in the foreground and background of the photo. The main factor causing this less dynamic area behind the reef is most likely the wave dampening effect of the reef. This nicely compares to the effects seen on oyster reefs in the Oosterschelde (The Netherlands), where similar patterns are observed. We discussed in the field how to optimize the measurements to really quantify the sedimentation/erosion processes (for details see further).

Figure 4.During flood the elevated area behind the reef becomes clearly visible. Photo taken on 20 November 2013.

Local people embrace the concept of the reef and were very interested when mission participants came to visit (Figure 5). The main activities on the island include fishing and agriculture. Also, people collect crabs the tidal flat that are valuable trades on the international market. The reef seems to give additional benefits as crabs get trapped in the rings during low tide and are collected (Figure 5).

Figure 5. Further impressions of the concrete reef and its surrounding. Photos taken on 20 November 2013.

Project workshop
On 21-22 November the project workshop took place in Lords Inn hotel in Chittagong. This meeting was kindly chaired by Dr. Shahadat.

Monitoring, results and experiences
Dr. Shahadat gives a presentation on the monitoring results obtained so far with contributions of Prof. Sayed and Dr. Sharif that is discussed with the group. Data collection of the concrete reef was started in January 2013. Monitoring was done on a monthly basis during low spring tide at new moon. This is because the sea is relatively calm at new moon compared to full moon. Monitoring will continue until end of 2014 (see further).
Spat settlement on the concrete rings was measured and expressed in total spat on all rings. Spat was counted on the inner as well as the outer ring. The data show that there is recruitment all year round, because every month spat are increasing whereas peaks are expected in April/May and October/November. In accordance with the bamboo reef pilot that was carried out in 2011, the spat settlement will be expressed in spat/m^2. Surface areas will be calculated, taking into account possible sedimentation within the concrete rings (decreasing the available surface area for settlement).

For conducting **growth** measurements, 25 rings out of 69 rings were selected. It is too difficult to measure same spat every time, so spat are randomly selected within specific zones on the inner and outer rings. Oyster spat length and width is measured. Because oyster spat are randomly selected we cannot monitor individual growth, but we actually measure mean spat size.

Mortality of oysters is much lower on the concrete rings than on the bamboo reef. We suspect that sedimentation on the horizontal bamboo reef was the cause of the high mortality. The vertical substrate of the concrete reef has no hampering of sedimentation so oyster survival is higher. It is important to keep track of mortality, therefore this will be done by counting dead shells.

Bed level profiles give insight in sedimentation patterns behind the reef, compared to reference location. However, shortly after installation of the reef, the reference site was excavated which disabled measurements there. New reference measurements will be collected in 2014 according an adjusted design (see monitoring 2014). This part is of crucial importance, because it gives us information on the area of influence by the concrete reef. Accumulation is seasonal as mud will erode mainly in the monsoon season. In July there is very limited fine sediment deposit. On the other hand, in October there is more deposition of fine sediment. During the field visit an elevated area behind the reef was clearly visible when the tide came in and gradually flooded the tidal flat.

Total Dissolved Solids are expressed in g/l. The TDS relates to salinity. Salinity is expressed in g/kg. TDS should theoretically by higher than salinity. TDS is measured using electric conductivity meter. The 2012 for TDS are probably expressed incorrect. The 2013 data are correct.

Biofouling of barnacles and anemones will limit available space for oyster settlement. However these "**non target species**" can also provide short term additional benefits as for instance the collection of crabs by the local community people. Possibly also octopuses occur on the reef when flooded. Local fishermen can help to give us information on these non-target species. Removing crabs might also help reduce predation on oyster spat. Although Kutubdia people are not particularly interested in crab as a food source, in contrast to Moheshkali Island, it is probably possible to introduce crabs as a food source in Kutubdia or use them for export.
Where algal cover is present, there are no barnacles observed. These algae develop at the end of the freshwater period. Algae were not present on al rings.

Additional research was conducted by carrying out a **mollusc biodiversity study**. Three islands were monitored (including Kutubdia island). About 250 mollusc species were found. Furthermore a study is conducted on the Alphine shrimp taxonomy. Expected is that 2-3 species are found that are new in the area. This study is a valuable contribution to the overall knowledge on mollusc diversity that is very scarce at the moment.

Mr. Asadi, who is student at Wageningen University, will be in Chittagong for around six weeks to carry out a brief internship research. He will collect living oysters (*Crassostrea madrasensis*) at Kutubdia and keep them under controlled conditions to measure eco-physiological parameters (clearance rate, adsorption, faeces and pseudo faeces). He will further develop his protocol and methodology together with Bangladeshi colleagues. The challenge will be to isolate individual oysters and keep them alive.

Monitoring 2014

The monitoring in 2013 gives valuable data on reef development thanks to the hard work that has been done by Bangladeshi partners last year. In 2014 monitoring will be continued and further improved with emphasis on the issues listed below.

- Bed profile monitoring is continued and reference sites will be included. Ideally two reference transects are monitored: one upstream and one downstream of the reef (see overview below).
- Sediment samples are taken in front and behind the reef at different intervals (see overview below).
- Wave measurements: Prof. Sayed developed an electronic device that sufficiently measures wave height. With high risk of theft, a wave sensor cannot be permanently installed. Wave measurements will be done as much as possible during different wind and wave conditions. Prof Sayed will try to develop a second sensor, sot that simultaneous measurements can be done in front and behind the reef structure.
- An elevated area behind the reef was clearly visible during the upcoming tide. It would be valuable to collect more pictures of the ascending waterlevel as it gradually inundates the tidal flat clearly showing elevated areas. This can be done each month.
- Current velocity: Dutch partners will explore if a simple device like an Ott current meter can be arranged and sent to Chittagong to collect data on current velocities. An easy method that gives an indication of flow velocity and patterns is the release of oranges or other floating elements in the neighbourhood of the reef and follow their flow pattern.
- Meteorological data: There is no weather station close to the pilot site. There is one located at Cox's Bazar but the data from this station seem to be unreliable because the weather station is on top of a mountain. The weather station in Chittagong can provide data that give an idea of weather conditions. Bengal partners will try to acquire these data.
- Crabs that left in the rings will be counted to get an idea of additional values. The local people will be asked to give additional information on the presence of crabs or other organisms.
- Record sediment accumulation inside the rings.
- In addition to the issues described above it is agreed to make a specific and detailed description protocol of the different parameters that are monitored. For example, when measuring TSS, describe precisely where the sample is taken, how deep, what time in the tidal cycle, etc., as well as the method to analyse the parameter. This information is important for data interpretation and eventually publication of the data.

Considering these issues we realize that monitoring time is short due to the limited exposure time of the reef en sometimes takes place in the dark. When time runs short, emphasis should be on monitoring of oysters, water quality, sediment and bed profiles.

Bed profiles using transect measurements

Tom Ysebaert discussed in detail with the Bangladeshi partners the transect measurments. A schematic overview is given in Figure 6. The following is discussed and agreed upon:

- Use smaller measuring distances when approaching the reef, and also behind the reef

- Make notes in which habitat you measure along each transect: bare mudflat, mangrove plantation area, salt marsh, ...
- Take sediment samples at proposed sites. These sediment samples can be analysed in the Netherlands.

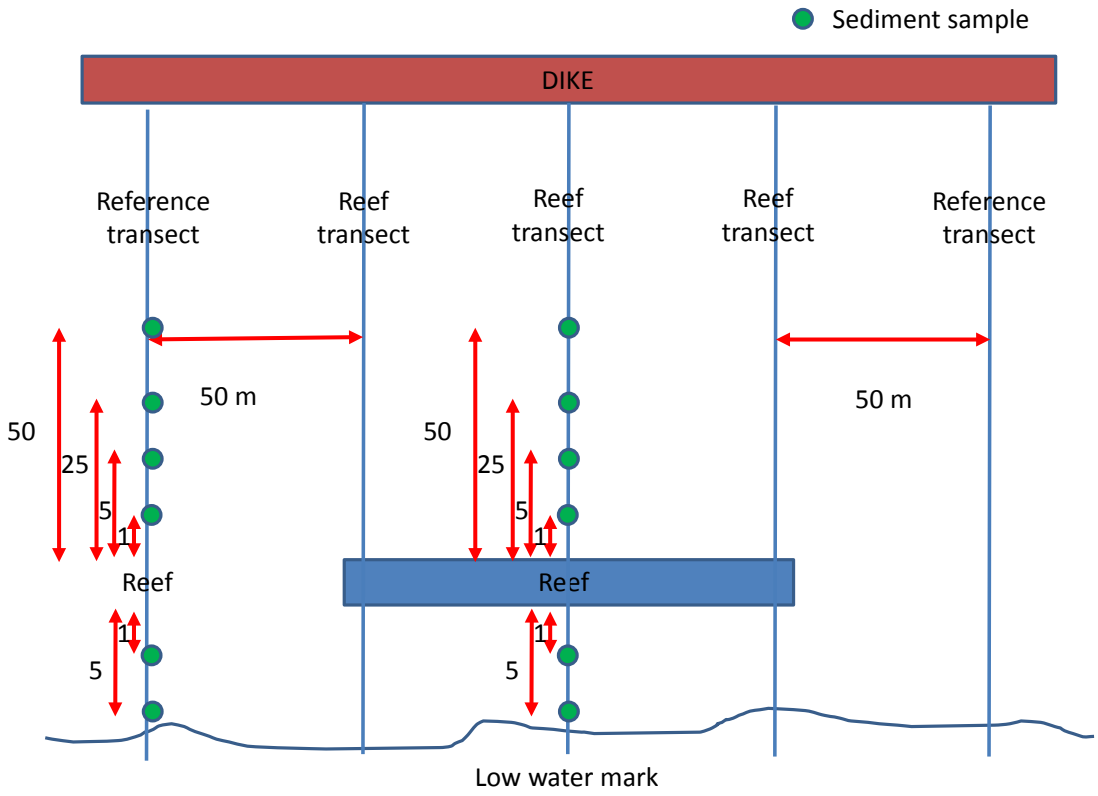


Figure 6. Schematic overview of transect measurements and position of sediment samples.

Development of an overall framework and conceptual model

An important focus of the ECOBAS project is to develop a conceptual model that describes the potential and application of oyster reefs to enhance coastal protection and aquatic food production.

Tom Ysebaert gives a presentation on the experience in the Netherlands with oyster reefs in the Oosterschelde and the broader perspective on the use of ecosystem engineers in coastal defence strategies. Ecological engineering is a very hot topic worldwide. It is a field that is gaining a lot of attention which underlines the relevance of the research (several interesting publications were published recently in high-ranked journals). Different natural protective features of coastal systems occur along an elevational gradient (coral reefs, shellfish reefs, sea grasses, salt marshes, mangroves, dunes). All these habitats with their typical ecosystem engineering organisms can contribute to coastal defence and shoreline protection, but in combination their contribution will be larger due to interactions and synergistic effects. ECOBAS should focus on this approach where we address the combination of ecosystem engineers for coastal adaptation, with a reef structure like an oyster reef as one of the elements.

Tom Ysebaert gives an overview of the experience in the Netherlands with the building with nature concept in general and oyster reefs in particular. Results are compared with the results within the ECOBAS project.

Overall framework

During the workshop we agree that the focus within ECOBAS should not be too narrow with solely focusing on reef structures, but that this should be framed within the broader concept as described above. The oyster reef can be a standalone measure but should preferably be considered within this wider context. A combination of measures is preferred, and in the case of Bangladesh this can be a reef structure in combination with salt marshes and mangroves (Figure 7). Also we need to think long term and also consider growing with sea level rise. Not all concepts are applicable everywhere. For example, the Cox's Bazar coast is in particularly suitable for oyster growth. We agree that the broader concept is not applicable to the whole coast of Bangladesh but in particular to the muddy coasts.

During the workshop also the term oyster reefs is discussed. An oyster reef seems a too narrow definition as it is now being applied within ECOBAS. For the future we should consider to broaden our definition to "reef structures", with an oyster reef as one example of a reef structure. Even when we provide a reef that has (theoretically) nothing growing on it, this structure can still contribute to coastal protection and deliver additional indirect benefits and services (e.g. sedimentation, mangrove expansion etc.). Reef structures can be concrete rings like in ECOBAS, oyster reefs like constructed in the Oosterschelde (gabions filled with shells), or other structures like reef balls that provide substrate for the settlement of oysters and other organisms and/or provide (refuge) habitat for species like crab, lobster, fish. As for the ECOBAS project, we decide to keep to our main objective, that is the combination of a reef structure for coastal protection with the production of oysters.

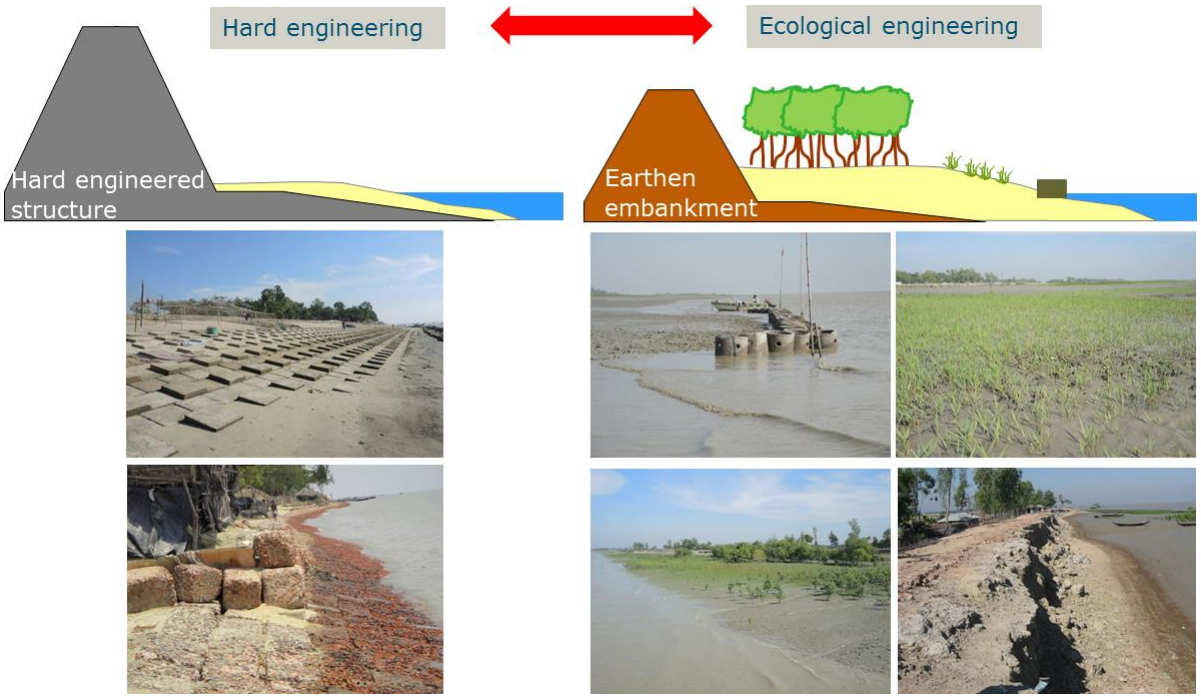


Figure 7. Hard engineering versus ecological engineering for coastal adaptation in Bangladesh.

Conceptual model

The conceptual model should describe how to develop and apply an oyster reef for coastal defence and food production within ecological as well as socio-economic boundary conditions. Dr. Shahadat proposed a structure for the conceptual model (Figure 8) that considers the 'suitability' for an oyster reef. This conceptual scheme should be further developed and underpinned with monitoring data, literature and expert opinion. Also we shall develop ranking and weighing factors for elements in the model. The coming year the model shall be further developed and refined and applied to the Kutubdia reef experiment.

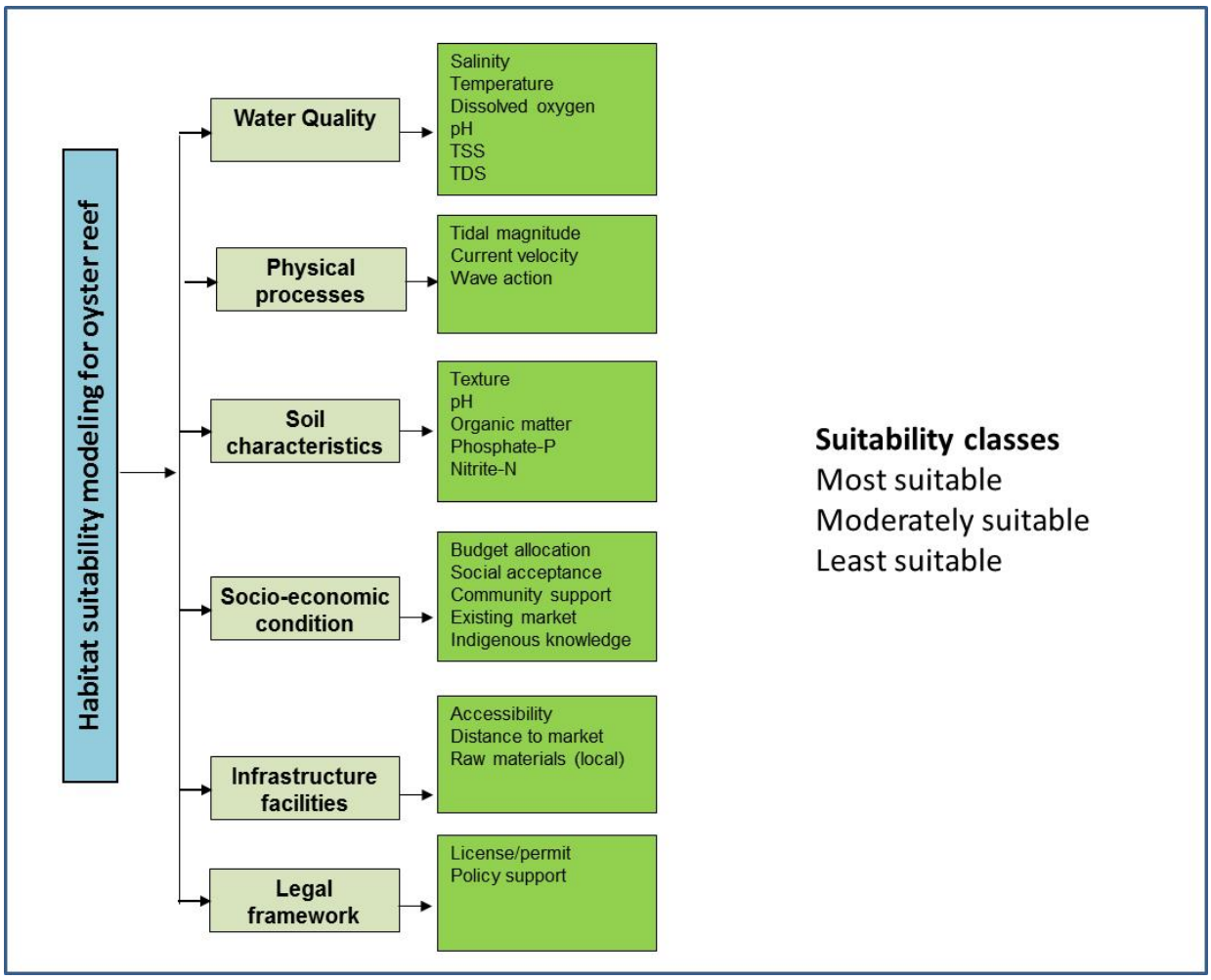


Figure 8. Conceptual suitability model for oyster reefs.

Social cost benefit analysis

Mr. Arie van Duijn discusses the guidelines for a Social Cost-Benefit Analysis (SCBA) of the eco-engineered shell fish coastal defence structures along the coasts of Kutubdia Island. Arie proposes a structure for the SCBA that is filled in together with the team. This discussion is summarized below.

Approach: compare alternatives based on cost & benefits, Net Present value, Sensitivity analysis, risks.

Alternatives to compare an oysterreef to:

- earthen embankment with shoulders
- earthen embankment
- sand filled tubes

Selection criteria for coastal defense alternatives**:**
- time frame
- Primary and secondary protection

Five scenarios were selected for comparison:

#	Scenario	Secondary measure
1	Earthen Embankment (EE)	-
2	EE with shoulders	-
3	EE + secondary measure(s)	Oyster reef
4		Mangroves
5		Oyster reef, salt marsh and mangroves

Remarks:

- Earthen embankment with shoulders and secondary measures is not taken into account as well as standalone secondary measures (only relevant in unpopulated Sunderban area).
- We include "Salt marsh vegetation" (*Spartina sp, Portasia caudata*), and sea grass (*Halophila beccari*).
- We exclude concrete blocks

Lifetime of coastal defence options

#	Scenarios	Average lifetime
1	Earthen Embankment (EE)	Average 6 months (high energy env. Prone to erosion)
2	EE with shoulders	Several years
3	EE + Oyster reef	-
4	EE + Mangroves	Should last as long as mangroves grow naturally
5	EE + Oyster reef, salt marsh and mangroves	-

- Life cycle of earthen embankments. These erode in monsoon season. They are not repaired until April. This has several reasons: the financial year doesn't start until July, bureaucracy also delays contractors, these are general purpose contractors. In high energy environments, where erosion is year round, lifetime is 6 months. In many places it will be longer.

Lifetime is uncertain and unknown.

The effectiveness of different alternatives is expressed. Effectiveness is defined here as the degree of contribution of an alternative to coastal protection, social and financial factors (investment and operation).
An oyster reef is effective if it breaks waves and enhances tidal flat deposition.
Earthen embankment (+ shoulders) is effective when it stop the water from intruding the land.
Alternatives need to be able to keep up with sea level rise.

The self-sustaining of different alternatives is expressed. A self sustaining alternative can sustain itself involving minimal economical input for as long as necessary. This is determined based on lifetime and self-maintaining capacity of different alternatives.

Risk of damage due to human activities is dependent on resource extraction, vandalism, etc.

Meeting with Wageningen project office, Dhaka

On Sunday 25th of November Dr. Tom and Marijn have visited Mw. Catharien Terwisscha van Scheltinga who is member of the Wageningen project office in Dhaka.

Notes:

- Mangroves are managed by the Ministry of Environment and Forest.
- Involve the Waterboard in the broader concept of ECOBAS
- Myanmar Maritime University in Yangon might also be interested in the ECOBAS concept
- We could include ECOBAS to the Wur Bangladesh website (-> Marijn)

Meeting at NL Embassy on project progress

On Sunday 25th of November Tom Ysebaert and Marijn Tangelder visited Mr. Martin Bos (First Secretary, Water Sector) at the NL Embassy in Dhaka. The goal of this visit was to inform him about the project progress. Mr. Martin Bos was very pleased with the progress made and the ECOBAS team is very grateful to the NL Embassy for their support that allows an extra year of monitoring. The final workshop of the ECOBAS project in 2013 was shortly discussed.

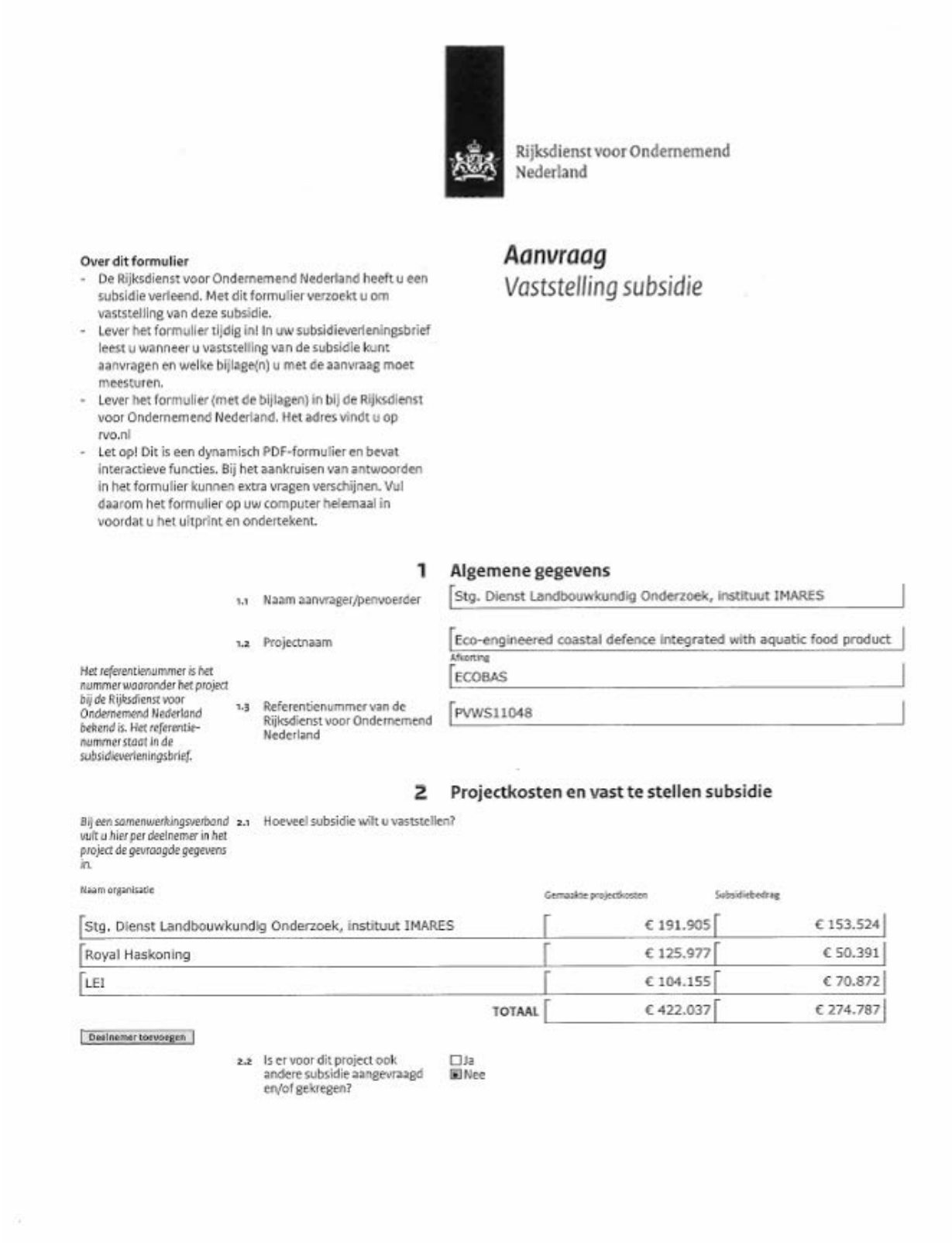
Additional notes:

- The Embassy is willing to assist in the organisation of a workshop mid 2014 where we discuss the broader concept of ECOBAS. Participants could be from: Waterboard, Ministry of Forestry, CEGISS, Blue Gold, IWM, Balance Island, Building with Nature.
- Jan Wal, who is working with Mott MacDonald is an interesting contact on mangrove planting. He is working with the social forestry group in Noakhali District.

Further steps and planning

- Continue monitoring until December 2014 and improve where possible (see “monitoring 2014”)
- Further define conceptual model
- Further define Cost Benefit Analysis
- Workshop with Water Board (May 2014)
- End workshop, international (December 2014)

Appendix B: Vaststellings formulier Partners voor Water



Rijksdienst voor Ondernemend Nederland

Over dit formulier

- De Rijksdienst voor Ondernemend Nederland heeft u een subsidie verleend. Met dit formulier verzoekt u om vaststelling van deze subsidie.
- Lever het formulier tijdig in! In uw subsidieverleningsbrief leest u wanneer u vaststelling van de subsidie kunt aanvragen en welke bijlage(n) u met de aanvraag moet meesturen.
- Lever het formulier (met de bijlagen) in bij de Rijksdienst voor Ondernemend Nederland. Het adres vindt u op rvo.nl
- Let op! Dit is een dynamisch PDF-formulier en bevat interactieve functies. Bij het aankruisen van antwoorden in het formulier kunnen extra vragen verschijnen. Vul daarom het formulier op uw computer helemaal in voordat u het uitprint en ondertekent.

Aanvraag
Vaststelling subsidie

1 Algemene gegevens

1.1 Naam aanvrager/penvoerder: Stg. Dienst Landbouwkundig Onderzoek, instituut IMARES

1.2 Projectnaam: Eco-engineered coastal defence integrated with aquatic food product

Afkorting: ECOBAS

Het referentienummer is het nummer waaronder het project bij de Rijksdienst voor Ondernemend Nederland bekend is. Het referentienummer staat in de subsidieverleningsbrief.

1.3 Referentienummer van de Rijksdienst voor Ondernemend Nederland: PVWS11048

2 Projectkosten en vast te stellen subsidie

Bij een samenwerkingsverband vult u hier per deelnemer in het project de gevraagde gegevens in.

2.1 Hoeveel subsidie wilt u vaststellen?

Naam organisatie	Gemaakte projectkosten	Subsidiebedrag
Stg. Dienst Landbouwkundig Onderzoek, instituut IMARES	€ 191.905	€ 153.524
Royal Haskoning	€ 125.977	€ 50.391
LEI	€ 104.155	€ 70.872
TOTAAL	€ 422.037	€ 274.787

Deelnemer toevoegen

2.2 Is er voor dit project ook andere subsidie aangevraagd en/of gekregen? ☐ Ja ☒ Nee

Aanvraag

Vaststelling subsidie
Rijksdienst voor Ondernemend Nederland

3 Checklist bijlagen

3.1 Kruis aan welke bijlagen u meestuurt

☒ Eindverslag over de uitvoering van de activiteiten en de resultaten ervan.

Voor Stg. Dienst Landbouwkundig Onderzoek, instituut IMARES
☐ Controleverklaring
> *Is de organisatie een onderwijs- of onderzoeksinstelling en wordt de verantwoording van dit project in de FRS/Sisa-bijlage opgenomen, dan is een controleverklaring niet nodig.*

Voor Royal Haskoning
Geen verdere bijlage(n) benodigd.

Voor LEI
Geen verdere bijlage(n) benodigd.

4 Verklaring en ondertekening

- Ik ben bevoegd en/of gemachtigd om deze aanvraag te ondertekenen.
- Ik verklaar dat dit formulier naar waarheid is ingevuld.

4.1 Ondertekenaar

Titel(s)	Voorletter(s)	Tussenvoegsel(s)
Dr.	M.C.Th.	

Achternaam: Scholten

☒ Man
☐ Vrouw

4.2 Organisatie

☒ Aanvrager
☐ Intermediair

4.3 Datum

Dag	Maand	Jaar
0 9	0 3	2 0 1 5

4.4 Handtekening

5 Vervolg

U levert het formulier in
Stuur het ingevulde en ondertekende formulier tijdig naar de Rijksdienst voor Ondernemend Nederland. Het adres en informatie over de uiterste inleverdatum vindt u in uw subsidie-verleningsbrief.

Heeft u daarna nog vragen?
Neem dan contact op met de Rijksdienst voor Ondernemend Nederland. De contactgegevens staan vermeld in uw subsidieverleningsbrief.

We verwerken uw persoonsgegevens, omdat dit noodzakelijk is voor de uitvoering van het subsidieprogramma. Uw persoonsgegevens worden niet voor andere doeleinden gebruikt en worden niet langer bewaard dan noodzakelijk is. Voor meer informatie zie rijksoverheid.nl/privacy

Appendix C: Financial overview

Penvoerder/aanvrager 1:	DLO (IMARES)
Projecttitel:	Eco-Engineered coastal defence Bangladesh

Organisatiesoort. Penvoerder/aanvrager 1 is een:	**Onderzoeksinstelling of non-gouvernementele organisatie**
Maak een keuze tussen de integrale kostensystematiek, de loonkosten plus vaste opslag-systematiek of de vaste uurtarief-systematiek:	**Integrale kostensystematiek**

1. Directe en indirecte kosten op basis van integraal tarief

Medewerker	Functie	Uurtarief	Uren	Uren x tarief
2014				0
Marijn Tangelder	junior onderzoeker	89.00	133	11,837
Tom Ysebaert	onderzoeker	116.90	97	11,339
Arjo Rothuis	senior onderzoeker	139.90	50	6,995
Aad Smaal	senior onderzoeker	139.90	40	5,596
2013				0
Christiaan vd Sluis	junior onderzoeker	84.70	14	1,143
Marijn Tangelder	junior onderzoeker	84.70	72	6,056
Tom Ysebaert	onderzoeker	109.10	60	6,546
Arjo Rothuis	senior onderzoeker	130.90	43	5,629
Aad Smaal	senior onderzoeker	130.90	56	7,330
2012				0
Christiaan vd Sluis	junior onderzoeker	85.50	141	12,013
Aad Smaal	senior onderzoeker	130.00	12	1,495
Tom Ysebaert	onderzoeker	109.90	76	8,352
Arjo Rothuis	senior onderzoeker	130.00	223	28,990
			Subtotaal:	113,322
			Geen opslag	0
			Totaal:	**113,322**

2. Projectspecifieke kosten verbruikte materialen

Omschrijving	Prijs per hoeveelheid	Hoeveelheid	Hoev.x prijs
Documentatie en voorlichtingsmateriaal	1,240.83	1	1,241
			0
			0
			0
			0
			0
			0
			0
			0
		Totaal:	**1,241**

Penvoerder:	DLO (IMARES)
Projecttitel:	Eco-Engineered coastal defence Bangladesh

3. Projectspecifieke kosten gebruik apparatuur

Omschrijving	Kosten
	0
	0
	0
	0
	0
	0
	0
	0
Totaal:	**0**

4. Projectspecifieke aan derden verschuldigde kosten

Omschrijving	Kosten
Kosten monitoring pilot door lokale onderzoekers	54,133.45
Reiskosten binnenland 2012 (vd Sluis, Ysebaert, Rothuis)	205.61
Reiskosten binnenland 2013 (Ysebaert, Rothuis, Tangelder)	46.13
Reiskosten binnenland 2014 (Smaal, Rothuis, Tangelder)	677.14
Reis- en verblijfskosten buitenland 2012 (Rothuis, Smaal, Sluis, Ysebaert)	14,476.75
Reis- en verblijfskosten buitenland 2013 (Smaal, Rothuis, Tangelder)	5,202.30
Reis- en verblijfskosten buitenland 2014 (Tangelder, Rothuis, Chowdury)	2,600.32
Totaal:	**77,342**

5.	**Totale projectkosten**	Totaal: **191,905**

Justification

Rapport C048/15
Project Number: 4303105401

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

Approved:	Dr. Pauline Kamermans Senior scientist
Signature:	
Date:	17th of March 2015

Approved:	Dr. Robert Trouwborst Head of department Delta and Aquaculture
Signature:	
Date:	17th of March 2015