Title: Coastal protection and seafood security in Bangladesh: Food for Thought

Contribution to the Ocean/Blue Economy for Bangladesh Workshop, 22-23 November 2017, Dhaka, Bangladesh

Authors: Tom Ysebaert, Henrice M. Jansen, Marnix Poelman (Wageningen Marine Research, The Netherlands)

Introduction

Healthy marine and coastal ecosystems, and their services, are essential to maintain the earth's life support system. Blue economy refers to the sustainable use of ocean resources for economic growth, improved livelihoods and ocean ecosystem health. It largely depend on marine and coastal ecosystems and the resources these ecosystems offer, but one that employs ecosystem-based and environmentally-sound technologies and practices. In order to sustainably use our coasts and oceans and to protect the health, livelihoods and welfare of people, it is increasingly recognized that at the same time we should also protect our coasts and oceans and reduce environmental risks and biodiversity losses. Furthermore, marine and coastal ecosystems are essential for future climate change mitigation and adaptation and measures should be implemented in such a way that these services are not jeopardized but strengthened.

In this contribution the authors, researchers at Wageningen Marine Research (The Netherlands), highlight their vision and present their expertise within the field of Blue Economy, focusing on nature-based solutions (Building with Nature) and food security.

Framework

Ocean and coastal resources and the space offering these resources will be increasingly used over the next decades (inevitably and substantially) with 9 billion people in 2050 all requiring food, energy, minerals, and space. This requires novel concepts, knew knowledge, sustainable and innovative alternatives and tools and spatial planning. Important issues include green energy at sea, transport and shipping, fisheries, environmental protection and biodiversity, seafood security and coastal protection (Figure 1).

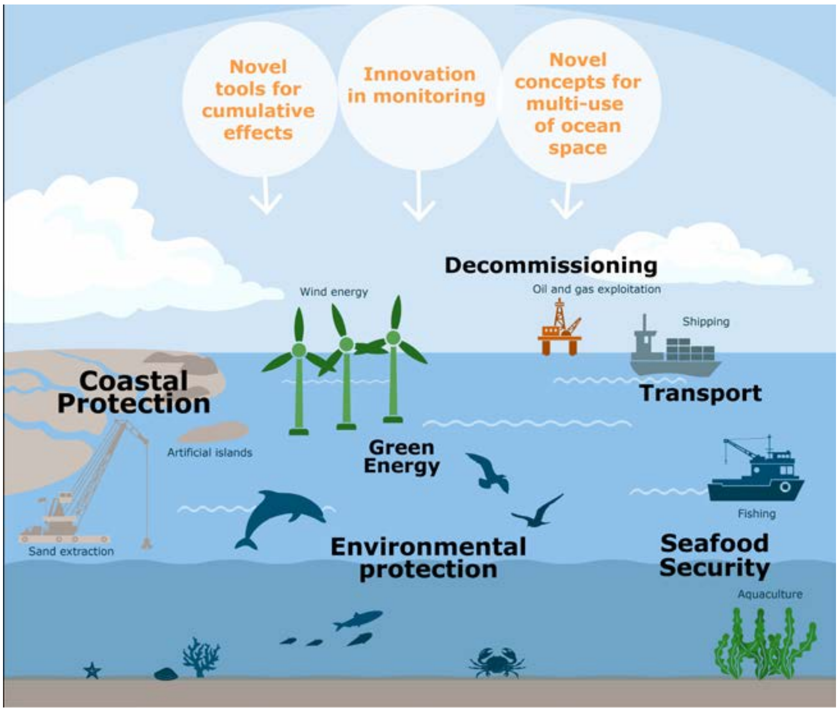


Figure 1. Some major challenges for a Blue Economy (figure from Wageningen Marine Research Development Plan 2017-2020).

In this contribution we deal with the following topics:

- Nature-based solutions at the land-ocean interface: Building with Nature
- Sustainable seafood security
  - Integrated multi-trophic aquaculture (IMTA)
  - Seaweed production

Nature-based solutions at the land-ocean interface: Building with Nature

Goal: Using knowledge of the natural environment and ecosystems to develop novel alternatives for coastal protection, food production and nature development that offer mitigation and adaptation to climate change.

Introduction

The impacts of climate change, from rising sea levels to increasing storm frequency and devastating floods and droughts, are affecting millions of people around the world. As a result there is an urgent need for robust and effective strategies and actions which allow human society and ecosystems to adapt to a changing world.

Healthy, well-functioning ecosystems offer risk reduction and enhance natural resilience to the adverse impacts of climate change and reduce the vulnerability of people. Ecosystem-based approaches offer a valuable, yet under-utilized way for climate change adaptation, complementing traditional actions such as infrastructure development. At the same time it offers multiple other benefits, including the provision of food.

The coastal area of Bangladesh

The coastal area of Bangladesh, being part of the Bay of Bengal, accounts for 32% of the its total land area, sustaining the livelihoods of more than 37 million people. The coastal area includes critical ecosystems such as tidal wetlands and mangroves (e.g. Sundarbans), as well as important natural resources (fisheries, agriculture, etc.). The Ganges-Brahmaputra tidal delta plain is by nature a very dynamic, diverse and active delta (Brammer 2014). The Bay of Bengal receives enormous amounts of freshwater from the Ganges-Brahmaputra-Meghna rivers, together with enormous amounts of sediments from the Himalayas, making it an ideal place for land reclamation. Human interventions, however, such as channelization and mangrove deforestation, changed drastically the water flow and sediment deposition processes in the coastal area, resulting in exacerbated land subsidence, increased (river bank and coastal) erosion and salt water intrusion (e.g. Auerbach et al. 2015, Brammer 2014). On a longer time scale, salt intrusion is aggravated by a tilting tectonic plate, which has reduced the volume of fresh water reaching the delta, particularly in the dry season. Combined with increasing water consumption upstream and an expected reduced water flow from the Himalayans, the potential of traditional arable farming in the southwestern Delta is declining.

In addition, climate change will potentially enhance the risk of flooding, coastal erosion and salt water intrusion, and therefore poses a serious threat to the densely populated coastal areas of Bangladesh (e.g. Karim & Mimura, 2008, Dasgupta et al. 2014). The impact of tropical cyclones will increase as a result of accelerated sea-level rise (Woodruff et al. 2013). Society must learn to live with a rapidly evolving shoreline that is increasingly prone to flooding from tropical cyclones. These impacts can be mitigated partly with adaptive strategies, and the challenge is not only to sustainably protect low-lying coastal areas of Bangladesh from storm-flooding and sea level rise, but also to do this in an affordable way.

Ecosystem-based coastal protection

Ecosystem-based adaptation, by employing ecosystem-based approaches and making use of green infrastructure, uses the potential of nature to buffer human communities against the adverse impacts of climate change through the sustainable delivery of ecosystem services (e.g. Jones et al. 2012, www.unep.org, www.iucn.org). Ecosystem-based adaptation offers a widely applicable, economically viable and effective tool to combat the impacts of climate change, complementing traditional actions such as infrastructure development (e.g. www.unep.org). Ecosystem-based solutions have the potential to naturally grow (with sea level rise) whereas hard protection solutions face the problem of degradation and maintenance. The low-cost, flexible approaches of ecosystem-based adaptation can also provide multiple other benefits.

In many locations throughout the world, protection against increasingly severe flooding and coastal erosion can be improved by the construction of large ecosystems such as tidal marshes, mangroves and reefs (e.g. Gedan et al. 2011, Temmerman et al., 2013; Cheong et al., 2013). These large ecosystems attenuate waves to a large extent and stimulate sedimentation, that counteracts the effects of sea level rise (Figure 2). In comparison with conventional flood-prevention methods, this approach is more resistant to climate change, in addition to being more cost-efficient and having many additional benefits, including biodiversity, nursery grounds for fish and crustaceans, provision of food, cleaner water, and climate change mitigation (e.g. carbon sequestration).

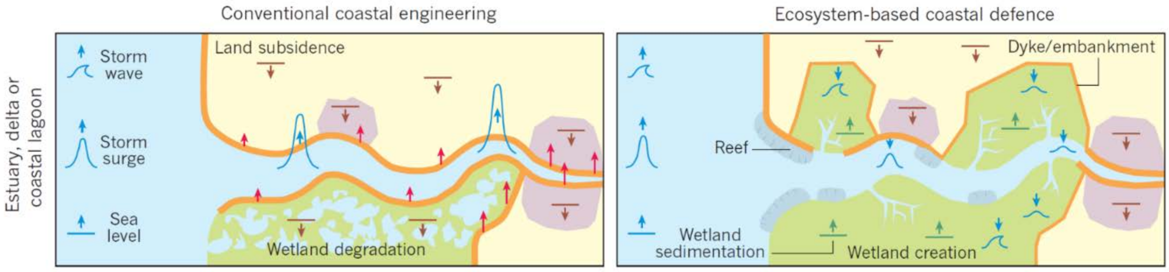


Figure 2. The schematic maps illustrate global and regional changes that increase the risk of coastal flood disasters (blue arrows indicate an increase or decrease in intensity of storm waves, storm surge and sea level), and the basic principles of flood protection by conventional coastal engineering (left) and new ecosystem-based defences (right). In the case of conventional defences, red arrows indicate the need for maintenance and heightening of dykes, embankments and sea walls with sea-level rise. In an engineered system, embankment of wetlands stimulates the landward heightening of storm surges and exacerbates land subsidence (brown arrows) due to inhibited sediment supply and soil drainage. In the case of ecosystem-based defence, wetland and reef creation attenuate landward storm surge propagation and storm waves, and stimulate wetland sedimentation (green arrows) with sea-level rise.. (Source: Temmerman et al., Nature 504: 79-83).

Eco-engineering can be seen as part of an ecosystem-based adaptation strategy, as it 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 mangroves, marshes, and shellfish reefs, or a hybrid approach that smartly makes use of sediments, in combination with existing coastal defence structures, will enhance the protection of coastal areas and communities against erosion and flooding. At the same time, when well-designed, it can provide other important ecosystem services, including the production of food.

In the Netherlands, extensive experience with eco-engineering has been achieved in the Building with Nature programme (www.ecoshape.nl). This innovation programme, using demonstration projects along sandy coasts, mud coasts, estuaries and large rivers, showed the advantages of including natural components in infrastructure designs. Flexibility and adaptability to changing environmental conditions and extra functionalities and ecosystem services can be achieved, often at lower costs on a life-cycle basis than `traditional' engineering solutions (De Vriend et al. 2014).

Building with Nature in Bangladesh

The interest for ecosystem-based adaptation and Building with Nature is growing in Bangladesh. In one of the Background Studies, Strategy for Ocean and River Management (Hossain et al. 2014), in preparation for the 7th Five Year Plan (2015-16 to 2019-20), Building with Nature is proposed as a novel Ecosystem Engineering approach, that should be one of the essential tools for ocean and coastal management in Bangladesh. Building with nature can contribute to protecting coastal areas and communities in Bangladesh from erosion and flooding, and enhancing the natural defence of the coast using living organisms and ecosystems, at the same time providing various ecosystem services and products to people. The ECOBAS project is mentioned as a promising example of such an approach (see BOX 1).

Box 1 – ECOBAS project

The ECOBAS project (Eco-engineered Coastal defence integrated with sustainable aquatic food production in Bangladesh, 2012-2014) aimed to provide Bangladeshi authorities with an alternative and more affordable approach for coastal protection and climate change adaptation, by using the eco-engineering concept utilizing reef structures with oysters to combat coastal erosion and provide a source of food. The project was financed by Partners voor Water and the Netherlands Embassy in Dhaka, Bangladesh, and was conducted by a Dutch-Bangladeshi consortium: Wageningen University and Research centre (Wageningen Marine Research (former IMARES) Wageningen Economic Research (former LEI)), Royal Haskoning DHV, and Institute of Marine Sciences and Fisheries of Chittagong University, Bangladesh.

The ECOBAS project consisted of a combination of desk studies, habitat suitability analyses, modelling, cost-benefit analysis and field pilots. The ECOBAS pilot consisted of a simple concrete structure (50m long, 0.7m high), mimicking a fully-grown oyster reef on Kutubdia Island. The hollow structures formed a habitat for crabs and fish that may be caught by local fishermen. After one year a large number of oysters were found, while the wave-dampening effects resulted in sediment being deposited behind the reef structure. According to model calculations, the oyster reef could grow in height by about 2 cm per year. This will allow it to keep pace with the sea level rise. The outcomes of the social cost-benefit analysis indicated that use of coastal ecosystems (i.e. oyster reefs and mangroves) in combination with the currently present earthen embankments (i.e. hybrid approach) 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 were (i) the novelty of the concept and its introduction/feasibility to Bangladesh, (ii) the active involvement and participation of the local community, (iii) the interest it has generated among stakeholders and in the media in Bangladesh, and (iv) the cooperation and adequate flow of information among the Dutch-Bangladeshi consortium partners.

During the final ECOBAS conference in November 2014, the Secretary of Water Resources responded enthusiastically to the concept and advocated further development of these concepts in Bangladesh.

Reef constructed on Kutubdia Island with developing mangroves and salt marsh vegetation in front.

The further implementation of ecosystem-based adaptation and Building with Nature for coastal protection in Bangladesh can be part of the Bangladesh Delta Plan (BDP), as one of the of the key points of the Bangladesh Delta Plan 2100 is to integrate climate change adaptation in a more strategic, knowledge-based and consistent way, making efficient use of natural and limited economic resources in Bangladesh (www.bandudeltas.org).

The ambition is to design and develop the coastal zone based on ecosystem-based approaches using eco-engineering techniques. The aim is to take the complete coastal foreshore and its ecosystems and components (i.e. tidal flats, marshes, mangroves, earthen embankments) into account as a hybrid, integrated, eco-engineered approach to reduce coastal erosion and flood risks and maximise ecosystem services, with a focus on food provisioning. The next step is to develop a blueprint for ecosystem-based adaptation for the entire Bangladesh coast, as to guarantee replicability and ensure that the concept can be implemented by the government Bangladesh' and elsewhere. Aspects should include:

- Build operational frameworks for ecosystem-based coastal adaptation in Bangladesh which operate across natural & social sciences;
- Identify where the approach can contribute to risk reduction and identify which ecosystems (oyster reefs, mangroves, marshes, tidal wetlands) are most promising (depending on local settings);
- Set up and design large demonstration project(s) in which the approach is further being tested, monitored and evaluated;
- Effective valuation of the ecosystem services delivered by the ecosystem-based approach compared to traditional engineering, including social cost-benefit analysis; aspects of the evaluation include the maintenance costs of the present embankments as they will be better protected by the ecosystems in front of them;
- optimise added-value of ecosystem-based approaches for fisheries and aquaculture, so that marine communities will benefit from additional food and nutrition security (see further); contribute to poverty alleviation;
- Advise the government, organize stakeholder involvement and participation of local communities, involve interested financial investors and sponsors.

Building with Nature and food production

A future for Bangladesh Polders

In large parts of the coastal area of Bangladesh farming is organised in polders, which have been constructed in the 1960s primarily for crop (rice) farming and for which extensive mangrove forests were removed. Many of these enclosed embankments have lost 1.0–1.5 m of elevation, whereas the neighbouring Sundarban mangrove forests has remained comparatively stable. This elevation loss is attributed to interruption of sedimentation inside the embankments, combined with accelerated compaction, removal of forest biomass, and a regionally increased tidal range. All of this has increased salt intrusion into the polders. So, ironically, the human interventions originally designed to allow for rice farming are now undermining it. In response to salt intrusion and an increasing demand for high trophic aquaculture products in the world market, farmers have switched from rice to shrimp farming. This transition set in motion economic development but also impacted livelihoods in coastal Bangladesh (Hossain et al. 2013, Abdullah et al. 2017). The predominant method of farming is extensive, with limited effect on water quality (no feed, no use of antibiotics), but productivity is relatively low. Due to a lack of knowledge, skills and access to quality inputs, also many novice farmers failed and became indebted. Solidaridad's Sustainable Agriculture, Food security and Linkages programme (SaFaL) demonstrated that shrimp farmers can rapidly and significantly improve their productivity and profits through the introduction of good aquaculture practices. Over 13.000 participating farmers in the southwestern polders have keenly adopted these sustainable shrimp farming practices; in some polders rice farming has been replaced entirely. However, a mono-culture shrimp farming landscape entails risks for disease outbreaks and economic losses. The removal of these mangroves also changed sediment dynamics, and increased the risk of flooding and also increased salt intrusion further inland, threatening rice production. The environmental degradation, sea level rise, land subsidence and more frequent drought and floods threaten the livelihoods and the productivity of these homesteads in the near future. South West Bangladesh is a cyclone hotspot where industrial, intensive shrimp farming would undermine coastal integrity and incur large risks from cyclones and devastating floods. Extending intensive farming is therefore not desirable as a method to increase local economic status, due its large scale impact on the vulnerability to flood risk and environmental health.

The Building with Nature approach offers a range of adaptive strategies that make use of natural processes, boost coastal and delta ecology, integrate economic functions, and reduce costs, thereby providing multiple benefits to society. Amongst these benefits are a range of ecosystem services, including coastal protection, food production, carbon sequestration and biodiversity conservation. We propose to redesign the layout of shrimp farms by integrating farm design with mangrove forests (see Box 2). Extensive farm practices, utilising the various ecosystem services of mangroves are seen as the best safeguard for the environment and livelihoods for this region. Mangroves are efficient in reducing hydrodynamic forces and capture fine sediment. The mangroves themselves provide a certain protection from flood and the enhanced sediment accretion due to the presence of mangroves increases elevation reducing flood risk even further. Mangroves surrounding the shrimp farms provide input of organic material through leaf litter, which after degradation ultimately contributes to the natural productivity of the shrimp farms. In well-designed separated systems, the pond effluents pass through the mangrove stands that can absorb nutrients such as phospate and nitrogen. As a consequence, the composition of the inlet water is improved and the risk of disease outbreaks is reduced.

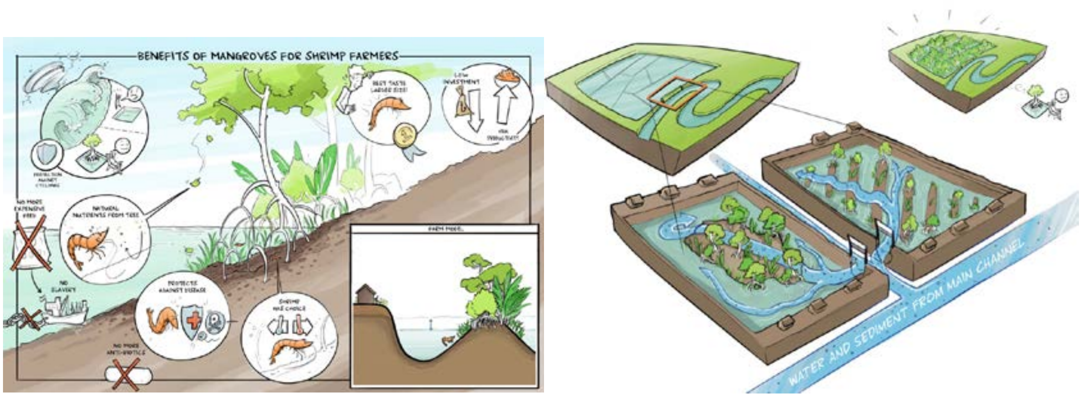
Box 2 – Mangroves and mud for sustainable shrimp farms

Improved farming system design, building on applied research by Deltares and Wageningen UR in Vietnam and Indonesia, is the next step in order to further increase coastal safety, resilience, enhance productivity, improve livelihoods, and increase the market value of the shrimp. Sediment management is one of the tools that can provide the boundary conditions for the improved design. There is a fair amount of background information available regarding the sediment dynamics on the Bangladesh coast. Sustainable integration of aquaculture in the Bangladesh coast has to be based on comprehensive understanding of complicated natural lower delta system in Bangladesh as well as thorough understanding of farming practices and all factors contributing to aquaculture productivity. The former is the remit of Deltares, the latter the remit of Wageningen-UR. This gives the consortium the necessary scientific foundation, while the experience, local connections and facilities of Solidaridad can provide the means and conditions for successful implementation and the monitoring of the success of the design.

The improved design chiefly consists of:

- Increasing pond depth, lay-out and water management
- Integrating mangroves of selected species, with embankments to reduce flood risk and with especially designed filtration basins, to enhance aquaculture productivity and reduce salt intrusion to inland areas
- Staging aquaculture design (using marine / estuarine species on the coast and fresh water species inland) to reduce salt intrusion and safeguard rice and other staple crops
- Improve sediment management to increase elevation of river and pond banks as well as homesteads to reduce flood risk

Based on the this proposed project, as well as on similar projects elsewhere in South-East Asia and available models we propose to ascertain the longer term and larger scale effects of this approach for coastal safety as well as salt intrusion and fresh water availability when adopted in other areas in the Bay of Bengal.



Benefits of mangroves for shrimp farmers (left) and integrated mangrove-shrimp systems to enhance resilience of coastal livelihoods in polders in Bangladesh (right).

Sustainable food security

Trends in global aquaculture production

Seafood is considered to be a vital component of a healthy human diet and food security in light of the expected global population growth. Although 70% of the globe consists of water, today only 17% of our food comes from fisheries and aquaculture. The need for a 'blue revolution' is therefore often advocated as a means to feed the world.

Currently, aquaculture supplies over 50% of fin- and shellfish consumed worldwide. This represents a paradigm shift in our exploitation of the sea that for centuries was dominated by capture fisheries. Aquaculture is the fastest growing animal food producing sector in the world and is an increasingly important contributor to global food supply and economic growth. Estimates for the worldwide demand for seafood vary from 161 million ton in 2022 (OECD-FAO Agriculture Outlook 2014), ~160 million ton in 2030 (Worldbank Fish to 2030 report) to ~ 235 million ton in 2030 (Subasinghe 2014). Indicating that by 2030, a production increase between 30 and 100 million MT above current level of 136 million MT should be realized.

Current aquaculture production takes place in fresh (56%) and marine (55%) waters, but mariculture activities are expected to expand significantly. In Asia the marine cultivation of low trophic species such as shellfish and seaweeds is dominant, while in Europe fish aquaculture is the largest sector, mostly driven by salmon production in Norway. Growth of the aquaculture, and particularly the fish cultivation, has raised concerns about the adverse effects of fish farming.

Seaweed production

Seaweed production in Asia has always been high and is still growing significantly, but it recently gains more and more interest in other parts of the world. Potential for food and feed

Seaweed cultivation is often addressed as a nature based solution as seaweeds in general deliver several ecosystem services (Radulovich et al 2015). Seaweed-environmental interactions relate to nutrient cycles, oxygen provision, carbon sequestration, ocean acidification, and local habitats. Whether the interactions serve as a service to the ecosystem of whether they may cause a negative impact depends on location, scale, cultured species, season and system configuration. When grown in eutrophic areas, seaweeds may for example extract excess nutrients form the water column, potentially resulting in better quality of the waters. Yet, when densities exceed the carrying capacity of the system, nutrient extraction might result in nutrient limitation with cascading effects to other trophic levels. Similarly, habitat created by seaweed farms may serve as a nursing and juvenile area for a range of fish and invertebrate communities thereby boosting biodiversity within farm sites, but simultaneously could also be used by exotic species and thereby as stepping stone for invasive species, e.g. linked to global warming. Finally, the produced seaweed could also serve as an alternative to those derived from agricultural products, avoiding the environmental drawbacks related to land-based production i.e. deforestation, eutrophication and desertification, and seaweed proteins may form an alternative to fish and meat, lowering the risk of overfishing and feed demand. Oils or biomass from seaweed could potentially replace fossil fuels in energy production

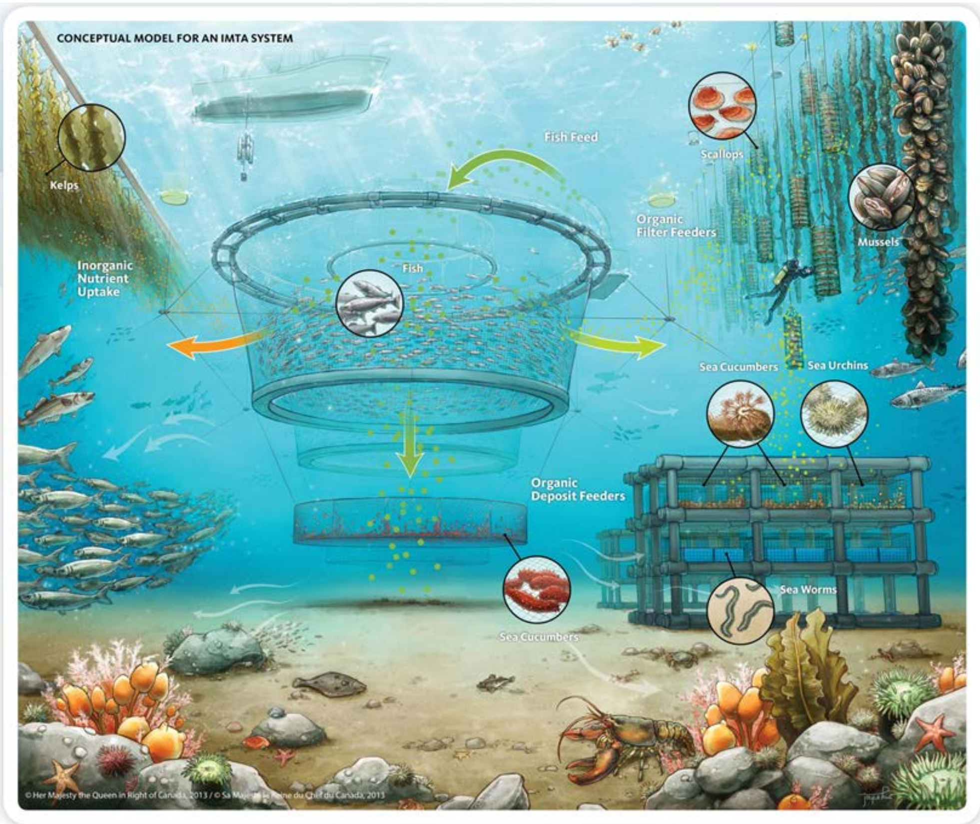
Integrated multi-trophic aquaculture (IMTA)

To tackle potential adverse effects of fish farming, the industry worldwide is searching for sustainable methods, and integrated aquaculture (IMTA) has been proposed as a potential tool assisting sustainable development. 'Integrated multi-trophic aquaculture' (IMTA) has become a popular term and refers to a form of integration with the explicit incorporation of species from different trophic positions. Integrated aquaculture has several benefits, including enhanced carrying capacity, bioremediation, product diversification, and disease prevention.

The concept of Integrated Multi-Trophic Aquaculture (IMTA) is simple; utilise the waste products from fed species (mainly fish) and co-produce other species lower down the food chain that will use this waste stream to grow; waste nutrients and energy converted to other products for harvest including shellfish, seaweeds and other species and supporting a reduction in the overall environmental impact from aquaculture activity. In marine aquaculture systems the production of fish, shellfish or algae is undertaken using a variety of production methods (cages, longlines, rafts) but generally produced alone in monoculture, where each species is grown separately IMTA is different. In an IMTA system the layout of the IMTA site is such that species are grown in proximity, in such a way that the shellfish and/or plants and other species, can recycle the nutrients that are lost from the fed culture of finfish (Hughes et al 2017).

Although the concept of IMTA seems simple, the practical implementation has been shown more challenging, and there are still some ecological, logistical and regulatory hurdles to be overcome before commercial adoption (in Europe) will be common practice (Hughes et al 2017). IMTA systems are basically an ecological puzzle which requires fine tuning of the integration in both space and timing of cultures. For example, fish growth (and waste production) in cold and temperate waters is highest in late summer when water temperatures are maximum. Production of kelp, the main seaweed species produced in Europe, is highest during late spring, demonstrating a seasonal mismatch in maximum waste production and maximum assimilation by seaweeds. This example indicates that the selection of species is essential for the ecological efficiency of IMTA systems.

Recent research is providing increased insight in the ecological and economic perspectives of development of successful IMTA systems. The adoption of IMTA can become an important tool for the economic development and environmental sustainability of the global aquaculture industry.



References

Abdullah AN, B Myers B, N Stacey, KK Zander, ST Garnett. 2017. The impact of the expansion of shrimp aquaculture on livelihoods in coastal Bangladesh. Environ Dev Sustain 19: 2093-2114.

Auerbach LW, SL Goodbred Jr, DR Mondal, CA Wilson, KR Ahmed, K Roy, MS Steckler, C Small, JM Gilligan, BA Ackerly. 2015. Flood risk of natural and embanked landscapes on the Ganges–Brahmaputra tidal delta plain. Nature Climate Change 5: 153-157.

Brammer H. 2014. Bangladesh's dynamic coastal regions and sea-level rise. Clim. Risk Manage. 1: 51-62.

Cheong, S., Silliman, B., Wong, P. Van Wesenbeeck, B., Kim, C., Guannel, G. (2013) Coastal adaptation with ecological engineering. Nature Climate change, 3: 787–791.

Dasgupta S, Kamal FA, Khan ZH, Choudhury S, Nishat A. 2014. River Salinity and Climate Change: Evidence form Coastal Bangladesh. World Bank Policy Research Working Paper 6817.

De Vriend HJ, van Koningsveld M, Aarninkhof SGJ, de Vries MB, Baptist MJ. 2014. Sustainable hydraulic engineering through building with nature Journal of Hydro-environment Research http://dx.doi.org/10.1016/j.jher.2014.06.004.

Gedan KB, Kirwan ML, Wolanski E et al. 2011. The present and future of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. Climatic Change 106: 7-29.

Hossain et al. 2014. Opportunities and Strategies for Ocean and River Resources Management. Background paper for preparation of the 7th Five Year Plan. Planning Commission, Ministry of Planning, Bangladesh.

Hossain MS, MJ Uddin, ANM Fakhruddin. 2013. Impacts of shrimp farming on the coastal environment of Bangladesh and approach for management. Rev Environ Sci Biotechnol 12: 313-332.

Jones HP, Hole DG, Zavaleta ES. 2012. Harnessing nature to help people adapt to climate change. Nature Climate Change 2: 504–509

Karim, M.F. ; Mimura, N. (2008). Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. Global Environmental Change 18:490-500.

Mitsch, W.J.; Jørgensen, S.E. (2003) Ecological engineering: a field whose time has com. Ecological engineering 20(5):363-377.

Temmerman, S., Meire, P., Bouma, T.J., Herman, P.M.J., Ysebaert, T., De Vriend, H.J. (2013) Ecosystem-based coastal defence in the face of global change. Nature 504: 79-83.

Woodruff J.D.; Irish, J.L.; Camargo, S.J. 2013. Coastal flooding by tropical cyclones and sea-level rise. Nature 504: 44-52.

Radulovich R.; Neori, A.; Valderrama, D.; Reddy, C. R. K.; Cronin, H.; Forster, J. Farming seaweeds. In Seaweed Sustainability: Food and Non-Food Applications; Tiwari, B. K.; Troy, D. . ., Eds.; Elsevier Inc., 2015; pp. 27–59.

Further information

Wageningen University and Research Centre

Contact: Prof. dr. Tom Ysebaert, **tom.ysebaert@wur.nl**

T + 31 (0)317 48 74 19, M +31 (0)6 30 46 17 73

Other contacts: **henrice.jansen@wur.nl**, **marnix.poelman@wur.nl**

Website: **www.wageningenur.nl**