Guidelines, Knowledge and Innovative Designs for Bio-Diverse Coastal Protection

EcoShape

singapore-delft water alliance

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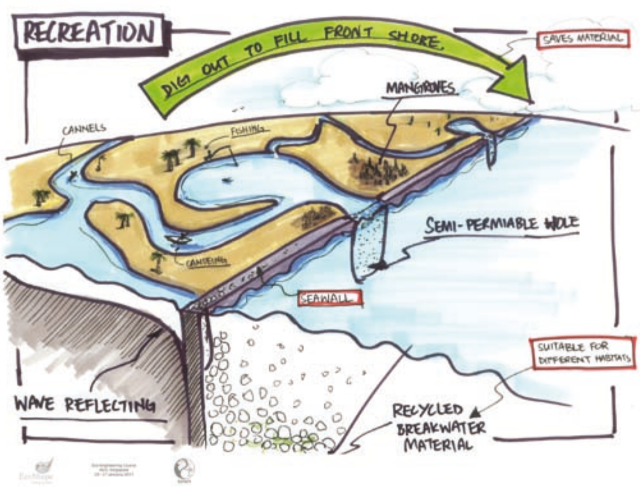
The Joint Singapore Marine Programme (JSMP) is investigating issues related to tropical, turbid waters and shoreline management to address the causes of deteriorated water quality, the response and interactions of sensitive ecosystems, and identify opportunities that these ecosystems offer for sustainable coastal and marine development. One study within this programme focuses on the development of guidelines and innovative designs for coastal protection in tropical environments.

The **primary objective** of this study is to establish science-based guidelines, develop tools and perform small-scale pilot studies **focused on developing (conceptual and prototype) designs for soft and hard coastlines in tropical environments by utilising eco-system services and eco-engineers** in order to *enhance* the ecological potential of the system while **maximizing the functionality** of the area (i.e. recreation, shipping, industry, safety).

Study Approach

This study focuses on combining existing and new knowledge on sediment dynamics, water quality and ecosystem dynamics into the practice of eco-dynamic designing of coastal protection in a tropical environment. This requires the development of **guidelines, innovative designs and pilot applications for 'bio-diverse coastal protection**. The study is a cooperative effort between three fundamental research projects, three applied research projects, and three data collection projects which are executed in an integrated fashion to achieve the end goal. The questions within these projects are being addressed by combining desk, field and flume studies, mesocosm experiments, process-based modelling and interactions with stakeholders. These projects are collectively investigating biotic, abiotic and socio-economic elements which are integral in the successful development of guidelines and designs for eco-dynamic coastal protection in tropical waters.



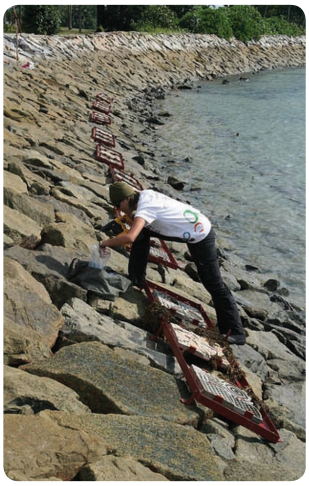
Example of a conceptual design (Eco-engineering course, January 2011).

Innovation

Large-scale marine infrastructure developments are essential for economic growth and safety in deltas and coastal areas in Singapore and surrounding countries. Extensive land reclamations continue to provide additional land necessary to sustain anticipated growth of the population and economy in the region. It is a major challenge for Singapore and its surrounding countries, to utilize opportunities for optimization and development of its marine coastal system in combination with increasing the ecosystem services of these developments.

This overall gain in fundamental and applied knowledge is essential to generate a better understanding of the physical boundary conditions required for the successful development of the marine coastal system while mutually enhancing the coastal/marine ecosystem services. This generated knowledge is also necessary for the establishment of (new) habitats and the effective restoration of sensitive coastal/marine ecosystems.

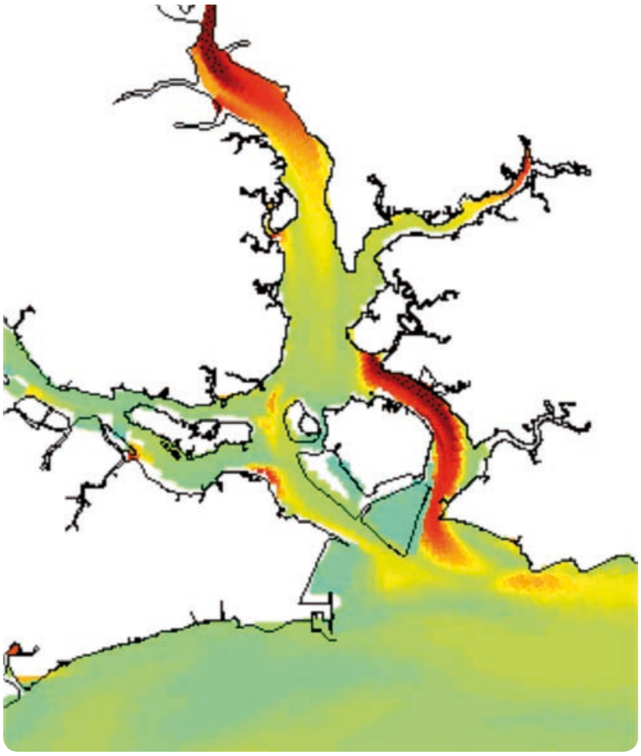
This project aims to develop an ecodynamic conceptual design for a coastal stretch in Singapore that will fulfil the desired coastal protection function of the area while at the same time increasing the ecosystem value. In the development of this eco-dynamic conceptual design, eco-dynamic designing steps will be developed and implemented, as well as published within the Building with Nature Eco-Dynamic Design Guidelines.

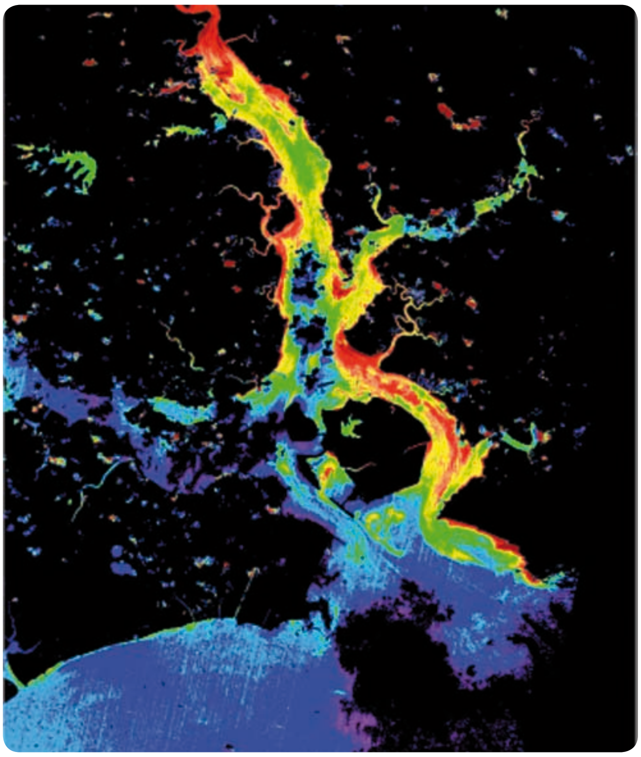


Pilot study on ecological optimization of sea walls (Peter Todd).

Facts and Figures

	% of Loss Globally	Singapore region	Ecosystem Services	
Coral Reefs	4-9% per year and 20% already destroyed	not quantified, but large areas of reef lost due to reclamation and remaining reefs suffered loss of up to 65% of the coral cover	Tourism, Coastal Protection, Carbon Sequestration, Fish Habitat	The world has effectively lost 19% of the original area of coral reefs; 15% are seriously threatened with loss within the next 10–20 years; 20% are under threat of loss in 20–40 years.
Seagrass Beds	~7% per year and 29% lost since 1980	Unknown, but major losses inferred from historic records & present distribution	Fish Nursery, Sediment Trapping, Fish Habitat	Seagrasses have been lost at a rate of 110 km2/year since 1980 and 29% of the known areal extent was lost since first recorded in 1879. Rates of decline have accelerated from 0.9% <1940 to 7% since 1990
Mangroves	1-3% per year and 20% lost since 1980	unknown, but major losses in most coastal regions in the area. Estimates for the island of Singapore 94-98%	Fish Nursery, Coastal Protection, Sediment Trapping, Timber Supply	An alarming 20 percent, or 3.6 million hectares of mangroves, have been lost since 1980. More recently, the rate of net loss appears to have slowed down, although it is still disturbingly high.





Modelled (left) and observed (right) sediment concentration (Bas van Maren).

Generated Knowledge

Applied Research

Ecological knowledge for coastal protection

Increasing urbanisation has resulted in extensive buffering of natural habitats with man-made protective structures. A good example is the artificial seawall which has become a ubiquitous feature of many coastlines around the world. Being vertically very steep, and structurally quite simple, this compressed intertidal region typically does not represent a shoreline habitat that can support the kind of biodiversity expected in this otherwise unique, land-sea environment. Understanding how the number of species is related to, or regulated by, topographical heterogeneity could enhance our ability to mitigate the alterations caused by coastal modifications to natural communities by engineering artificial structures to better mimic the natural environment.

The aim of this study is to examine how the limited small-scale habitat structure of seawalls around Singapore may be engineered to enhance their biodiversity. This will be done using complex concrete tiles attached to seawalls to determine if structural diversity can enhance the biodiversity. Understanding how to improve the value of seawalls as surrogates of natural habitats is important for intertidal biodiversity conservation on modified shorelines.

Fundamental Research

A wide variety of new knowledge is being generated within these studies in order to meet the project objectives. This new fundamental knowledge is related to the ecological studies of corals, seagrasses and mangroves of Southeast Asia, as well as to the sediments and morphology in these waters.

Sediments

Turbidity in Singapore's coastal waters has increased in the past decades, but the reasons for this increase are poorly known. One of the possible sources of sediment may be from the largest nearby river, the Johor River. Quantifying this flux is difficult due to the limited availability of discharge and sediment loads from the river and surrounding land. In order to better understand this system, a sediment transport model has been setup, to be calibrated with satellite images. The aim hereby is to devise methods to setup sediment transport models for which no, or only limited, field data is required.

Major research components and innovation:

- Quantify changes in turbidity in an anthropogenically heavily influenced environment in which a limited amount of historic data exist through analysis of indirect observations (visibility), land use change (determining fluvial sediment loads), satellite images, and state-of-the-art numerical models.

Mangrove mesocosm experiment, Singapore (Thorsten Balke).

Field measurements of mangroves (Thorsten Balke).

- Determine surface SSC from satellite imagery in a tropical environment, and combine this with numerical models to quantify sediment fluxes.

Mangroves

Due to a variety of anthropogenic influences, mangrove areas are in decline on a global scale, while remaining mangroves are exposed to rapidly changing abiotic conditions. The latter makes it difficult to predict both the short-term sediment dynamics and the long-term bio-geomorphological development of mangroves. Therefore, the net effect of sediment trapping by mangroves and its contribution to the clearing of coastal waters is hard to predict.

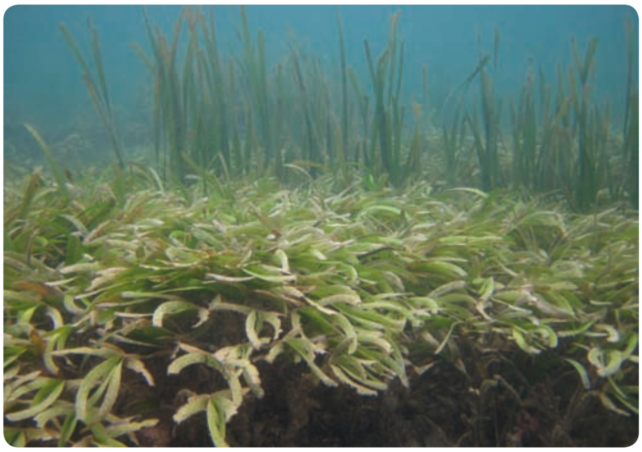
Mangroves in Thailand (Thorsten Balke).

The present study addresses gaps in current knowledge, and will yield valuable modelling tools that allow scenario studies to predict the response of mangroves to ongoing global change processes and anthropogenic disturbances. The impact of these disturbances on water quality (for example, turbidity) is still poorly understood by lack of in depth knowledge on both the short- and long-term sediment dynamics within mangroves. Developing models will support a balanced evaluation of the benefits of mangrove restoration and protection in tropical ecosystems. It will identify to what extent, and on which time scales, mangroves can I) act as buffering mechanism against anthropogenic sediment inputs; II) reduce turbidity in coastal waters; (III) maintain water depth of nearby tidal channels and IV) contribute to coastal protection.

The project should provide quantitative insight into how bio-physical interactions are affected by hydrodynamic forcing and ecosystem scale changes. The project should also provide fundamental knowledge needed for mangrove restoration and the use of mangrove forests to improve water quality and ecosystem functioning in Singapore, and in the region.

Corals & Seagrasses

Seagrass meadows and coral reefs play a vital role in supporting tropical coastal marine communities and maintaining biodiversity of associated flora and fauna. They are an important component of coastal fisheries productivity and they play an important role in maintaining coastal water quality and clarity. Seagrasses are also important as food source for marine mammals.



Clockwise: Bintan seagrass shading experiment (Paul Erftemeijer), seagrass (Paul Erftemeijer), seagrass (Siti Yaakub).

In the coral studies, the growth and vitality of massive Porites coral colonies is being monitored (by staining) along with a host of environmental parameters at various sites along the Thai-Malay peninsula. Coral cores will then be drilled from these colonies to analyse the historic trends and patterns of growth over the past several decades, in relation to historic meteorological and physico-chemical data on these waters & sites.

In the seagrass studies fundamental knowledge is gained on past and present distribution of seagrasses in the Singapore region, their natural dynamics as well as damage and recovery capabilities through a series of field and mesocosm shading experiments. Differences between pioneering (more sensitive) and climax (more robust) species are also being investigated. Both the coral and seagrass studies are being carried out in a variety of Southeast Asian waters to represent a wide range of habitats and levels of anthropogenic influence.

Ecosystem interaction knowledge

Many restoration projects have shown that (re)generating soft-bottomed ecosystems (mangroves forests, seagrass meadows and coral reefs) is often very difficult and unsuccessful. The present project aims at enhancing the restoration and regeneration success, by generating the fundamental knowledge from ecological alternative stable states theory so that it can be used in ecological design. This theory underlines the need of establishing positive feedback loops to successfully establish stable ecosystems.

This research aims at identifying the importance of self-facilitating and large-scale facilitation by ecosystem connections as critical factors needed for ecosystem-based designs for building (and restoring) ecological coastlines that both enhance biodiversity and coastal protection in tropical environments.

Some of the specific knowledge gains from the fundamental research will provide:

- Boundary conditions for individual ecosystems and how these are affected by connections between the ecosystems;
- Boundary conditions for establishment of ecosystem species (mangroves, corals and seagrasses) as pioneers;
- Boundary conditions regarding sedimentation and turbidity for certain mangrove, seagrass and coral species; and
- Knowledge, scientific but also practical, on how to improve the tropical marine environment and to increase safety.

Field work (Erik Horstman).

Mangroves (Erik Horstman).

In this project, knowledge will be generated on how large-scale marine infrastructure projects may be used to extend and strengthen local ecosystems. This represents a paradigm shift from ecosystem impact towards ecosystem-based design. Integrating ecosystem requirements from the start into engineering designs may offer opportunities to 'improve' (i.e., restore functionality and/or diversity) and extend coastal ecosystems while in the same time achieving engineering targets. Moreover, as many ecosystems offer valuable ecosystem services (e.g., wave attenuation, food production, etc), the economical benefits of such approach may be positive.

Outreach

The fundamental and applied research is also being complimented by educational workshops and courses. One example of this was an exciting SECORE coral breeding workshop, hosted by TMSI in their St. John's laboratory. The aim of the SECORE workshop was to enhance the cooperation between aquaria and research institutions for developing and applying coral breeding techniques. Participants learned essential hands-on techniques, such as the collection of coral gametes during spawning events, fertilisation techniques in the lab, rearing of embryos, maintenance of larval cultures, and settlement and transport of larvae.

In addition to the SECORE workshop, an accredited Eco-Engineering course was given at NUS in partnership with SDWA. This successful Eco-Engineering course was aimed at teaching and implementing the five Building with Nature Eco-Dynamic Design steps through a series of lectures and interactive break-out sessions. The participants of this course included representatives from academia, water-related research institutes, water-management agencies and water (engineering) consultants within Singapore, as well as from Hong Kong and Indonesia.

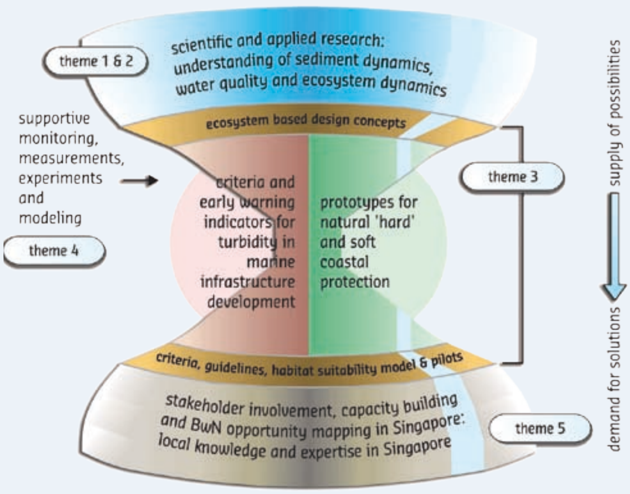
SECORE Coral Breeding Workshop March 2010 – St. John's Island, Singapore

Paul Erftemeijer: 'Ultimately, this knowledge would also allow for the incorporation of specific measures and requirements into the design of maritime constructions, such as promoting the growth of corals and related organisms onto these structures. In this way, marine construction works can contribute to and create new opportunities for nature development, the very purpose of the Building with Nature program.'

Eco-Engineering Course – NUS, 20-21 January 2011

EcoShape and SDEA gave an 'eye opening and informative' Eco-Engineering course where four different cases were used to exercise the Eco-Dynamic Design (EDD) process, thereby exploring opportunities for building with nature: 1) Tuas View, 2) Pasir Panjang Terminal and Labrador Park, 3) East Coast Park and 4) Southern Islands.

The **Joint Singapore Marine Programme (JSMP)** is a collaboration between the Singapore Delft Water Alliance (SDWA) and EcoShape, Building with Nature (BwN). The JSMP combines the Case Singapore projects of Building with Nature and SDWA Marine into one coherent programme. The primary goal of SDWA is scientific capacity building and strengthening of fundamental research activities in Singapore. The primary goal of BwN is to develop a green perspective for water-related infrastructure by providing tools and knowledge for sustainable design of such works. To achieve these goals, research is carried out along five thematic lines: scientific and applied research (themes 1&2), ecosystem based designing (theme 3), supportive monitoring, experiments and modelling (theme 4), and governance (theme 5).



For additional information, please contact: **www.EcoShape.nl** & **www.sdwa.nus.edu.sg**