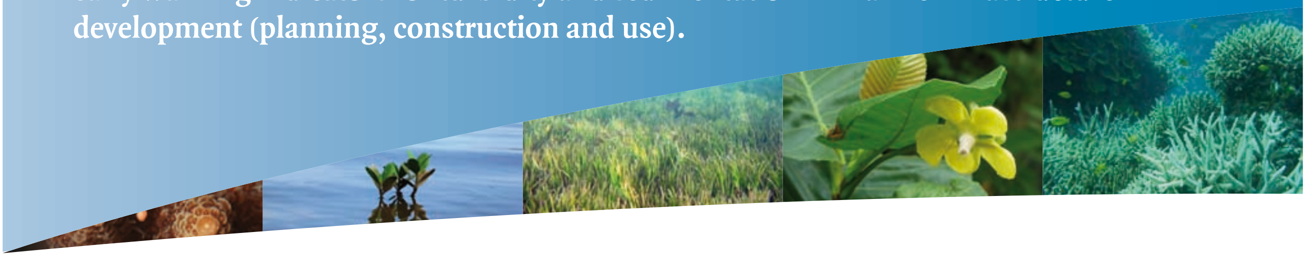
Prediction and Monitoring of Species Response to Sedimentation and Suspended Sediments

EcoShape

singapore-delft water alliance

Prediction and Monitoring of Species Response to Sedimentation and Suspended Sediments

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. More specifically, one goal of the programme is to establish science-based criteria and early warning indicators for turbidity and sedimentation in marine infrastructure development (planning, construction and use).



The **primary objective** of this study is to develop species response curves and a prototype numerical tool for the assessment of species response to the effects of dredging operations, as well as identify early warning indicators for negative species response during these activities.

Study Approach

This study, within the JSMP, focuses on combining existing and new knowledge on sediment dynamics, water quality and ecosystem dynamics into the development of early warning indicators for turbidity and sedimentation. This requires the development of **species response curves for seagrass and coral species** found in Singaporean waters and the development of a prototype **quick assessment MapTable tool to determine the stressor intensity levels** in the ecological areas due to dredging activities. Subsequently, the effect regime of this stressor can be determined and **mapped to an expected ecological effect.** This study is actually a cooperative effort between three fundamental research projects, three applied research projects, and four 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 early warning indicators for turbidity and sedimentation in tropical waters.

Seagrass shading experiment in Bintan, Indonesia (Paul Erftemeijer).

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	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.

Innovation

Large-scale marine infrastructure developments are essential for economic growth and safety in deltas and coastal areas in Singapore and surrounding countries. This may include dredging of ports and navigation channels, land reclamation and coastal and wave protection structures. It is a major challenge for Singapore and its surrounding countries, to utilize opportunities for optimization and expansion of this infrastructure without compromising the quality and value of its coastal ecosystems.

High quality, fundamental and applied knowledge is essential to improve the predictability of the effects of dredging and marine infrastructure development, aid in the setting of realistic and ecologically meaningful criteria and best practices for dredging operations, and contribute markedly to the sustainable management and recovery of these critical ecosystems, both in Singapore and elsewhere in the world.

Specific attention is paid in this study to the interactive role of duration, magnitude and frequency of sediment disturbances in determining the level of impact on critical marine ecosystems. Furthermore, the research carried out into the resilience and post-impact recovery of tropical seagrass and coral species is all new and much-needed to fill major gaps in current knowledge. Through the application of acquired system knowledge and innovative use of bio-geomorphological principles, this programme aims to contribute to a paradigm shift towards ecosystem-based design of maritime infrastructure developments and operational practices and a more sustainable sediment management in the turbid, tropical waters.

This study aims to develop a prototype operational modelling tool to demonstrate the effect-chain from dredging operation to ecological effects. This prototype tool should enable the user to approach dredging assessments not (only) from an ecological perspective, using the species response curves, but also from the contractor's perspective. Furthermore, the effectiveness of mitigating measures (e.g. environmental windows, green-valve, etc.) could be assessed as a first estimate.

(Minder de Vries).

Field work (Erik Horstman).

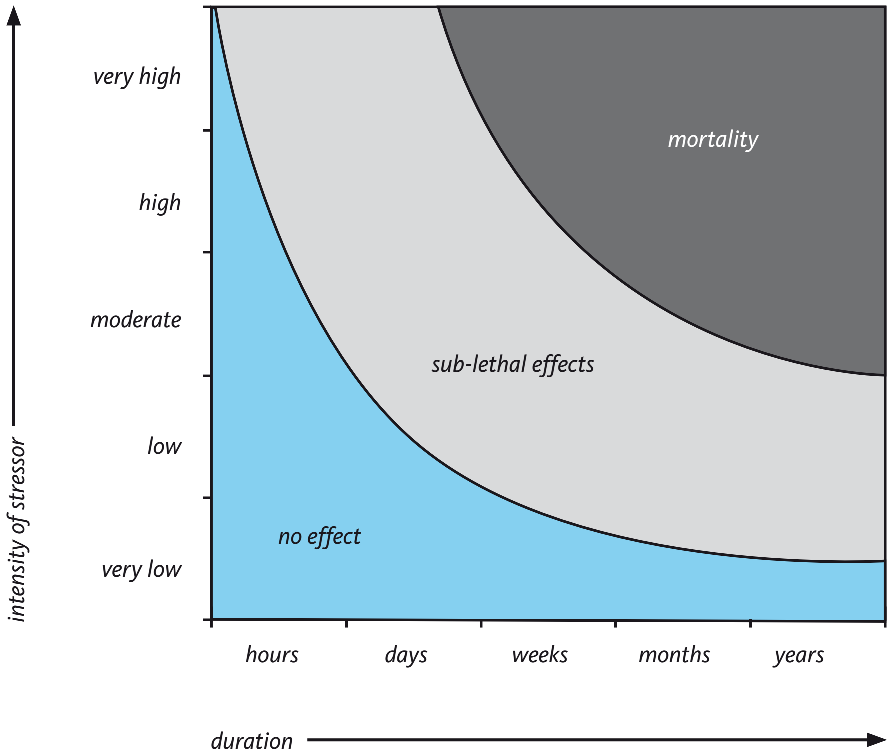
Generated Knowledge
Applied Research

Criteria for turbidity and early warning indicators

Impact assessment studies typically focus on the prevention of adverse impacts of Marine Infrastructure Development (MID) projects. Often this is done by setting rigid criteria for physical parameters such as turbidity, overflow or sedimentation intended to protect sensitive ecosystems. Unfortunately, these criteria and associated restrictions frequently lack local ecological meaning and their scientific justification is often poor. Effect monitoring studies are conducted to detect ecosystem changes as a result of MID projects. Low but long-lasting impact levels and the results of cumulative stressors may cause chronic effects that are difficult to predict. Moreover, recovery, if any, of sensitive ecosystems takes place over long time scales. For these reasons, this study aims at developing early warning indicators that allow management actions to be taken before (irreversible) impacts occur. This work integrates fundamental knowledge on the causes of increased turbidity in coastal waters and effects of turbidity and sedimentation on the dynamics, resilience and recovery of sensitive ecosystems into science-based criteria and effective early warning indicators for adaptive management of MID projects and their acceptability in use.

This research involves field- and mesocosm experiments in which corals and seagrasses will be subjected to variable levels of shading- and sedimentation. In the experiments, not only the magnitude, but also the duration of the stress factor will be manipulated, and the differential response of tolerant and sensitive coral/seagrass species will be compared. Post-stress recovery (including the role of recruitment) and the effect of repetitive stress events on corals and seagrasses will also be examined. This will be done by monitoring coral settlement on artificial substrates under varying environmental conditions, as well as seagrass recovery in experimental gaps and artificially buried plots.

Sedimentation on corals (Tony Ayling).



Impact of the intensity and duration of a stress factor on an ecological objective (Erftemeijer et al., in prep.).

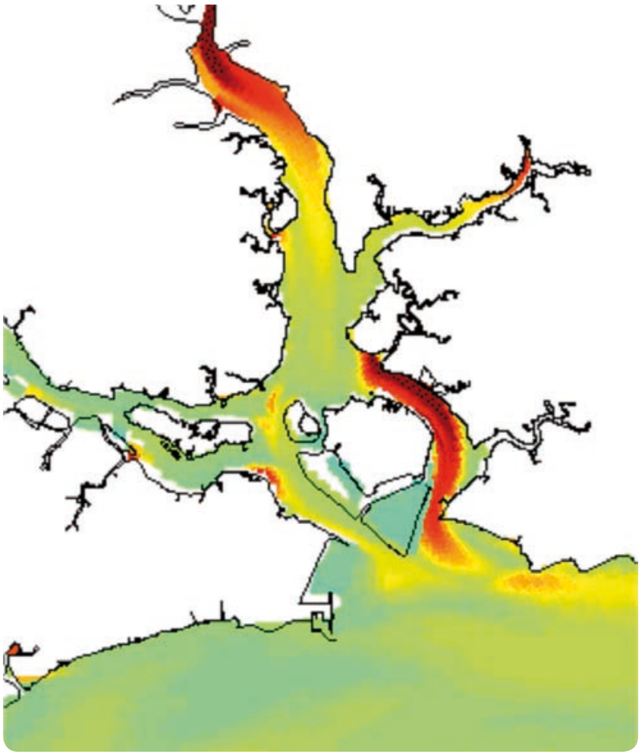
This research should generate much needed knowledge on the stress response behaviour and critical thresholds of these valuable ecosystems, as well as on the factors that contribute to their resilience and recovery potential. The study also aims at developing a standardised methodology to determine species response to stressors and its relationship with the intensity & duration of the stress, to derive ecologically meaningful (science-based) criteria for dredging and construction works.

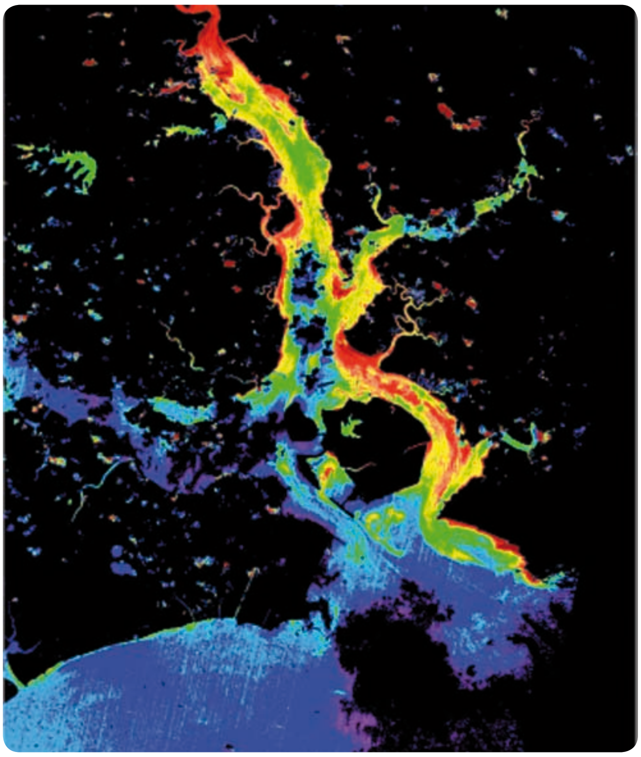
Fundamental Research

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 ecological studies of corals and seagrasses of Southeast Asia, as well as the sediments studies in these waters.

Sediments

In order to understand and predict the effects of anthropogenic sediment disturbances (e.g. from dredging, reclamation and maritime construction works) on coral reefs, seagrass meadows and other sensitive ecosystems, it is important to first understand and characterise the natural variability in turbidity and sedimentation to which these systems are normally exposed. It is a working assumption that these systems are adapted to (and can tolerate) the natural fluctuations in suspended sediment concentrations and sedimentation rates in the absence of anthropogenic influences. Only when turbidity levels or sedimentation rates, as a result of human activities, are in excess of those natural fluctuations in terms of magnitude and/or duration, these systems may experience significant stress and could





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

potentially be in danger of significant sub-lethal or lethal impacts.

An innovation component of this research should be the determination of the relative response of coral reefs and macro-algae to (primarily sediment-related) environmental stresses, and determine the effect of coral reefs and macro algae on sediment dynamics (sedimentation, turbidity) near reef systems.

Corals & Seagrasses

Seagrass meadows and coral reefs in tropical ecosystems play a vital role in supporting coastal marine communities and in maintaining diverse 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.

Increased turbidity and sedimentation as a result of anthropogenic perturbations (including both land-based and maritime activities) constitute one of the most significant threats to sensitive but critical ecosystems such as coral reefs and seagrass beds in tropical coastal waters. However, natural variability in background turbidity and sedimentation in such waters due to storms, wind- and wave induced re-suspension, as well as seasonal river plumes suggests that these ecosystems must have developed a certain degree of plasticity and resilience to tolerate, adapt to, and/or recover from such stress events. A series of mesocosm experiments are being carried out to investigate the specific response of corals and seagrasses to increased levels of sedimentation and turbidity.

Coral coring in Singapore (Jani Tanzil).

Seagrass shading experiment in Bintan, Indonesia (Paul Erftemeijer).

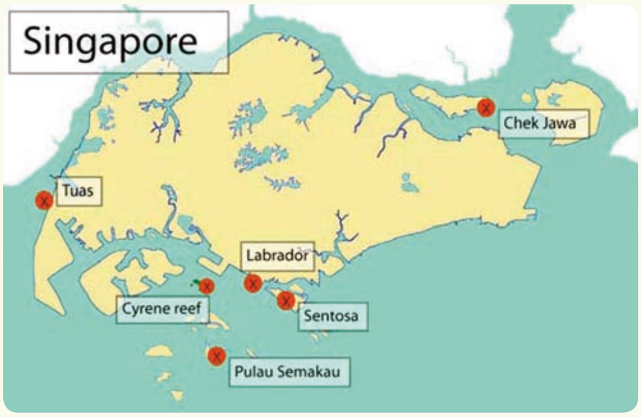
Outreach

The coral and seagrass research is also being complimented by preservation programming and educational workshops. One example is the participation in a series of Seagrass Watch sites around Singapore to aid in the gain of scientific data and knowledge, as well as to further habitat preservation. These six watch sites are routinely monitored by volunteer groups and scientific organizations to gain specific knowledge on species diversity, light conditions and tolerance, and ecosystem health. This knowledge is necessary in determining the seeding nature of corals and seagrasses, for example in Singapore waters, to gain a greater understanding towards the improved preservation of these integral ecosystems and the health of topical marine environments.

Sedimentation on coral, Pulau Hantu, Singapore (Chris Klok).

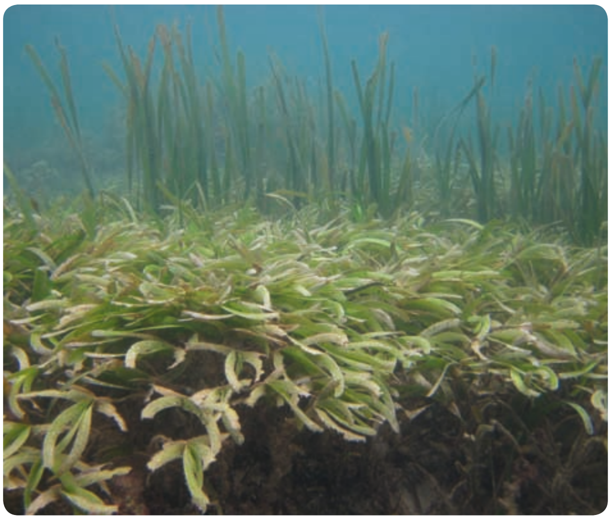
Seagrass Watch - Singapore

'The Seagrass-Watch is the largest scientific, non-destructive, seagrass assessment and monitoring program in the world. Seagrass-Watch aims to raise awareness of seagrass ecosystems and provide an early warning of major coastal environment changes. Seagrass-Watch monitoring efforts are vital in tracking global patterns in seagrass health, assess human impacts and support responsive management of seagrass areas.'



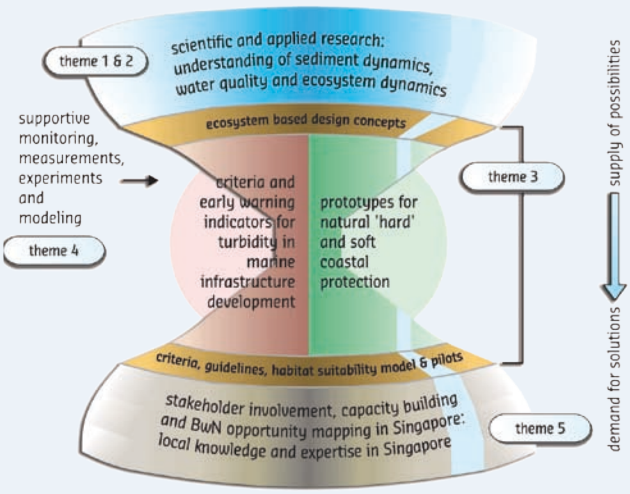
Map and photo from the Team Seagrass Website, www.seagrasswatch.org/Singapore.html.

Seagrass (Siti Yaakub).



Seagrass in Bintan (Paul Erftemeijer).

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**