BUILDING WITH NATURE: CREATING SUSTAINABLE SOLUTIONS FOR MARINE AND INLAND WATER CONSTRUCTIONS

New research initiative towards a Centre of Excellence.

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ABSTRACT

Restrictions and limitations placed upon the construction of large-scale, marine and inland water projects actually lead to missed opportunities, not only for developers, but also for society and for nature. Ports and marine construction industry suffer due to market limitations; society suffers since large-scale, marine and inland water constructions are essential for economic growth; and nature suffers when opportunities are missed for creating and restoring valuable habitats, which should in fact be seen as an integral part of the design and construction procedures for such projects. Social and political acceptance of these projects is severely delayed by environmental laws and regulations that often only attempt to restrict undesirable consequences of a project by imposing restrictive – and usually poorly justified - norms and standards. A truly integrated assessment, on the contrary, should recognise that effects on an ecosystem are dynamic in nature and can be both negative and positive. The "Building with Nature" approach presented in this paper adopts the natural environment as a starting point for project development and evaluation.

Additional research is needed to better understand the dynamics and the relationships in the chain-of-effects between the project, the construction techniques and ecosystem development so that decision-making can be based on both economic and ecological benefits and costs. The major players in the Dutch dredging industry have launched an initiative to boost the research at the interface of ecology and construction in the marine and inland water environment. A consortium of industries, universities, research institutes, consultants and government bodies in the Netherlands have jointly developed an ambitious research programme.

The aim of the new research programme is to identify and fill-in the gaps in knowledge that currently pose restrictions on "Building with Nature". Realisation of a paradigm shift in our appreciation of marine, coastal and inland water construction works requires scientific breakthroughs in research related to:

- ecosystem dynamics (i.e. resilience, recovery, regeneration, regime shifts) and habitat development in response to changes brought about by water-related constructions
- derivation of measurable norms and standards (both biotic and abiotic) related to desired and/or allowable changes in an ecosystem that are also socially and politically acceptable
- economically-viable design methods and construction techniques for water-related constructions that fulfil the norms
- development of a governance model based on a better understanding of the motivators of various stakeholders and partnership arrangements (regional, national and international)
- advanced monitoring strategies, data processing techniques and predictive skills.

The combined five year research programme will be carried out through a "virtual" organisation by teams of researchers working together at their home institutes and at a designated research location. The resulting knowledge and experiences will be gathered in a Centre of Excellence, which can be translated and adapted to other international situations and policy frameworks and will be published in the form of Best Practices.

Keywords: Research, environment, ecology, policy, legislation, marine infrastructure, "Building with Nature".

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INTRODUCTION

Marine infrastructure development projects are crucial both for our safety and for economic development of regions, harbours and industrial activities. Current environmental impact studies are usually focussed on rigid criteria for physical parameters such as turbidity, overflow or sedimentation, which are typically set at fixed levels.

In theory, the setting of such rigid thresholds is intended to protect the natural environment. In reality, however, these criteria often lack ecological meaning, their scientific justification is often poor as they typically ignore site-specific background conditions, in particular the spatial and temporal variability, non-linear stress responses and natural dynamics of the ecosystems involved. This results in suboptimal solutions and missed opportunities for environmental protection and enhancement.

Research is needed to better understand the dynamics and the relationships in the chain-of-effects between the project, the construction techniques and ecosystem development so that decision-making can be based on both economic and ecological benefits and costs.

The initiated research focuses on:

- Generation of advanced knowledge about stress responses of aquatic ecosystems to replace intuitive cause-effect relationships.
- Development of a better set of indicators to be made available and generally applied so that this may lead to more appropriate ecological criteria and standards as well as the identification of ecological opportunities for large, infrastructural projects in natural systems, thus better balancing ecological and economic merits of these projects.
- Improvement of the predictability of marine infrastructure effects, accommodating the integral assessment of cumulative man-induced effects and natural resilience.
- Development of appropriate monitoring strategies and assessment frameworks.

The effort can be summarised as the paradigm shift towards improved design practices based on local ecosystem knowledge rather than ex-post mitigating of undesirable effects of marine infrastructures. A centre of excellence in this domain is created by the participating research & knowledge institutes – governed by a steering group from industry & government authorities.

Apart from these more scientific results, the economic, socio-political and ecological consequences will be validated in practical case studies (prevention is usually much less costly - and far more desirable than ex post mitigation of effects). This affects the dredging industry, an over 5 billion euro/year free world market, but even more the ultimate stakeholders beyond the dredging industry: national authorities (coastal defence, land reclamation), port authorities and other industries involved in marine constructions..

PROBLEM STATEMENT

Large-scale, marine and inland water constructions are essential for safety and economic growth and for providing sufficient safety and quality-of-life in highly-populated, deltaic areas. Approximately half of the Netherlands would not exist without coastal protection and drainage canal systems. Anticipated sea-level rise resulting from climate change will lead to an even increased demand for marine and coastal construction schemes to protect low lying land from the seas and this phenomenon will occur world wide. Large-scale projects such as land reclamations may affect the surrounding ecosystem, both during and after construction. The magnitude and extent of these effects is heavily dependent upon the type and layout of the construction, the construction technique applied and the type of ecosystem. The effects on the ecosystem can be either temporary or permanent and may be either negative (e.g. damage to the ecosystem) or positive (e.g. creation of new habitats). Environmental laws and regulations usually attempt to prohibit or mitigate undesirable effects by imposing norms and standards.

Restrictions and limitations placed upon the construction of these projects may actually lead to a number of missed opportunities. Governments and local authorities are frustrated in their implementation of long-term policies; ports and waterway authorities suffer due to market limitations brought about by limited opportunities for expansion; society suffers since large-scale, marine and inland water constructions are essential for economic growth; and nature suffers when opportunities are missed for creating and restoring valuable habitats. Social and political acceptance of these projects is severely delayed by environmental laws and regulations that often only attempt to identify and restrict undesirable consequences of a project by imposing restrictive norms and standards.

In current practice, the most common Environmental Impact Assessment (EIA) approach focuses on the analysis of the consequences of a predefined project design. This usually involves identifying the most probable environmental impacts that may be expected during the lifetime of the project. By definition, these impacts concentrate primarily on the negative effects of the project. The EIA then defines "acceptable" impacts based upon local or international legislation or guidelines. This generally leads to a definition of measurable indicators that need to be monitored during the project to ensure that particular values (e.g. temperatures, turbidity, etc.) are not exceeded. Due to the generalised nature of EIA legislation, these indicators are often easy to measure "proxies" for processes that are known to affect system functions in general and, as such, are often necessarily overly restrictive to allow for large margins of uncertainty. This traditional view of the EIA approach is summarised in the left-hand diagram in Figure 1, in which the environment is "shielded" from the project by the various layers of rules and legislation.

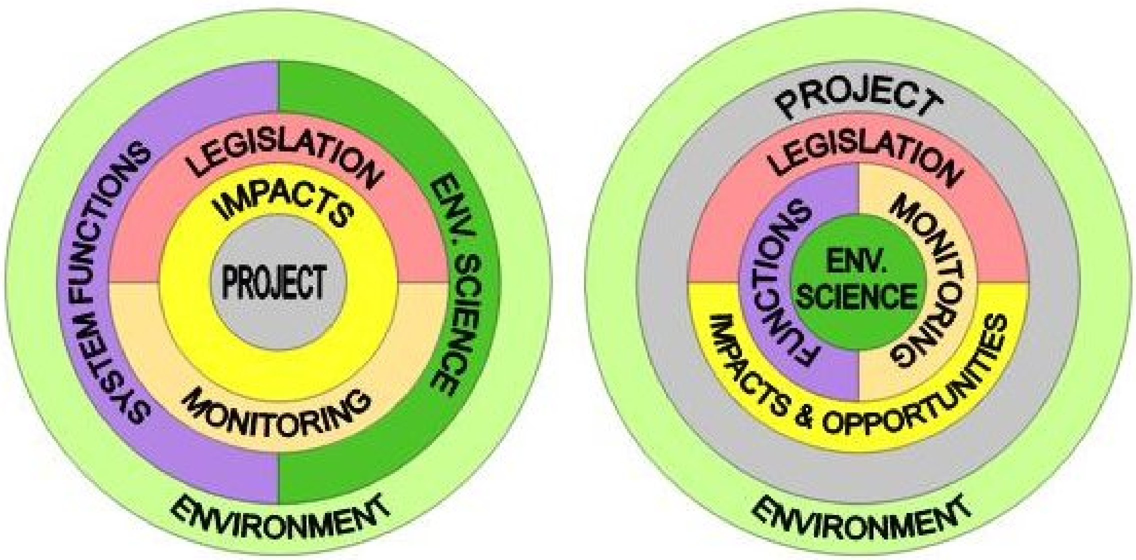

Figure 1. The traditional view of the EIA approach to projects (left-hand side) compared to the ecosystem-based approach proposed in this research proposal (right-hand side).

However, a truly integrated assessment should recognise that effects on an ecosystem are dynamic in nature and can be both negative and positive. The objective of the "Building with Nature" research programme is to realise a paradigm shift away from the more general, defensive EIA approach towards an approach that is based on local ecosystem knowledge that should be integrated into the project design already in the earliest stages of the project. In this approach, the knowledge about the ecosystem is first used to identify all possible system functions (e.g. ecological, economic, social, recreation, etc.). Identification of these functions then allows a selection of the most relevant indicators specific to that particular function in that particular ecosystem. The design of the project should then incorporate aspects to improve or enhance particular functions while at the same time minimising impacts to others. The resulting EIA legislation should therefore also take into account the "added-values" of the enhancements and not just concentrate on the "costs" of impacts and mitigating measures. The result of this paradigm shift is that ecosystem knowledge should form the centre of the design and construction procedures for projects, from inception to execution, so that the project is now more closely integrated with the environment as shown in the right-hand side of Figure 1. The reason that this alternative approach is not yet applied in practice may be related to incomplete knowledge of the complexity of our ecosystems, which thus demonstrates the need for this research programme.

VALUE CREATION

Ecological Benefits

The ecological systems in the world are critical to the functioning of the earth support systems such as for example our food production, fresh water supply and oxygen production by photosynthesis. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total value of our planet.

The economies of the earth would stop functioning without the services that are provided by the ecosystems and therefore it could be concluded that the value of ecosystems is infinite. It is clear that in fact there is a very strong link between the well functioning of eco-systems, the well being of people and the world's economy. Until now the economic value of eco-systems is hardy or not at all considered in the stages of project development. This is probably caused by a poor understanding of how ecosystems are linked to economic systems. Constanza et al. have attempted to estimate the “incremental” or “marginal” value of ecosystem services. (the estimated rate of change of value compared with changes in ecosystem services from their current levels.)

Ecosystem services that were considered in the study by Constanza et al. were amongst others water regulation, water supply, nutrient cycling, food production and recreation. These ecosystem services are largely or partly provided by marine ecosystems. The methodology adopted by Constanza et al. to estimate the value of ecosystem services resulted in the estimate that the total value per hectare for all coastal ecosystem services is some 4,000 US$/year (global average at 1997 price levels). The total value per hectare specifically for seagrass area was estimated to be 19,000 US$/year. Enhancement of ecological functions provides benefits by increasing the value of ecosystem services (e.g. the one-time cost for restoring mangroves is a few hundred US$ per hectare whereas the Millennium Ecosystem Assessment (2005) estimates the economic value of mangroves for the fishing industry alone as 75 - 1,675 US$ per hectare of mangrove per year.)

Economic Benefits

Within the accessible world market for marine construction works the total annual turn-over of contracts is a multi billion dollar market. The two major contracting firms that will participate in this research programme represent a significant percentage of this world market. The results of the research programme will enable the participating (hydraulic) engineering and marine construction companies and consultants to improve their competitive edge and to provide knowledge on how to develop and comply with optimal standards and to work with potential clients to find sustainable solutions.

Socio-political Benefits

Law makers and policy makers will profit from increased knowledge on the effectiveness of standards and procedures, whilst society will benefit from more transparent decision-making, a sense of ownership of the major infrastructural projects and better and more broadly informed discussions between decision makers, NGOs and the public. Faster realisation of the projects can lead to faster economic development of a region, whilst improved designs and construction techniques will minimise ecological impacts, stimulate ecological development and recovery, and create new areas of natural beauty and cultural significance.

TOWARDS A TRULY INTEGRATED ASSESSMENT

The innovations required within this research programme in order to bring about the required paradigm shift can be identified by considering all aspects of the project cycle and their various interrelationships. Figure 2 places these aspects in context and identifies the areas in which scientific breakthroughs are required above and beyond the knowledge and effort applied in current practice (labels highlighted in yellow).

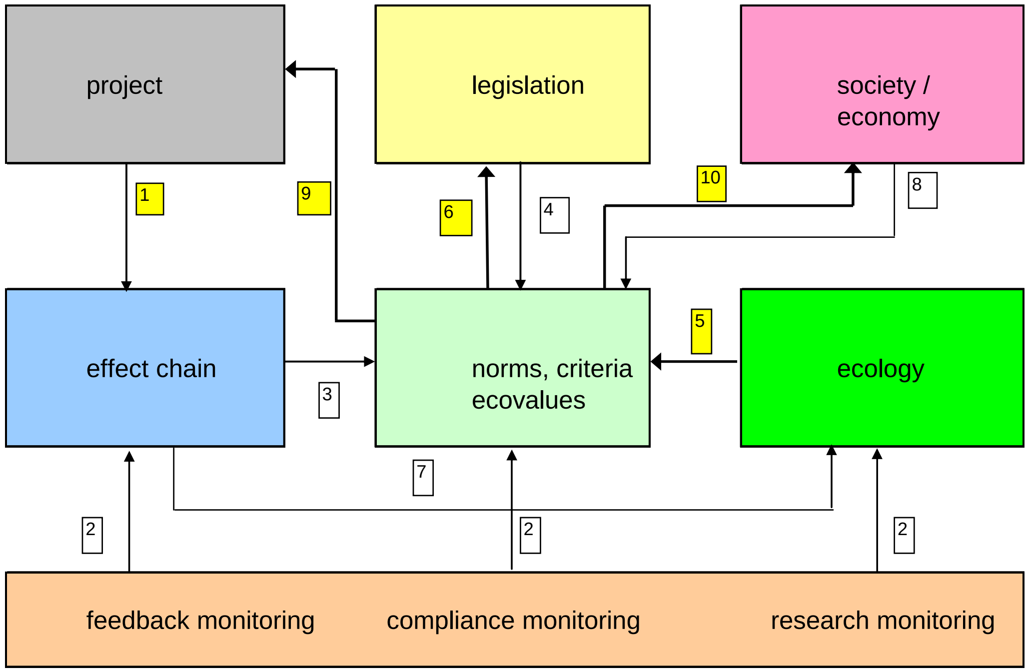

Figure 2. Problem context.

The problem as shown in Figure 2 is described in detail as follows:

1. a project has consequences for the natural environment
2. the effects of interactions with the environment must be monitored to quantify the direct effects of the project activities (feedback monitoring); to control compliance with predefined objectives (compliance monitoring); and to better understand ecosystem dynamics (research monitoring)
3. the effects of the project are evaluated against predefined criteria and objectives
4. norms and standards are imposed through legislation
5. better ecosystem knowledge must lead to more appropriate norms and standards
6. suggestions for changes to norms and standards as a result of improved ecosystem knowledge need to be translated into new legislation
7. knowledge of cause-effect relations within the entire effect chain needs to be integrated with knowledge of ecosystem dynamics (e.g. resilience & recovery) that, in turn, can be used to adapt norms and standards (via step 5)
8. social and economic interests also affect the definition of “acceptable” norms and standards
9. the governing norms and standards need to be taken into account at all stages of the execution of the project – through inception, design and realisation
10. more appropriate norms and standards which are defined such that ecological opportunities will be realised and adverse environmental effects are minimised will lead to a broader social acceptance

The scientific breakthroughs required in this research program that represent an additional effort with respect to current levels of practice are related in particular to steps 1, 5, 6, 9, and 10.

An example of changes in the ways that norms and standards may be applied is visualised in Figure 3. In this case, it is envisaged that the traditional, static approach to the implementation of a norm (blue line) may be replaced by a more dynamic approach (red lines) that includes concepts of natural ecosystem dynamics as well as duration of exposure. The objective is to respect the existing norm value while at the same time to recognise that a slight and/or temporary exceedance of this value may not necessarily lead to irreversible destruction of an ecosystem.

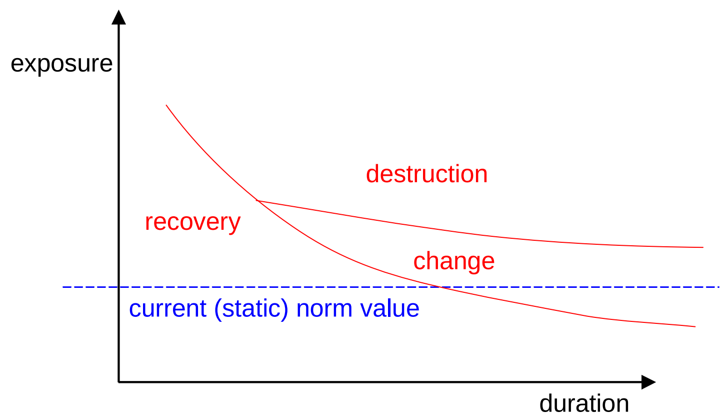

Figure 3. Possible changes in approach to norms and standards.

PROGRAMME STRUCTURE AND APPROACH

The research program will be arranged into several well-defined work packages each aimed at specific issues. The definition of each of the work packages represents a strategic choice of themes by the consortium partners based on current experiences and real-world problems and a prioritisation for the solution of these issues. The main work packages are:

1. Ecologically Meaningful Criteria: to find generic principles with regards to the impacts on the natural system that could guide the establishment of ecologically meaningful criteria for marine infrastructure development projects which are linked to the policy and legislative framework through environmental state indicators thereby enhancing the possibility of achievement of societal goals and increasing social acceptance.
2. Natural Dynamics & Cumulative Impacts: to derive practical methods and approaches that can distinguish between natural dynamics (incl. environmental variability) and impacts from infrastructural developments in the aquatic environment and effectively accommodate the assessment of cumulative effects.
3. Predictive Modelling and Effective Practice: to translate knowledge on the effects of interventions in the marine environment into validated tools to predict these effects and to investigate the effectiveness of innovative means for design and implementation of marine construction works.
4. Landscaping for Ecological Enhancement: to demonstrate that an ecosystem approach in marine construction projects through an ecological design and realization (ecological landscaping) will turn threats into sustainable opportunities.
5. A fifth work package will contain several case studies.

Table 1: Integrated research packages.

	WP1	WP2	WP3	WP4
	Ecologically meaningful criteria & indicators for sustainable development	**Natural dynamics & cumulative impacts**	**Evaluation of predictions & mitigation**	**Landscaping for Ecological Enhancement**
A. System knowledge - physical processes - ecological processes - institutional aspects (e.g. legislation) - economic aspects	resilience & tolerance intensity-duration of stress find generic mathematical principles accomodate uncertainties legislative framework agreeing acceptable damage	statistics & power analyses temporal & spatial scales distinguish impact from natural dynamics measurability of effects	prediction elements ecological effect chain validation of predictions effectiveness mitigating measures	habitat creation predicting colonization connectivity & larval supply morphological & ecological sustainability economic valuation of ecosystems substrate composition
B. Measurements & monitoring - research monitoring - compliance monitoring - feed-back monitoring	translate into measureable parameters testing principles in case studies time scales	appropriate monitoring strategies choice of reference sites time scale (beyond compliance) monitoring dynamics & recovery	monitoring predicted impact selection of appropriate parameters time scale (beyond compliance) effectiveness of mitigation validation campaigns	monitoring colonization measuring/monitoring enhancement (gain)
C. Governance models and strategies - problem structuring - stakeholder analysis - accommodate complex interactions - stimulate 'social learning' - use of science in policy & legislation	analyse limitations posed by existing legislation application of flexible / variable norms use of (scientific) knowledge in policy&legislation communication betw. science and policy makers 'social learning'	feedback to norms and legislation use of (scientific) knowledge in policy & legislation	integrated assessment frameworks feedback to legislation and norms use of knowledge in effect-chain approach	stakeholder participation dealing with perceptions
D. Implementation technology & best management practise	technical/practical feasibility good management practise dissemination	appropriate monitoring strategies length of monitoring programme	real-time forecasting methods good management practices effective mitigation	diversify availability of different substrates technical /practical feasibility
WP5: Case studies	**Various case studies to be identified during the programme (incl. Maasvlakte-2, Tropical Case-Singapore etc.)**			

Each of these work packages is inspired by ecology and benefits from developments in four generic research tracks A-D as specified in the first column of the overview table (Table 1). The five work packages collectively address the key targets of the new approach, however with a very distinctive focus. WP1 and WP4 directly address the key targets, linking ecosystem knowledge to governance, legislation and managements aspects (WP1) and pursuing ecological gains as an integral part of marine, coastal and inland water construction works (WP4). WP2 and WP3 form indispensable building blocks by providing fundamental ecosystem knowledge and insight in impact measurability (WP2), as well as data sets and predictive tools for assessment of process impacts, delayed system responses and the effectiveness of mitigating measures (WP3). Synthesis is achieved through application and testing of new concepts and tools in the context of several case studies (WP5).

A key element to guarantee focus of activities and coherence between work packages is the use of environmental state indicators that are defined as 'a reduced set of parameters that can simply, adequately and quantitatively describe the dynamic-state and evolutionary trends of the natural environment'. Collectively, they reflect a variety of interests (ecological, economic and societal). The identification of such environmental state indicators is a main deliverable of WP1, with input from other WPs as regard to ecosystem knowledge (WP2), predictability (WP3) and ecological enhancement (WP4). Moreover, the indicators act as the starting point for further ecosystem analysis (WP2), development of predictive tools (WP3) and exploration of ecological opportunities (WP4).

Short-term field experiments and longer-term monitoring programmes form another binding element in the programme. They are an absolute necessity to overcome the present lack of data (particularly post-construction data). Although operationally embedded in WP3, all five WPs will contribute to the design of measurement strategies, participate in the experiments and make use of the data. To ensure easy access for all participants, the provision of verified data and meta-information is a key deliverable of WP3.

The scope of the programme includes inland construction works in fresh water systems, albeit that the emphasis is on infrastructure development in marine, coastal and estuarine environments.

The results of this programme should lead to deliverables that can directly be applied in the process from conceptual design to realisation of marine infrastructure projects. For example the programme aims at delivering dedicated integrated assessment methodologies and improved governance models, methods for derivation of norms within a cost-benefit analysis framework to include economics and ecosystem values within a socio-political context, recommendations for internationally accepted Best Practices (e.g. design methodologies, construction techniques, monitoring strategies) and advanced monitoring strategies and data processing techniques for in-situ observations.

The deliverables shall be based on proof-of-concept through well-documented case studies.

WORK PACKAGES

Work Package 1 - Ecologically Meaningful Criteria and Indicators for Sustainable Development

Acquiring permits for marine infrastructure development projects is a complex process based on the evaluation of several criteria against extensive legislative requirements. In many cases scientific understanding of the overall complexity of the (ecological) processes involved is inadequate. This results in criteria for physical parameters, such as turbidity, overflow or sedimentation, that are typically set at fixed levels. In theory, the setting of such rigid thresholds is intended to protect the natural environment. In reality, however, these criteria often lack ecological meaning, their scientific justification is often poor (resulting in arbitrary thresholds that are either too strict or too weak), and they often typically ignore site-specific background conditions, in particular the spatial and temporal variability and dynamics (cf. natural dynamics in WP2).

The rigidity of criteria and thresholds faced in infrastructural development projects worldwide can be considered costly both from an environmental as well as an economic perspective. Weak thresholds do not fulfil the aim for which they have been developed as they do not sufficiently protect the natural environment. In addition they may result in a loss of social acceptance of infrastructural projects once it becomes clear that environmental damage has occurred in spite of existing criteria. Situations in which thresholds have been set too strict result in a waste of money and other resources. Whilst not damaging the natural environment per se, they do reduce the opportunities to create an added value by achieving ecological goals through the ‘building with nature’ principle (cf. landscaping for ecological enhancement in WP4).

To accommodate the abovementioned problems, a more flexible and ecologically justified approach to deal with criteria is required. The term ‘environmental state indicator’ is introduced to link criteria to management purposes. Environmental state indicators can provide answers to questions that arise from society in the context of sustainable development, for example through the policymaking or legislative framework. Environmental state indicators typically operate at a more aggregate level and can consist of one or more (ecologically meaningful) criteria.

From a policy point perspective, data, analytical tools or the scientific understanding are often lacking to say whether current patterns of change to the natural environment are sustainable. Information to assist actions that need to be taken is often not available. Data and understanding are needed and acquiring them can be expensive and time consuming. In addition to gathering basic data, and developing understanding of the environmental factors to which it relates, information needs to bear effectively on environment related decision making. Indicators can deliver the information to help make decisions. They often appear to be simple measures, but their success lies in accurately summarising and communicating key aspects of complex environments.

A good environmental state indicator:

- has an agreed, scientifically sound meaning;
- represents an environmental aspect of importance to society;
- tells us something important, and its meaning is readily understood;
- has a sound and practical measurement process;
- helps focus information to answer important questions;
- assists decision making by being effective and cost-efficient to use.

The main objective of this work package is to find generic principles with regards to the impacts on the natural system that could guide the establishment of ecologically meaningful criteria for marine, coastal and inland water infrastructure development projects which are linked to the policy and legislative framework through environmental state indicators thereby enhancing the possibility of achievement of societal goals and increasing social acceptance.

Research Questions – Work Package 1:

- How can generic principles concerning the knowledge of the effects of infrastructural developments on the natural system be applied to establish ecologically meaningful criteria?
- How can ecologically meaningful criteria be used to develop environmental state indicators that provide the link with the policy and legislative framework?
- How can governance models be developed to deal with infrastructural projects in a way that meets goals for sustainable development set by society?

Work Package 2 - Natural Dynamics and Cumulative Impacts

Natural ecosystem dynamics and environmental variability produce uncertainties in the prediction and detectability of environmental impacts. Whilst construction works such as dredging, for example, can cause an above average elevation of turbidity over critical marine ecosystems, these elevations may in many instances be within the long-term background range for the area and may be short-lived when compared to naturally occurring events such as storms, floods or other climatic and seasonal variations.

Environments that are characterised by major natural variability and hence substantial ecosystem dynamics therefore pose a challenge to the prediction, assessment, monitoring and evaluation of impacts of planned marine infrastructure developments and subsequent post-impact recovery. Setting fixed targets, thresholds and reference levels in an environment that itself is characterised by natural changes/dynamics at a variety of temporal and spatial scales is a challenging task and may not always be practical.

Better understanding of natural dynamics is therefore of paramount importance to achieve an effective implementation of risk assessments as well as predictive modelling before, and effective monitoring during and after construction works. Effective methodologies to carry out such assessments and monitoring activities are currently lacking.

The main objective of this work package is to derive practical methods and approaches that can distinguish between natural dynamics (incl. environmental variability) and impacts from infrastructural developments in the aquatic environment and effectively accommodate the assessment of cumulative (anthropogenic) effects.

Research Questions - Work Package 2:

- How to distinguish between natural dynamics of an ecosystem and the effects of infrastructural developments?
- How to establish the true cumulative effect of all positive and negative pressures on the ecosystem?

Work Package 3 - Predictive Modelling and Effective Practice

Considerable effort, time and money is often spent on making predictions of physical changes, ecological impacts and potential (post-construction) ecosystem recovery, as part of the overall EIA- and permitting process for planned marine infrastructure developments. Still, because of limited availability of data and validated models, these predictions come with a high degree of uncertainty. Monitoring programmes are usually limited to compliance monitoring during project implementation, in the vicinity of the construction works. Hardly any attention and effort is devoted to post-construction monitoring of ecosystem behaviour and recovery, as funding for monitoring activities soon dries up once the construction has been completed. Therefore, the predictions made at the onset of such developments are rarely evaluated or validated, and post-construction analysis of monitoring data is poor.

To reduce possible impacts of marine infrastructure development on the natural system, specific mitigating measures are usually formulated as part of the EIA process and permitting procedures. Because of limited insight in natural system dynamics and uncertainties in the impact predictions, the definition of environmental criteria and required mitigating measures tends to be on the conservative side. Moreover, the effectiveness of such mitigating measures is often poorly understood and scientific proof on their functioning is hardly available.

It is in this context that there is a need to evaluate and validate predictions of impacts and recovery potential over longer time-scales beyond compliance monitoring. Research is also needed to improve the understanding of effectiveness of mitigating measures. This will lead to greater credibility of (ecological) impact predictions, contribute to better modelling capacity, create improved effectiveness of mitigating measures and allow for well-informed decision making.

The main objective of this workpackage is to translate knowledge on the effects of interventions in the marine environment into validated tools to predict these effects and to investigate the effectiveness of innovative means for design and implementation of marine construction works.

The outcome of this work package directly adds to the overall objective of this research programme by providing scientifically sound and well-validated knowledge on intervention-impact relationships in the marine environment. This will result in monitoring strategies based on ecologically meaningful criteria, facilitate the design of ecologically attractive project schemes and thus increase the social acceptance of infrastructural works in natural systems.

Research Questions - Work Package 3:

– How to translate knowledge on the effects of interventions in the marine environment into validated tools to predict these effects?

– How to investigate and determine the effectiveness of innovative means in the design and implementation of marine construction works?

Work Package 4 - Landscaping for Ecological Enhancement

Presently, in analysing 'sustainable aspects' of proposed projects in the 'wet environment', measures are being considered to mitigate or compensate for any predicted negative or less desirable effects. Very rarely opportunities are considered that could improve or add to the overall sustainability of the considered project. This shortage of 'positive thinking' is likely to be caused by 3 factors:

- the reactive, conservative attitude in analysing, in stead of a pro-active sustainable approach; this study shall contribute to a paradigm shift to reverse these processes..
- a 'deficiency' of the available models to predict or evaluate effects of any protective or promoting action; this research program, through WP's 1 to 3, aims to upgrade and renew predictive tools.
- a limited experience in 'opportunity thinking' by most proponents and by opponents alike; dissemination of results of this program, more specifically of this work package, shall encourage a discussion between al stakeholders to explore realistic and practical means for ecological and sustainable enhancement.

Using mechanisms of the ecosystem in the design and implementation of marine infrastructural projects will offer the opportunity to incorporate environmental protection or even enhancement with economical and social benefits in such projects. The development of such artificially created habitats (landscaping) can also play a role in providing habitats for target species such as commercial or endangered species, in areas where nature does not provide the resources at present. Landscaping as an integral part of aggregate extraction operations may also offset the negative impacts of other types of human activities. For example fisheries impact could possibly be balanced by creating refugia or nursery grounds thereby benefiting both industries.

Understanding ecosystem mechanisms and basic morphodynamics are key factors to produce effective designs for sustainable landscaping projects. At present such detailed knowledge is lacking and without this knowledge any assessment of the opportunities will not be possible. Development of such knowledge is now subject of the other work packages.

Ecological designing of construction projects aimed at enhancing both natural and economic values will have implications on all levels, not only in the project, but also for society (decision process, legislation, social and political acceptance).

Research Question – Work Package 4:

– How to promote an ecosystem approach in marine construction projects through an ecological design and realization (landscaping for ecological enhancement) turning threats into sustainable opportunities?

Work Package 5 - Case Studies

These case studies will serve to gather (field) information on system characteristics and impacts of running (or past) infrastructural developments in order to apply and test generic principles, innovative techniques, scientific hypotheses and new approaches to demonstrate the real practical application in a variety of planning and management situations. Such applications will be readily transferable to other geographical areas.

The main objectives of this case study are:

- Evaluate how the governance model could be enhanced and decision making facilitated on the basis of scientific breakthroughs in the field of integrated assessment of functional and ecological requirements.
- To test and demonstrate prediction models, working methods and monitoring strategies that will be developed under the Building with Nature program.

CONCLUSIONS

The research programme embodies a new and innovative approach to a truly integrated assessment of large-scale marine and inland water projects. The programme represents a unique integration of scientific knowledge from both technical universities as well as life-science universities.

Key targets of the programme are the establishment of ecologically meaningful criteria to evaluate project impacts, development of environmental state indicators that provide answers to questions that arise from society in the context of sustainable development, the application of eco-engineering concepts to turn ecological threats into sustainable opportunities and the development of modelling and monitoring concepts that assist in the design of projects in the marine, coastal and inland water environment by combining ecological functions with socio-economic functions.

The role of the knowledge and research institutes in this consortium is to provide a bridge between fundamental research and practise in water-related and ecological issues by converting new knowledge and model concepts into applications. Care has been taken in developing the various work packages to ensure the appropriate mix of scientific depth with the integration of knowledge. Scientific excellence is guaranteed through the participation of renowned research institutes and university groups with international experience and representing all relevant disciplines.

Case studies and field validation will be used to develop, calibrate and improve assessment standards and tools. The participating institutes and universities provide access to the wider international network of expertise in marine and aquatic ecology; providing opportunities where necessary to consult and include experts from other institutes in this network that are not currently listed as consortium members.

The participation of Dutch government agencies and leading international consultants will contribute to the integration of the new know-how into sustainable project development. The additional research effort includes not only ecological, technological and social aspects of large-scale constructions but also represents an integration of these individual research components into a framework for sustainable solutions and decision-making.

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