# Book of abstracts

**VLIZ YOUNG MARINE SCIENTISTS' DAY**

*site Oud Sint-Jan, Brugge*
*25 February 2011*

VLIZ

VLIZ YOUNG MARINE SCIENTISTS' DAY 2011

# BOOK OF ABSTRACTS
## VLIZ YOUNG MARINE SCIENTISTS' DAY

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**25 February 2011**

Photo cover:
Green sea urchins (*Psammechinus miliaris*) from the Belgian part of the North Sea
(Karl Van Ginderdeuren)

# PREFACE

This is the 'Book of Abstracts' of the 11th edition of the VLIZ Young Scientists' Day, a one day event that was organized on 25 February, 2011 in site Oud Sint-Jan, Brugge.

This annual event has become more and more successful over the years. With more than 300 participants and over 100 scientific contributions, it is fair to say that it is thé place to be for Belgian marine researchers and for the end-users of the research. It is an important networking opportunity, where young scientists can meet and interact with their peers, learn from each other, build their personal professional network and establish links for collaborative and interdisciplinary research.

Marine scientists from all Flemish universities, associations and scientific institutes – and representing all marine science disciplines – have contributed to this volume. The book thus illustrates the diversity, quality and relevance of the marine sciences in Belgium: it provides a beautiful and comprehensive snapshot of the state-of-the-art of marine scientific research in Flanders in 2011. Young scientists present their research in an exciting way and communicate their fascinating science – and its importance to society – to the wider public. We thus hope to demonstrate the excellence of Flemish marine science and to increase its national and international visiblity.

The volume of research that is presented holds a great promise for the future. It shows that marine science is a very lively discipline in Flanders, and that a new generation stands ready to address the grand challenges and opportunities that our seas and oceans represent.

The 'Ostend Declaration' (cf. next page) which was adopted at the occasion of the EurOcean 2010 conference (http://www.eurocean2010.eu/) establishes the future priorities for European marine research in the coming decade. During this conference it was unanimously agreed that the Seas and Oceans are one of the Grand Challenges for the 21st Century.

I want to congratulate all participants with their contributions, and I invite them all to actively participate in VLIZ-events and activities in the future.

Brugge, 25 February 2011

Dr Jan Mees
Director VLIZ

# Ostend Declaration

The European marine and maritime research community stands ready to provide knowledge, services and support to the European Union and its Member and Associated States, recognising that

## *"The Seas and Oceans are one of the Grand Challenges for the 21st Century".*

In doing so, we acknowledge:

- the critical role of the oceans in the earth and climate systems;
- the importance of coasts, seas and oceans and their ecosystems to our health and well-being;
- the increasing impacts of global environmental change on the marine environment and the significant socio-economic consequences of those impacts;
- the ongoing need for basic research to address major gaps in our fundamental knowledge of coasts, seas and oceans;
- the enormous opportunities for innovation, sustained wealth and job creation in new and existing maritime sectors such as aquaculture, renewable energy, marine biotechnology and maritime transport; and
- the need to translate these messages to all sectors of society.

Furthermore, we underline **the crucial role of marine and maritime science and technology** in providing knowledge and understanding of the seas and oceans and their biodiversity in creating new opportunities and technologies which will support and progress:

- job creation through smart, sustainable and inclusive growth (Europe 2020);
- implementation of the Integrated Maritime Policy for the European Union (2007), the European Research Area (EC Green Paper on ERA, 2007) and other policies such as the Common Fisheries Policy;
- Good Environmental Status in our marine waters by 2020 (Marine Strategy Framework Directive); *and*
- related grand challenges including food, energy and health, as identified in the Lund Declaration (2009).

The marine and maritime research community recognises that significant progress has been made in response to the Galway (2004) and Aberdeen (2007) Declarations, evidenced in the adoption of the Integrated Maritime Policy for Europe (2007), its environmental pillar the Marine Strategy Framework Directive (2008) and the European Strategy for Marine and Maritime Research (2008), and commits to building future progress within this comprehensive policy framework.

## *Addressing the Seas and Oceans Grand Challenge*

The EurOCEAN 2010 Conference identified priority marine and maritime research challenges and opportunities in areas such as food, global environmental change, energy, marine biotechnology, maritime transport and marine spatial planning, including seabed mapping. The Conference delivered an unequivocal message on the societal and economic benefits Europe derives from the seas and oceans and of the crucial role that research and technology must play in addressing the Seas and Oceans Grand Challenge.

**The European marine science and technology community, building on existing achievements and initiatives, is ready to address this challenge in partnership with industry and the public sector, and call upon the European Union and its Member and Associated States to facilitate this response by delivering the following proactive and integrating actions:**

### 1. Joint Programming

Develop an integrating framework, combining the assets of European programmes with those of Member States, to address the Grand Challenge of the Seas and Oceans, including the identification and delivery of critical marine research infrastructures. The **Joint Programming Initiative on "Healthy and Productive Seas and Oceans"** has the appropriate scale of integration and should be actively supported by the European Commission and Member States.

### 2. European Ocean Observing System

Support the development of a truly integrated and sustainably funded "**European Ocean Observing System**" to (i) re-establish Europe's global leading role in marine science and technology; (ii) respond to societal needs by supporting major policy initiatives such as the **Integrated Maritime Policy** and the **Marine Strategy Framework Directive;** and (iii) support European contributions to global observing systems. This could be achieved through better coordination of national capabilities with appropriate new investments, in coordination with relevant initiatives (e.g. ESFRI, EMODNET, GMES) and the engagement of end-users.

### 3. Research to Knowledge

Establish appropriate mechanisms to keep under review current marine and maritime research programmes and projects with a view to enhancing their impact by (i) exploiting the results of this research; and (ii) identifying existing and emerging gaps. This should be supported by a **repository for the reports and findings of national and EU marine and maritime research projects, programmes and initiatives**, with capacity for archiving, translating, analysing, reporting and developing integrated knowledge products to facilitate policy development, decision making, management actions, innovation, education and public awareness.

**To address effectively the Seas and Oceans Grand Challenge it is essential to prioritise initiatives and programmes to enhance:**

- **Innovation**

Provide enhanced support for innovation and the commercialisation of new marine/maritime products, processes, services and concepts in support of the Innovation Union and the Europe 2020 Strategy;

Promote actions to raise awareness within the marine scientific community of the innovation potential of marine science, and opportunities to make use of it in cooperation with ocean industries.

- **Training and Career Development**

Establish appropriate training and mobility opportunities for marine researchers and technologists and provide stable and attractive career pathways to ensure the highly skilled workforce that will be needed to support expanding marine and maritime sectors;

- **International Cooperation**

Establish at EU level a mechanism to strategically enhance international cooperation (i.e. between European consortia and third country partners) in science and technology, with support for networking initiatives, preparatory phase projects and concrete actions;

Strengthen bilateral/multilateral cooperation with key funding organisations, intergovernmental bodies and marine/maritime science institutions outside Europe to overcome barriers to, and deliver workable solutions for, joint funding of relevant international research programmes and infrastructures.

**The European marine and maritime science community is committed to playing its role, in partnership with industry and the public sector, to bridge the gap between science and innovation to support sustainable development.**

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# ANNUAL VLIZ THESIS AWARDS MARINE SCIENCES 2010

Every year VLIZ awards two marine Master theses. Fundamental as well as applied marine researchers in all disciplines of marine sciences can apply. The prize amounts to 500 EUR and is reserved for young scientists that are graduated at a Flemish university or college for higher education.

The 2010 winners of the Annual VLIZ Thesis Award Marine Sciences are:

## THOMAS VANDORPE

Renard Centre of Marine Geology,
Ghent University

*for the thesis entitled:*

**Seismic stratigraphy of Plio-Pleistocene deposits on the shelf edge SW off Mallorca, Spain**

## &

## QUINTEN VANHELLEMONT

Afdeling Protistologie en Aquatische Ecologie
Vakgroep Biologie, Universiteit Gent

*for the thesis entitled:*

**Gebruik van MODIS-beelden om de variabiliteit in biomassa van microfytobenthos in intergetijdengebieden te evalueren op regionale en globale schaal**

***Use of MODIS imagery for the assessment of the variability in intertidal microphytobenthos biomass at regional and global scale***

# SEISMIC STRATIGRAPHY OF PLIO-PLEISTOCENE DEPOSITS ON THE SHELF EDGE SW OFF MALLORCA, SPAIN

Vandorpe Thomas

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The seismic data, obtained on the southeastern shelf and shelf break of Mallorca, display a great variety of depositional features.

The seismic grid has been divided into two parts: one where a Miocene reef prevails and one where sediments of Plio-Pleistocene age are abundant. They are separated by a NE-SW-orientated fault, which has a maximum offset of 250 meters. The area north of the fault-line contains a thick package of sediments on top of the reef and shows a weak shelf break with mass transport deposits, while the area south of the line has shallow reef positions and is characterized by steep slopes and a sharp shelf break. This can be explained by the hard nature of the carbonate reef. The reef in the area belongs to the platform margin of the Miocene Llucmajor reef deposits. Subaerial erosion after the Messinian Salintiny Crisis created U- to V-shaped wedges in the reef.

The entire Plio-Pleistocene sequence has been divided into two sequences (1 and 2) and each sequence subdivided into two major units (A and B). Unit 1A drapes the reef, is heavily faulted and is of Lower Pliocene age. Unit 1B has a Lower- Pliocene to lower Upper-Pliocene age and has been correlated to transparent seismic facies observed all over the Mediterranean during this period (e.g. Hernández-Molina *et al*., 2002). Its upper boundary is the Upper Pliocene Revolution (UPR, 2.4Ma). Sequence 2 consists of higher amplitude reflector deposits and displays mainly two different facies: cut-and-fill structures, which have a northwestern sediment infill and aggradational (sub) parallel continuous strata. Both unit 1B and sequence 2 are elongate mounded drift deposits. The observed cut-and-fill structures indicate towards a fluctuating strength of a current. This current may have originated from the permanent deviatory current of the Balearic Current, running through the Mallorca Channel, or from the semi-permanent wind-driven storm currents inferred by Werner *et al.* (1993).

Sequence 2 displays divergent (unit 2A) to sigmoidal (unit 2B) sub-units in a canyon system along the fault. The current causing the elongate mounded drift deposits eroded sediment of units 1B and 2A. When currents slowed down, sediment was again deposited on steep slopes in the canyon, causing occasional failure and thus the sigmoidal deposits. The alternating sub-units of lower and higher amplitude reflectors of sequence 2 have been correlated to Marine Isotopic Stages. Unit 2A has been deposited from the UPR (2.4Ma) to Middle Pleistocene Revolution (MPR, 0.92Ma) and was subject to sea-level variations in the order of 50 meters. Unit 2B has been deposited from the MPR to present and was subject to sea-level variations in the order of 100 meters.

Sedimentation rates have been calculated based on the observed thicknesses and calculated ages. Rates before the UPR are in the order of 4.5cm/ka, but have to interpreted with caution, as few data are obtained from this period. After the UPR, rates vary greatly, but tend to be higher on average. Especially after the MPR, when they reach15cm/ka.

## References

Hernández-Molina F.J., L. Somoza, J.T. Vazquez, F. Lobo, M.C. Fernández-Puga, E. Llave, and V. Díaz-del Río. 2002. Quaternary stratigraphic stacking patterns on the continental shelves of the southern Iberian Peninsula: their relationship with global climate and palaeoceanographic changes. Quaternary International 92(1):5-23.

Werner F.E., A. Viúdez and J. Tintoré. 1993. An exploratory numerical study of the currents off the southern coast of Mallorca including the Cabrera Island complex. Journal of Marine Systems 4(1):45-66.

# GEBRUIK VAN MODIS-BEELDEN OM DE VARIABILITEIT IN BIOMASSA VAN MICROFYTOBENTHOS IN INTERGETIJDENGEBIEDEN TE EVALUEREN OP REGIONALE EN GLOBALE SCHAAL

## *USE OF MODIS IMAGERY FOR THE ASSESSMENT OF THE VARIABILITY IN INTERTIDAL MICROPHYTOBENTHOS BIOMASS AT REGIONAL AND GLOBAL SCALE*

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Intergetijdengebieden komen voor op de overgang van mariene naar terrestrische ecosystemen, daar waar de helling van het strand klein genoeg en de getijhoogte groot genoeg is. Door de getijdenwerking treden er zeer grote fluctuaties op in lichtintensiteit, temperatuur en vochtigheid. De sterke stromingen bij het opkomen en afgaan van het getij zorgen voor een grote turbiditeit in de waterkolom en voor een instabiliteit van het sediment. Deze condities zijn niet geschikt voor de groei van hogere planten, maar eencellige algen die in en op het sediment leven (microfytobenthos) kunnen hier uitstekend gedijen. De primaire productie in intergetijdengebieden is zeer belangrijk voor de kustzone en deze gebieden zijn zowel uitstekende kraamkamers voor vissen als goede voedselgronden voor vissen en vogels.

Onder invloed van de verhoogde lichtintensiteit bij laag tij migreert het microfytobenthos naar de oppervlakte en kan daar uitgestrekte matten vormen. Het voorkomen van microfytobenthos-matten in tijd en ruimte is echter zeer variabel (*patchy*) en het is duur en moeilijk om deze op grotere schaal *in situ* te observeren. In dit thesisonderzoek werden satellietdata gebruikt om de spatio-temporele verspreiding van het microfytobenthos in intergetijdengebieden te bepalen.

De gebruikte satellietdata waren afkomstig van de Moderate Resolution Spectroradiometer (MODIS). Voor twaalf sites wereldwijd werden wolkenvrije beelden verzameld voor 2003. De eerste twee MODIS-banden, in het rode en nabij-infrarode deel van het spectrum en met een grondresolutie van 250 meter, werden gebruikt om de Normalized Difference Vegetation Index (NDVI) te berekenen. De NDVI is gebaseerd op het principe dat planten licht in het fotosynthetisch actieve deel van het spectrum absorberen, maar langere golflengtes (zoals nabij-infrarood) reflecteren. De index wordt vaak gebruikt om de gezondheid van terrestrische vegetatie te bepalen. De NDVI kan waarden aannemen tussen -1 en +1. Negatieve waarden stemmen overeen met water, ijs en wolken, 0 stemt overeen met kale bodem en hoe dichter bij 1, hoe gezonder de vegetatie.

De berekende NDVI-waarden waren gemiddeld hoger en hadden een grotere spreiding voor de sites met een hogere breedteligging. De laagste NDVI-waarden, met de kleinste spreiding, werden geobserveerd in de tropische sites.

Per maand werd een gemiddelde NDVI-waarde berekend en deze gemiddelde waarden werden vergeleken met de maandelijkse gemiddelde temperatuur en neerslag. Voor sites in gematigde klimaten is de variatie in de maandelijkse NDVI sterk gecorreleerd met temperatuur. De hoeveelheid microfytobenthos wordt hier dus sterk beïnvloed door de seizoenaliteit, met name de temperatuursverschillen. Voor mediterrane en subtropische sites is er een sterke correlatie met neerslag; de productiviteit van het microfytobenthos is verschillend voor het droge en natte seizoen. Voor de tropische sites is er geen correlatie tussen de NDVI en neerslag of temperatuur; waarschijnlijk door de aseizoenaliteit van deze gebieden.

Om te onderzoeken of deze trends in het hele intergetijdengebied optreden, werd elke site in vijf hoogteklassen ingedeeld. Dit gebeurde op basis van het percentage van beelden waarop elke pixel op aanwezig was. De laaggelegen delen van de intergetijdengebieden zullen het langst onder water staan; de hooggelegen delen het minst lang. Pixels die op meer beelden voorkomen, zullen dus hoger gelegen zijn. De trends blijken gelijk te zijn in deze vijf hoogteklassen, maar met lagere waarden op lager gelegen gebieden. Door de kortere blootligging van het sediment tijdens laagtij

heeft het microfytobenthos in laaggelegen zones minder tijd om aan fotosynthese te doen, te groeien en te migreren.

De seizoenale variatie van de NDVI op ruimtelijk vlak werd voor twee gebieden geanalyseerd. Uit deze analyse bleek dat gekende ruimtelijke patronen van aanwezigheid en groei van microfytobenthos in het intergetijdengebied afgeleid kunnen worden uit satellietdata. Deze patronen worden sterk bepaald door lokale variabelen zoals korrelgrootte en stroming.

De NDVI berekend met de eerste twee MODIS banden bleek zeer geschikt om het voorkomen van microfytobenthos in tijd en ruimte in kaart te brengen voor de grote intergetijdengebieden.

# ANNUAL VLIZ NORTH SEA AWARD – 2010

Each year the Flanders Marine Institute (VLIZ) awards a scientific prize to foster innovative fundamental or applied research on the structure and functioning of the North Sea ecosystem, with emphasis on coastal and estuarine areas of the Southern Bight and the Channel. The prize is awarded to a researcher (or a research team) working and residing in a country bordering the North Sea. The prize amounts to 1000 EUR and is indivisible. It is granted to reward a recent original scientific contribution, preferably having relevance to the sustainable management of the area concerned. Studies pertaining to the biodiversity of the local ecosystem are equally welcomed. The contribution has to be of postgraduate or postdoctoral level.

The Annual VLIZ North Sea Award 2010 is awarded to:

## MARIJN RABAUT

Research Group Marine Biology,
Biology Department, Ghent University

*for his scientific contribution entitled:*

***LANICE CONCHILEGA*, FISHERIES AND MARINE CONSERVATION:
TOWARDS AN ECOSYSTEM APPROACH TO MARINE MANAGEMENT**

# *LANICE CONCHILEGA*, FISHERIES AND MARINE CONSERVATION: TOWARDS AN ECOSYSTEM APPROACH TO MARINE MANAGEMENT

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Oceans and coastal seas are being heavily exploited, leading to biodiversity losses and degradation of the integrity of ecosystems. Of all human activities at sea, fisheries is considered to be one of the most intensive. The vision on the marine environment has proved to be largely utilitarian until now, which has lead to a focus on the maintenance of the benefits from the exploitation of resources. In the end, this approach did not prove to be efficient and in response to continuous degradation, concepts as 'ecosystem approach' have now become the key concepts to manage the marine environment. In this respect, 'marine protected areas' (MPAs) have been installed in an attempt to halt the deterioration of the sea. The integration of marine conservation and fisheries management is therefore necessary and should be based on ecological knowledge. The North Sea is one of the most exploited marine areas in the world, with the Belgian part of the North Sea (BPNS) as a symbol for the intensivity of these activities. Therefore, the coastal marine areas that are situated in North-Western Europe and largely consist of sedimentary sand banks and swales are the focus of this thesis. Particularly in this system, macrobenthos (*i.e.* invertebrate fauna larger than 1mm) is recognized as fundamentally important in the functioning of marine ecosystems and this ecosystem component is the focal point of this thesis. High density aggregations of the ecosystem engineer *Lanice conchilega* (sandmason) are further studied in depth. *Lanice conchilega* is a tube dwelling bristle worm (Annelida, Polychaeta, Terribellidae). Experiments were designed to generate insights that can support conservation strategies and the relation with impacts of fisheries activities is investigated. As the management of important ecosystem engineers may protect numerous associated species and functions by expanding distributional limits for a lot of species, these organisms have been proposed as conservation targets in modern marine management. Therefore, proving the value of the ecosystem engineer *L. conchilega* within this framework is the basic aim of the thesis. Chapter 1 pictures the broader context of conservation and fisheries management as well as what is the state of the art on the knowledge of *L. conchilega*.

Chapter 2 evaluates the effect of this species on the macrobenthic community and on sediment characteristics of its habitat based on a long term data set in Belgian coastal waters. Both sediment composition and community structure of the associated macrofaunal matrix are affected by the presence of *L. conchilega*. There is a positive correlation between the steadily increasing macrobenthic densities and densities of *L. conchilega* (R = 0.59; p < 0.001). Species richness is increasing with *L. conchilega* densities, except for the highest *L. conchilega* density class. There from we can conclude that *L. conchilega* is able to restructure the macrobenthic community in a ''babushka'' like organization, indicating that *L. conchilega* expands the niche breadth of several associated species. A species rank list is created according to each species' association with *L. conchilega*. This species rank list is extensively discussed based on all ecological knowledge available. Species are favoured by the habitat modifying ability of the polychaete tubes, which create and regulate refuge for species, alter the interactions between local species and change the physical factors of the environment. Addendum I is fully complementary to Chapter 2 as it evaluates the ecosystem engineering consequences on a North Sea scale. The presence of *L. conchilega* in different habitats in the North Sea and its effect on the abundance, species richness, diversity and community structure in these habitats are evaluated. In four different habitats (shallow muddy sands, shallow fine sands, deep fine sands and shallow medium sands), the density of the surrounding benthos increases with increasing density of *L. conchilega* and were most obviously pronounced in shallow fine sands. This addendum shows that *L. conchilega* patches are responsible for an increased habitat quality in an otherwise uniform habitat, resulting in a higher survival of the surrounding benthic species.

Chapter 3 characterizes the physical features of dense aggregations and discusses this together with the biological characteristics in order to determine whether these dense aggregations can classify as 'reefs'. To classify as reefs, ecosystem engineering activities need to significantly alter several habitat characteristics. Results showed that the elevation and sediment consolidation of the biogenic mounds was significantly higher compared to the surrounding unstructured sediment. Areas with *L. conchilega* aggregations tend to be extensive and patchiness is high (coverage 5-18%). Individual aggregations are found to persist for several years if yearly renewal of existing

aggregations through juvenile settlement occurred. This renewal is enhanced by local hydrodynamic changes and availability of attaching structures (adult tubes). This chapter concludes that the application of the definition for reefs as found in the Habitats Directive provides evidence that all physical and biological characteristics are present to classify *L. conchilega* as a reef builder. As a range of aggregation development exists, 'reefiness' is not equal for all aggregations and a scoring table to quantify *L. conchilega* 'reefiness' is presented.

The reef structures formed by *L. conchilega* are targeted in Part II to generate detailed knowledge on the impact of mobile fishing disturbance. Chapter 4 describes a laboratory experiment in which four disturbance regimes to *L. conchilega* reefs were applied. Survival drops significantly after 10 days and after 18 days (with a disturbance frequency of every 12 and 24 hours, respectively). Besides the physical impact on *L. conchilega* itself, Chapter 5 tests the vulnerability of the species that live in close association with *L. conchilega*. A treatment zone was exposed to a one-off experimental trawling during an intertidal *in situ* experiment. Subsequently, the impact on and recovery of the associated fauna is investigated for a period of nine days post-impact. Community analysis shows a clear impact followed by a relatively quick recovery. This impact and subsequent recovery is largely explained by two species: *Eumida sanguinea* and *Urothoe poseidonis*. Species analysis confirms the beam-trawl passage significantly (p = 0.001) impacted *E. sanguinea* for the whole period of the experiment. The experiment confirmed that closely associated species of *L. conchilega* reefs are impacted by beam-trawl fisheries. Chapter 4 and 5 (*i.e.* Part II) provides insight in the resistance and therefore also in the resilience of the reef system and indicates that the reef structure itself can persist under intermediate beam trawl pressure but the integrity of the reef is hurt as the system as a whole degrades immediately after disturbance.

The relation between the ecological value of the observed increased benthic diversity and the abundance for flatfish seemed to be an important knowledge gap. Therefore, Chapters 6 and 7 (*i.e.* Part III) investigate the ecological interactions between the benthic habitat created by *L. conchilega* and flatfish. The biotic structuring factor on flatfish' habitat preference was addressed for the first time. Chapter 6 investigates in an *in situ* experimental sampling design, the structuring effect of biogenic reefs on the distribution of post-larval *Pleuronectes platessa* in an intertidal nursery area. The density distribution of this flatfish species was significantly (p < 0.0001), which can be explained by the presence of *L. conchilega* reefs.

As effects on habitat preferences of flatfish within nursery areas are thought to be related to food availability as well, Chapter 7 evaluates the importance of biogenic habitats as a feeding ground for juvenile flatfish species (*P. platessa* and *Limanda limanda*). Both the distribution and feeding behaviour of the two flatfish species *P. platessa* and *L. limanda* are studied in function of the presence of high densities of an ecosystem engineer. In this chapter, two different ecosystem engineered habitats are tested for (*L. conchilega* reefs and *Owenia fusiformis* aggregations) and sampling is done in two different coastal areas (the BPNS and the Dutch part of the Wadden Sea). General responses are identified by comparing relative differences between ecosystem engineered habitats and adjacent non-ecosystem engineered habitats. Results show that both flatfish species select for the ecosystem engineered habitat. This behaviour is further investigated using stomach content analyses. For *P. platessa* occurring in *L. conchilega* reefs, this selection is explained as a feeding behaviour. For the habitats created by *O. fusiformis*, no such a relation is found. Therefore, Chapter 7 suggests that the juveniles use ecosystem engineered habitat both as a shelter (antipredation behaviour) and/or as feeding ground. These small-scale aspects of larger nursery grounds can be considered as 'Essential Juvenile Habitat' (EJH) and merit attention in habitat suitability models as well as in marine conservation measures. Part III shows that *L. conchilega* reefs also have bottom up effects on juvenile flatfishes. Linking these results to Part II points out that further modification of these biogenic habitats may lead to a loss of one or more ecosystem functions which flatfish species depend on.

In the last part of this thesis (Part IV), the results on *L. conchilega*, fisheries and marine conservation are discussed in the framework of their potential value in an application of the ecosystem approach supporting marine management. Chapter 8 brings literature on marine conservation strategies in soft-bottom temperate areas together in one 'systems approach' that provided answers to the questions 'why?', 'how?' and 'what is the effectiveness?' of MPAs. This 'systems approach' was visualized in a flow chart and includes three phases: setting policy objectives, decision making and evaluating the eventual effects of the MPA. The analysis indicates that the relation between fisheries and MPA-management is the most challenging because of conflicting interests and institutional differences. Activities limited in space and not relying directly on ecosystem functions (e.g. offshore energy production and aggregate extraction) are generally easier to manage than fisheries. The systems approach is applied to the Belgian case and proved useful in providing insight into the complex interactions of various authorities with scattered jurisdictions.

Chapter 9 further discusses the (international) legislative framework of marine protection. As marine ecosystems are threatened, conservation strategies are set out in international policy to face the large scale of the marine ecosystems. However, not only the scale is important to manage marine ecosystems, also ecosystem dynamics should have a prominent place in the strategies. The chapter points out that too strict interpretation of international legislation is expected to fail in its aim of implementing a sustainable use of the sea. The Belgian case has been developed as an example, pointing out that international (EU) legislation is excessively strictly interpreted which decelerates the implementation rate. We therefore suggest applying a robust though flexible interpretation of environmental legislation in the marine environment. We acknowledge that there is a risk of undermining the final goal of environmental legislation if increasing flexibility is translated into looser protection.

Finally, Chapter 10 discusses the results of the present thesis. The restructuring capacity of *L. conchilega* through its effect on the niche of several associated species has been re-evaluated by revisiting the original and fundamental concepts of niche theory. Furthermore, the wider resilience of *L. conchilega* reefs was attributed to the ecosystem engineer itself as well as by the closely associated species (which define the biological features of the reefs). This resilience is discussed with preliminary results of a one-off experimental beam-trawl study that has been performed on subtidal reefs. Chapter 10 continues by evaluating the conservation value of *L. conchilega* aggregations. From a general nature conservation perspective this particular tube builder is considered an important ecosystem engineer, and provides the template for other ecosystem processes, making *L. conchilega* useful within a conservation context. Therefore, the 'label' under which the aggregations may potentially be preserved has been discussed. Potential conservation under the 'reef label' is compared with the conservation value of other reef forming tube worms. These tube reefs all change the benthic community significantly without hosting unique species, they build elevated bioconstructions, generate a biogenic concretion through an increased consolidation, change the sedimentary environment and they can appear and disappear very fast but they all have similar mechanisms that enhance stability and longevity. However, prioritization between different habitats is possible and needed. The mapping of biogenic habitats within conservation strategies will be important and the use of remote sensing techniques (Addendum II and III) as well as species distribution models are discussed. Finally, the potential use of marine protected areas and the relation to fisheries management are discussed. This part provides an onset of how an ecosystem approach can be applied based on ecological insights and on focused research on anthropogenic impact. As ecosystem engineers merit increased scientific and conservation emphasis, the thesis results are to be interpreted as a first step towards the application of the ecosystem approach to marine management.

The thesis concludes that *L. conchilega* is not only a model organism for studying the sediment-animal-interactions contributing to the strength of a benthic engineer in modifying its habitat and thereby affecting other species, but it is also a useful ecosystem engineer within a conservation context. As such, the knowledge built up in this thesis can potentially contribute to the transition to a more resilient relationship between society and ecosystems.

# ORAL & POSTER PRESENTATIONS

# CORROSION IN BALLAST TANKS – EXPERIMENTAL SETUP TO ESTABLISH A REGRESSION BETWEEN THE CHEMICAL AND STRUCTURAL PARAMETERS OF GRADE A[1] STEEL AND THE OBSERVED RATE OF CORROSION[2]

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Corrosion in ballast tanks is a common problem in the shipping industry. The condition of the ballast tanks is one of the factors that determines the life expectancy of a merchant vessel. It is expensive and time consuming to keep protective coatings ship shape and/or to replace corroded parts. Therefore finding a durable solution and defining which parameters are detrimental to the corrosion rate of ship construction steel are valuable assets to increase the life expectancy of a vessel.

Corrosion means a deterioration of the metal caused by its environment and will result in subsequent loss of body mass. The experiment at the Antwerp Maritime Academy investigates the corrosion rate of steel in an aquatic environment by means of weight loss, thickness measurements, an experimental photographical approach and electrochemical methods such as the Tafel plot and linear polarization measurements.

This experiment at the Antwerp Maritime Academy is the continuation of an "in situ" research program exploring the chemical and microbiological parameters of corrosion on board of merchant navy ships. The "in situ" aspect turned out to be a decisive element and was maintained during the experiment. The team went on board of more than 30 ships effectuating hull repair jobs and they collected approximately 50 samples of steel.

The set-up of the project is as follows:
In 3 test tanks, filled with natural sea water, the samples are exposed to three environmental scenarios:
▪ completely and permanently submerged steel;
▪ steel in quasi dry condition (saturated atmosphere is reproduced);
▪ steel that is exposed to a water spray for 4 hours per day, simulating the dry/wet condition of ballast tanks;

The samples used in this project are predominantly grade A-steel , some are AH steel and one sample is a unique experimental corrosion resistant steel. All of the samples are exposed to uniform conditions. Temperature, pH and ORP (oxygen reduction potential) are monitored continuously.

At regular intervals, measurements are carried out to determine the rate and composition of the rust prevailing:

*The weight measurement*
All samples are weighed with an accuracy of 0.01g. The starting weight will be the reference to determine the rate of corrosion. The samples will be weighed again after 6, 12 and 18 months.

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[1] Grade A steel is the most common ship construction steel usually mild steel containing 0.15 to 0.23 % carbon, and a reasonably high manganese content. Both sulfur and phosphorus in the mild steel are kept to a minimum (less than 0.05 %).

[2] A research project by Capt. Kris De Baere and Helen Verstraelen of the Antwerp Maritime Academy and Dr Silvia Lenaerts and Dr Geert Potters of the University of Antwerp. Research cooperators: Tiny Aerts, Aurélien Lorent, Tijl Pissierssens and Joris Timmermans, bachelor and master students of the Antwerp Maritime Academy.

*The thickness measurement*
The thickness is determined by using an ultrasonic device. The samples were measured day one and this will be repeated after 1, 2.5, 6.5 and 12 months.

*Photographical analysis*
This is a very experimental approach. Corrosion will be quantified based on discoloration and change in surface roughness of the samples. Sophisticated visual and statistical techniques will be applied. In the beginning the pictures will be taken every day and afterwards the frequency will decrease. Color histograms will be used to analyse the different corrosion products.

*Electrochemical analysis*
By means of a potentiostat the corrosion rate in mm per year is established. This test is done before the samples are exposed to $H_2O$ and will be repeated after 6 months and 1 year. This method will be conducted by KDG.

At present, only an instinctive prognosis, based on the photographic data, can be presented. Currently the project is still in its infancy and the material available in this stage of the experiment is solely photographical. Following items can be visually observed:
- The samples that are alternating wet and dry, corrode faster than the always dry or always wet samples.
- Corrosion rate and the appearance of the rust are different for each sample.
- The corrosion resistant steel also shows a layer of rust. We suppose that the CRS (corrosion resistant steel) will go into a passive state and the oxidation layer will protect the underlying steel.

It is expected that the project will show that corrosion is depending on the chemical composition of the steel. Especially the impurities captivated within the crystal structure of the steel are suspected to be a detrimental factor. The accent lies on the enclosures because industrial standards only allow for small differences in chemical composition. This will be clarified by a chemical analysis of the samples and a thorough study of the crystal structure.

# GENETIC POPULATION STRUCTURE OF BLUE SEA STAR, *LINCKIA LAEVIGATA*

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The blue sea star, *Linckia laevigata,* is commonly found in shallow water reef flats throughout the Philippine archipelago. Though it is characterised as being rather sedentary in its adult phase, it has a long planktonic larval duration (PLD) of 22-28 days (Yamagutchi, 1977). Therefore, it has a great potential for large distance dispersal, which is expected to be associated with high gene flow and a shallow genetic population structure. To test this hypothesis, this study investigates its genetic population structure and connectivity pattern in the islands of the Eastern Visayas (Philippines) by using partial sequences of the mitochondrial cytochrome oxidase I gene (COI) as genetic marker. In July and August 2010, 151 *L. laevigata* tissue samples were collected at five sampling stations: San Jose, Northern Samar; Almagro, Western Samar; Marabut, Western Samar; Salcedo, Eastern Samar; and Merida, Leyte. Samples were preserved in absolute ethanol, which was replaced after 24 hours. Then, the samples were stored at 4°C (Kochzius *et al.*, 2009). Molecular genetic analysis will be done in the Plant Biology and Nature Management (APNA) Laboratory at the VUB Etterbeek campus from November 2010 – April 2011.

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# SEDIMENT MOBILITY IN RESPONSE TO TIDAL AND WIND-DRIVEN FLOWS ALONG THE BELGIAN COAST, SOUTHERN NORTH SEA

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The effect of hydro-meteorological forcings (tidally- and wind-induced flows) on the transport of suspended particulate matter (SPM), on the formation of high concentrated mud suspensions and on the occurrence of sand-mud suspensions has been studied using long-term multi-parametric observations. Data have been collected in a coastal turbidity maximum area (southern North Sea) where a mixture of sandy and muddy sediments prevails. Data have been classified according to variations in subtidal alongshore currents, with the direction of subtidal flow depending on wind direction. This influences the position of the turbidity maximum; as such also the origin of SPM. Winds blowing from the NE will increase SPM concentration, whilst SW winds will induce a decrease. The latter is related to advection of less turbid English Channel water, inducing a shift of the turbidity maximum towards the NE and the Westerschelde Estuary. Under these conditions, marine mud will be imported and buffered in the estuary. Under persistent NE winds, high concentrated mud suspensions are formed and remain present during several tidal cycles. Data show that SPM consists of a mixture of flocs and locally eroded sand grains during high currents. This has implications towards used instrumentation: SPM concentration estimates from optical backscatter sensors will only be reliable when SPM consists of cohesive sediments only; with mixtures of cohesive and non-cohesive sediments, a combination of both optical and acoustic sensors are needed to get an accurate estimate of the total SPM concentration.

# INFLUENCE OF ALIEN MACRO-CRUSTACEA (MALACOSTRACA) ON MACROINVERTEBRATE ASSEMBLAGES IN BELGIAN COASTAL HARBOURS

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Harbours, which are often situated in estuaries and are characterised by intensive international ship traffic, tend to be very susceptible to aquatic invasions (Wolff, 1999; Nehring, 2006). Since alien macrocrustaceans are known to be very successful across many European waters (Bernauer and Jansen, 2006), a study was performed on their distribution and impact in the four Belgian coastal harbours (Nieuwpoort, Ostend, Blankenberge and Zeebrugge). Biological and physical-chemical data were gathered at 43 sampling sites distributed along a salinity gradient in the four harbours. One third of all crustacean species recorded were alien and these represented on average 30% of the macrocrustacean abundance and 65% of the macrocrustacean biomass. The large share of alien crustaceans in the biomass was mainly due to several large alien crab species. Most alien species were found in the oligohaline zone, whereas the number of indigenous species slightly increased with increasing salinity. The low number of indigenous species observed at low salinities was probably not only caused by salinity, but also by the lower water quality in this salinity range. The site-specific biocontamination index (SBCI) was used to assess the impact of alien species. The harbour of Nieuwpoort and Ostend scored best and were classified as good, indicating a limited abundance and a low species-richness of alien macrocrustaceans. Zeebrugge and Blankenberge were characterised by a severe biocontamination, which is for the harbour of Zeebrugge probably related to the intensive international ship traffic. Due to its nearby location, it is likely that alien species dispersing from Zeebrugge colonised the harbour of Blankenberge rapidly. Sampling locations situated more inland generally had a higher SBCI, mostly due to the dominance of one or two alien species, reaching high abundances. Consistent monitoring of estuarine regions and harbours, which are seen as hotspots for introductions, could help in understanding and predicting the impact of alien species on native biota.

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# SEA, BEACH AND BIRDS: PLASTICS EVERYWHERE

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International attention to marine debris has recently increased as the annual global production of plastics is augmenting and the build-up of these materials in the environment may become problematic. The AS-MADE project (Assessment of Marine Debris) aims to assess the occurrence and distribution of debris (mainly plastic litter) in the Belgian marine environment. This project is conducted by the Laboratory of Environmental Toxicology and Aquatic Ecology of Ghent University (project coordinator), the Research Institute for Nature and Forest (INBO), the Coordination Centre for Integrated Coastal Zone Management (ICZM) and the Flanders Marine Institute (VLIZ).

The occurrence of (plastic) litter was observed offshore (floating litter and litter on the seafloor), on beaches as well as in the seabirds. The latter was performed by analyzing existing data on stomach contents of beached Northern Fulmars (*Fulmarus glacialis*) and on entanglement of beached birds along the Belgian coast.

In the offshore Belgian waters, the ship-based surveys of floating litter suggested that for each swimming Razorbill (*Alca torda*) there is one larger piece of plastic floating around (0.66 items per km²) (Vanermen and Stienen, 2009). Sheet-like plastics (packages and wraps), party balloons and fishing gear were commonly observed floating litter. On the seafloor, on average approximately 2500 plastic items per km² were found, consisting mainly of fragments of monofilament line and fragments of hard plastic.
On the beach both debris and beached birds were sampled. Marine debris surveys were conducted on 4 Belgian beaches with differing tourism intensity and different sedimentation/erosion regimes. Up to 4.5kg (7852 items) of small debris per 100m beach was collected of which 72% (~3.24kg) was plastic. At least 12% of this debris was related to tourism. On average 4873 industrial pellets were collected per 100m beach.

Ingestion and entanglement are two major threats of plastics to seabirds. Entanglement of birds in plastics has been monitored along the Belgian coast since 1962. Our study indicates that some species are more sensitive than others (with Northern Gannets *Morus bassanus* being highly sensitive) and that fishing gear is the main threat. Beached Northern Fulmars are used as offshore plastic pollution indicators because they accumulate large quantities of plastic items in their stomachs. About 95% of all individuals found along the Belgian beaches contained plastics with 56% containing industrial pellets and 94% user plastics (i.e. small parts of sheet-like plastics: foil/wraps/…, threadlike plastics, foamy plastics, and fragments: bottles/boxes/toys/lighters/… or cigarette filters, rubber, rubber bands, etc). Furthermore more than half (51%) of the beached Fulmars had more than 0.1g of plastic in their stomachs, which is much higher than the proposed OSPAR (Van Franeker et al., 2005) guideline: i.e. no more than 10% of the birds should contain more than 0.1g of plastics. This study demonstrates that different types of plastics are present in each compartment of the Belgian marine ecosystem have an impact on the seabird health.

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# THE MICROBIOTA OF COMMON SHRIMPS (*CRANGON CRANGON*) FROM CATCH TO CONSUMER

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The common shrimp (*Crangon crangon*) is a typical product of the Belgian fishery that has recently received a regional product label, "Purus". "Purus" shrimps are exclusively caught in the North Sea by Belgian trawlers and prepared by Flemish fishermen predominantly in a traditional way; without preservatives, colorants or other additives and landed within 12h after catch.

Fresh seafood such as shrimps are very sensitive to spoilage causing off-odours and off-flavours. The main factors limiting shelf life are enzyme and microbial activities. Freshly caught shrimps are naturally contaminated with a diversity of microorganisms. The presence of these microorganisms depends among other things on the environment, water temperature, area of catch and handling and processing procedures (Jay, 1986). Most of the microorganisms on fresh seafood and during aerobic ice storage are psychrotrophic gram-negative, rod-shaped, strict aerobic or facultative anaerobic microorganisms of marine origin such as the genera *Aeromonas*, *Pseudomonas*, *Moraxella/Acinetobacter*, *Shewanella*, *Flavobacterium* or the family *Vibrionaceae* (Liston, 1980).

In this study the microbial population of cooked and peeled shrimps without preservatives was investigated during storage at different temperatures until spoiled.

Shrimps were caught, sorted, washed and cooked on board according to normal fishery procedures. At these different stages of processing, shrimps were collected and put on ice for transport. Microbiological analyses started one day after catch. In order to study the effect of the shell, some cooked shrimps were peeled manually as sterile as possible in the laboratory. From all different stages of processing, shrimps were stored on ice (0 ±0.5°C) and at 7.5±0.5°C (extreme refrigerator conditions) for several days. Microbiological analysis was performed at regular time intervals during storage. The study of the microbiota was done on several general and group-specific growth media. Molecular techniques [rep-PCR $(GTG)_5$ analysis, 16S rRNA and *gyr*B gene sequencing] were used for clustering and identification.

DGGE analysis based on the V3 region of the 16S rRNA gene was performed from plateswabs of the different media and direct from the shrimp matrix to visualise shifts in the total microbial community on shrimps under different conditions.

The results showed that the boiling process leads to a two $^{10}$log decrease in microbial count. In addition, a steep decrease in bacterial count was noticed after peeling. Results of total counts during storage showed that cooked and peeled shrimps stored at the highest temperature were microbiologically spoiled ($>10^8$ cfu/g) after 7 days, while iced shrimps had a shelf life of 12 days.

DGGE analysis showed clear shifts in the total microbial community under different conditions. Analysis of the microbiota using 16S rRNA gene sequencing limited the identification of the microorganisms to genus level. Further identification to species level was performed by sequencing analysis of the household gyrase B subunit (*gyr*B) gene and phylogenetic tree analysis. Using *gyr*B sequence analysis, several species of especially two marine genera (*Pseudoalteromonas* and *Psychrobacter*) were identified. These genera were dominant under practically all conditions tested (cooked, peeled, ice stored, temperature abuse) and were specific for seafood without preservatives.

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# SPATIAL AND SEASONAL VARIATIONS OF METAL CONCENTRATIONS IN SEDIMENTS FROM THE SCHELDT ESTUARY

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Estuaries concentrate pollutants carried along by rivers from the whole drainage basin into a relatively compact system that can be monitored more easily. They offer a last opportunity to control outputs to the marine environment where substances become diffuse and difficult to manage. Therefore, estuaries are crucial links in water quality management (Van Damme *et al.*, 2005). The Scheldt Estuary used to be heavily contaminated by metals. Current metal concentrations in the estuary have decreased, but historical contamination is still traceable in deposited sediments (Baeyens *et al.*, 2005). Metals in aquatic environments can occur in a dissolved or particle-bound form. Both dissolved metals and metals bound to suspended solids in the water column can be transported towards the sea.

The distribution of metals (As, Cd, Cr, Cu, Mn, Ni, Pb and Zn) in subtidal and intertidal sediments of the Scheldt Estuary is studied in field sampling campaigns. Subtidal samples are collected along the whole estuary, from Ghent to the mouth. Intertidal sediments are studied on a freshwater tidal flat and tidal marsh at about 103km distance from the river mouth. Both subtidal and intertidal samples show correlations between metal contents and sediment characteristics: metal concentrations correlate positively with the organic content of the sediment and negatively with its median grain size. Subtidal sediment metal concentrations in the estuary decrease towards the river mouth. This can be explained by (1) tidal mixing with less polluted suspended particles originating from the marine environment, (2) the degradation of organic particles and (3) the increase of dissolved oxygen and salinity, causing metal mobilization.

Sediments on a freshwater tidal marsh contain higher metal concentrations than subtidal sediments at the same location. This difference is due to the smaller grain size and the larger organic content of the intertidal sediments. Seasonal variations in intertidal sediment metal concentrations result in lower concentrations during winter because of the larger median grain size which is caused by a higher river discharge. Deposition of suspended solids on tidal marshes causes retention of particle-bound metals in the estuary.

The research described resulted in a Master's thesis to obtain the degree of Master of Science of Biology.

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# PLASTICS ON YOUR PLATE? DETECTING MICROPLASTICS IN SEDIMENTS AND ORGANISMS

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Marine litter has been an issue of concern for decades. However, recently international attention has increased due to the fact that the annual global production of plastics is increasing and the buildup of these materials in the environment may become problematic. Under influence of UV-light and mechanical forces, plastics also tend to break down into smaller particles in the size range of 1 mm and smaller. These so-called microplastics have been detected in the water column and in sediments at high concentrations and organisms like mussels and barnacles have been shown to ingest them during laboratory trials. Very small particles (<20µm) can even translocate to the circulatory system (Browne *et al.*, 2008). Whether or not field-collected mussels (or other organisms) contain microplastics – which could eventually end up on our plate – is unknown as no techniques currently exist to extract these particles from organic tissue. Moreover, current techniques to extract microplastics from sediments are not very efficient and thus the concentrations presently reported in literature may be underestimations.

The most widely used method to extract microplastics from sediments is based on flotation of the plastics in a saturated salt solution (Thompson *et al.*, 2004). However, PVC for example has a density higher than that of such a solution and hence cannot be extracted in this way. Chemicals with a higher density than regular salt – e.g. sodium iodide (NaI), which would allow to extract PVC - are expensive to use on a large scale. Here, a new method using a fluidized sand-bath and the use of NaI on a small scale is proposed. This technique allows to achieve an extraction efficiency of 100% for PVC particles and 98% of fibres after one sand-bath extraction and maximally 3 subsequent NaI extractions.

To study the occurrence of microplastics in mussels (*Mytilus edulis*) and lugworms (*Arenicola marina*), we have developed a new method. In brief: field-collected organisms are allowed to clear their digestive system in filtered seawater which is subsequently analyzed for the presence of plastic particles. After the clearance step, the tissue of the organisms is digested in nitric acid. The resulting mixture is diluted and filtered over a 0.8µm membrane filter which is examined microscopically. A small number of particles have been observed in the clearance water of both mussels and lugworms, but no fragments were found in digested tissue. More research is, however, needed to improve the microscopic examination of the material collected on the membrane filters.

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# A CLOSE UP ON THE SOFT-SEDIMENT MACROBENTHOS AROUND OFFSHORE WIND TURBINES

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Two offshore wind farms became functional in the Belgian part of the North Sea during 2009 and 2010 on respectively the Thorntonbank (C-Power) and the Bligh Bank (Belwind). During the past five years, a monitoring programme has been carried out to determine the baseline situation on the soft-sediment macrobenthos in these areas, together with any primary impacts that could have arisen during and after construction. During the first and second years after implementation of the turbines no large-scale impacts were detected on the macrobenthos (Reubens *et al.*, 2009; Coates et al, 2010). Therefore, a small scale sampling strategy was carried out during 2010 to detect any impacts around the fifth gravity based turbine on the Thorntonbank. Macrobenthic communities can be highly dependent of sedimentological characteristics such as median grain size and organic matter content (Pearson and Rosenberg, 1978; Wilhelmsson and Malm, 2008). The increased epifaunal communities colonizing the hard substrates (turbines) could produce organic enriched sediments, possibly modifying the soft-sediment macrobenthic communities (Kerckhof *et al.*, 2010). Sediment samples were taken along four gradients, two parallel and two perpendicular to the currents. Samples at one and seven metres from the scour protection systems (boulders) were taken during June and September 2010 by divers. Samples further away from the boulders (15, 25, 50, 100, 200m) were taken during September 2010 using a Van Veen grab on a small research vessel. To detect organic enrichment in the sediments several elements were analysed such as total organic matter, chlorophyll a and fatty acid concentrations. The macrobenthos was identified to species level and their subsequent biomass was determined. First results show a shift from Nephtys cirrosa communities to a dominance in *Corophium acherusicum* and *Lanice conchilega* at the closest samples to the boulders. These results show the importance of a small-scale monitoring strategy to determine the effects of wind turbines on the soft-sediment macrobenthos. Any impact detected at small-scale can be extrapolated to a possible large-scale impact. Since future plans have been made to construct additional wind farms in the Belgian part of the North Sea it is very important to understand the possible changes that could occur in the marine environment.

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# OCEAN ACIDIFICATION IMPACTS ON THE PHYSIOLOGY AND ADHESIVE PROPERTIES OF THE STARFISH *ASTERIAS RUBENS*

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The increase in atmospheric $CO_2$ due to anthropogenic activity is an acidification of the ocean which could lead to pH as low as 7.7 and 7.4 by 2100 and 2300, respectively. The impact of this phenomenon will depend on the considered organisms and ecosystems. In particular little is currently known on the effects of acidification on temperate ecosystems. The intertidal rocky shores are of great interest in this context as intertidal organisms face tidal pH and temperature changes. They may harbor organisms pre-adapted to the changes predicted for the coming years and centuries. Furthermore, the intertidal environment will be more affected as shallow waters will face the highest decrease in seawater pH. Therefore, we studied the effects of ocean acidification on *Asterias rubens*, the common starfish of the Belgian coast which is known to structure some intertidal shores through its predator activity. Effects on the physiology but also on the adhesion capacities of the organism were investigated using organisms maintained at pH 8.1, 7.7 and 7.4 for periods of 15 and 31 days. Our results showed that *Asterias rubens* did not regulate its acid-base balance as no accumulation of $HCO_3^-$ was observed and no dissolution of the skeleton as a buffer was detected by measures of $Mg^{2+}$ and $Ca^{2+}$ in the coelomic fluid. However, the starfish showed no consequence from the decrease of the coelomic fluid pH as all activities measured (respirometry, adhesion capacities) were not significantly affected by seawater pH decrease. Equilibration of the coelomic pH with the seawater pH was fast (typically less than 24 hours). The former was always lower than the latter. This suggests an accumulation of respiratory $CO_2$ inside the organism which creates a respiratory acidosis and so a decrease of the pH. In conclusion, it seems that *Asterias rubens* withstands the effects of ocean acidification, at least for short terms (one month). If this is confirmed, the balance between the predator and its prey (*Mytilus edulis*, the blue mussel) may shift with time as many studies have shown deleterious effects on the latter. The rocky intertidal shores may face changes in the coming centuries and move to a new equilibrium.

Keywords: ocean acidification; echinoderms; acid-base regulation.

*These authors have contributed equally to this work.

# QUANTIFICATION OF INTERDEPENDENCIES BETWEEN ECONOMIC SYSTEMS AND ECOSYSTEM SERVICES: AN INPUT-OUTPUT MODEL APPLIED TO THE SEINE ESTUARY

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The aim of this paper is to assess the contribution of an ecological-economic input-output model towards two of the precepts advocated by the sustainability strategy of integrated coastal zone management and Post-Normal Sciences. According to these precepts, decision support tools should offer a holistic perspective and handle high uncertainty. Non-sustainability seems to be partly due to an inadequate use of "narrow-system-boundary" tools that are non-holistic. Consequently, they fail to capture important ecosystem services and ignore interdependencies between them. To comply with the precepts, our method firstly allows environmental assets to be evaluated in multiple units. Secondly, it integrates economic data to results from researches in natural sciences. Both enable coverage of interdependencies between ecosystem services. An application to the Seine Estuary addresses the impacts of maritime transportation infrastructures on nursery habitats for commercial fish (*solea solea* sp.). Due to the high level of uncertainty and lack of data on the state of most fish stocks in Europe and given the unsustainable harvest of the remaining stocks, measures applied to fish habitats on the basis of the precautionary principle might acquire greater political acceptability in the future. Out of a total of 44 fish stocks in European fishing zones, the state of the stock is unknown or undefined for 57%, the harvest is sustainable for only 4%, and the remaining 32% is overfished (ICES, 2008). In response to these figures, the I-O model developed in this paper is used to answer the following question: what would be the ecological and economic impact of a fish nursery restoration measure applied on the basis of the precautionary principle and the principles that the polluter should pay, two principles stated in the Marine Strategy Framework Directive (European Parliament and Council, 2008). On the basis of these principles, the environmental measure that we consider consists in restoring 20% of the high fish density nurseries destroyed between 1834 and 2004. The security margin ensuring the precautionary principle is quite important since the scenario would consist in recovering the surface that existed in the estuary in 1890-1915. The expected impact is an increase in fish stocks, which should increase the resilience of fish populations to fishing activities and their capacity to regenerate for the future. Our results show that the restoration of a total of 24.38km$^2$ of subtidal sandy nursery areas over the period 2004-2015 would result in a stock of sole in 2015 that exceeds the "business as usual" scenario by 17.5% – 22.9%. In spite of high restoration costs, the negative macro-economic impact is very low. However, on the sector level, a trade-off results between nurseries and the sectors of mines, harbors and fossil fuel manufacturing, which see high decreases in their benefits compared the scenario "business as usual". However, our paper suggests that enlarging the allocation rule of restoration costs to indirect polluters of third order (tertiary sectors) could strongly reduce the economic impacts. This shows that high restoration costs are not a problem *per se* but rather a question of cost allocation.

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# MODELLING BIOTA-MUD INTERACTIONS IN ESTUARIES

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The ecological literature describes many examples of the influence of benthic biota (microphytobenthos, benthic animals) on sedimentation/erosion properties of intertidal sediments. On a larger scale these biota-mud interactions can affect transport dynamics and estuarine morphology. Modelling of these relations is often based on empirical, statistical approaches. The reverse process, namely how mud content of sediments influences the composition of the biological community, is well known from a descriptive point of view. Numerous field studies have linked the composition of the benthic community to sediment characteristics. However, these relations are usually described from an ad-hoc, location-specific point of view and generalisations are rare or absent.

Within the present project, generalisations of these descriptions will be sought. The aim of the project is to develop and test model formulations for the mutual influence of mud on benthic (and pelagic) communities and, vice versa, for the influence of biological communities on mud content.
The influence of mud on benthic communities is investigated through the (statistical) analysis of a large macrobenthic dataset that is available for the Westerschelde and Oosterschelde. These two estuaries nowadays differ substantially from each other due to human interferences over recent centuries. After the Delta Works only the Westerschelde remained a true estuary with an open connection to the sea, while the Oosterschelde got partly closed off by a storm surge barrier. This has abruptly reduced the in and outgoing tidal volume of this basin by approximately 30%. Furthermore, the Oosterschelde has changed into a sedimentation basin (i.e. channels are filling up) with a pronounced trend towards the erosion of the intertidal areas. On average, mud content in the sediment is nowadays much lower in the Oosterschelde compared to the Westerschelde. The different (morphological) evolution these two systems undergo make them interesting study areas to compare. The benthic communities present in both systems still show similarities and have many species in common, but abundance and dominance often differ.

The data set was analyzed through B-spline quantile regression to account for heteroskedasticity and realized species abundances distributions typically showed non-linearity along single environmental gradient (sediment texture in present case). The analysis shows a well-defined turnover of species predominance between Westerschelde and Oosterschelde (from mud-fitted to sand-fitted), related to a trend towards coarser sediment in the intertidal areas of the Oosterschelde. Moreover the rate of change increases progressively during time (analysis span: 2000-2008), suggesting still a transitional situation. In Oosterschelde, sand-fitted ones gradually replace mud-fitted assemblages of species, following the general erosive trend generated by the Delta Works.

This framework will be further extended converting the observed patterns in specific abundances in modeled effects on sediment dynamics (i.e. if the changes in Oosterschelde's species compositions have the effect to 'buffer' or further 'emphasize' the existing erosive trend). A more general quantification of biotic responses along the sediment texture gradient will result in a better understanding of the morphological evolution of estuarine ecosystems. The final aim is to include the biotic influences into existing morphodynamic models, increasing accuracy in 'biologic' and 'fluvial engineering' future scenarios predictions. This project is part of the innovative program Building with Nature (www.ecoshape.nl).

# GENETIC SELECTION OF PERCIFORM FISHES: FUNCTIONAL GENOMIC POTENTIAL OF NATURAL AND CULTURED POPULATIONS

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With a growing world population and recurrent problems of hunger and malnutrition, food security is of major societal and international concern. The growing need for nutritious and healthy food will increase the demand for fishery resources. Unfortunately, the production of marine capture fisheries is close to the maximum ecosystem productivity and cannot be increased substantially in the future. Therefore, the interest in aquaculture has grown substantially the last 40 years. To ensure a sustainable development of aquaculture, the selection criteria have to lead to an improvement in production efficiency and a greater adaptability of the selected animals. The rapid advances of genomic technologies that lead to large amounts of genomic information will show the way for a selection procedure solely based on the genotype. In this project we exploit the large amount of available genomic data of fish species to identify, both between and within species, functionally important regions and selection-sensitive areas. Our main objective is the study of functional genomic regions susceptible to positive selection in sea bass. The project has four major objectives: 1) identification of potential selection-sensitive areas by an in silico comparison of three fully sequenced Perciform genomes (stickleback, Nile tilapia and sea bass); 2) Development of genetic markers for a genome scan of natural and cultured populations of sea bass; 3) Genome scan and candidate gene analysis in natural populations of sea bass, and 4) Genome scan and candidate gene analysis in cultured sea bass populations.

# MEIOFAUNA OF DEEP-SEA COLD SEEPS IN THE EASTERN MEDITERRANEAN AREA, WITH SPECIAL EMPHASIS ON NEMATODE BIODIVERSITY AND CONNECTIVITY

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Seeps are among the most geologically and widely spread of the deep-sea reducing environments. The use of *in situ* video and photography with deep submersibles provided evidence for a variety of topographic structures on the deep-sea floor such as pockmarks (seafloor depressions), brine pools or mud volcanoes associated with fluid, gas and mud escape. Sulphide provides an unlimited energy source but remains toxic for most metazoans. Microbial mats of sulphide oxidizing bacteria are often formed at the surface of seep sediments where reduced outflows and a source of oxygen are present.

Most cold seeps support, compared to common bathyal environments, highly productive ecosystems characterised by an impoverished species richness, a high biomass and an elevated dominance by a few adapted taxa able to survive in the toxic hydrogen sulphide. Megafaunal seep communities and the associated microfauna are relatively well described from a wide number of seep locations. Studies on the biology of the meiofauna (<1mm, mainly nematodes and harpacticoid copepods) from deep-sea cold seep areas are scarce.

Several reduced deep-water environments in the Nile fan at the Egyptian margin and on the Calabrian Arc were sampled for meiofauna during the MEDECO (2007, HERMES project), and the Maria Merian cruise (2009, HERMIONE project). These samples allow us to get insight in the nematode community structure and biodiversity of the different areas. By sampling both reduced and hemipelagic sediments, it is possible to test if the seep fauna is closer related to the local non-seep fauna than to the taxa found at other seeps from different geographical areas. Molecular studies give insights in the phylogenetic and phylogeographic relationships of seep-nematodes, not only in the Eastern Mediterranean area, but also with more distant seep communities.

In general, densities are similar to those found in other deep-sea studies in the Eastern Mediterranean area. A significant difference in genus composition and diversity exists between the reduced and hemipelagic sediments. Hemipelagic samples both from within the seep and outside the seep influence are characterised by a high genus diversity and were dominated by more typical deep-sea genera like *Acantholaimus*, *Halalaimus*, *Thalassomonhystera*, *Microlaimus*, *Theristus* and *Tricoma*. The nematode assemblages from the reduced sediments of all cold seep sites are genus-poor, and strongly dominated by the genus *Sabatieria* (*mortenseni*), which is also the dominant genus in the REGAB cold seep adjacent to the Congo canyon in the Gulf of Guinea (Equatorial West-Arica, South Atlantic).

It can be concluded that seep sediments which are strongly affected by reduced fluids, generate a habitat which is difficult to colonize by most of the typical deep-sea nematode species. Apparently, dominant nematodes from these isolated habitats are often cosmopolitan eurybathic species with very high tolerance levels. The presence of *Sabatieria* (*mortenseni*) as prevailing species in different remote seeps can indicate a possible interconnection. In order to gather deeper insights in this topic it was already possible to extract DNA from these deep-sea nematodes present in the cold seeps. Next to this, parts of the nuclear DNA were sequenced successfully.

# COCKTAILS IN THE ARCTIC: ARE THE POLAR BEARS LOADED YET?

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Although persistent organic pollutants (POPs) are present in all oceans, the Arctic Ocean in particular accumulates POPs due to northward sea and air currents. Extensive databases exist that contain field measurements of POP concentrations in Arctic species, yet they represent a haphazard collection of measurements in various tissues and species. This makes it difficult to evaluate in a uniform way if the Arctic cocktail of POPs is expected to adversely affect Arctic ecosystems. In this study we have for the first time quantified if this POP cocktail has been affecting the Arctic ecosystem in a negative way during the last 25 years (1985 to 2010). A bioaccumulation model was used to standardize 50,000 measured concentrations in different matrices of various species to lipid tissue concentrations of 96 POPs (PCBs, HCHs, HCB, DDTs and PAHs) in 26 species ranging from northern shrimp (*Pandalus borealis)* to the polar bear (*Ursus maritimus).* After cross-validation of predicted lipid tissue concentrations, they were compared to contaminant threshold levels, i.e. maximum tissue concentrations beyond which adverse effects are expected and this for all 96 chemicals in all 26 species. Lipid tissue concentrations of most POPs in all species decreased 10 fold between 1985 and 2010. Depending on the species considered, current day tissue concentrations are 1,000 (polar bear) to 10,000 times lower (blue mussel, *Mytilus edulis*) than the corresponding threshold levels. However, the opposite was found for PAHs in mammalian top predators such as the polar bear, which had lipid tissue concentrations that increased 100 fold over the past 25 years, reducing the margin of safety (threshold concentration divided by tissue concentration) from 10,000 to 100. This increase in PAH concentrations can be explained by an increasing (and oil consuming) world population. When calculating the total effect on polar bears of all 96 POPs together, i.e. of the Arctic POP cocktail, the margin of safety is 10 times lower today (10) than it was 25 years ago (100). This indicates that the increase in PAHs over time is the main determinant of the effects of the Arctic POP cocktail. Our results therefore show that past regulatory efforts to phase out legacy POPs are overshadowed by rising PAH exposure in the Arctic environment.

# SAME LOOKS, DIFFERENT PREFERENCES: SALINITY EFFECTS ON THE COEXISTENCE OF CRYPTIC SPECIES

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Behind the morphological similarity of many species, a substantial hidden genetic diversity can be found. This hidden or cryptic diversity leads to a significantly higher biodiversity in ecosystems than previously regarded and is important for estimating total diversity on earth. It has been well documented in the marine nematode, *Rhabditis (Pellioditis) marina* (Derycke *et al.*, 2008), where several cryptic species occur sympatrically (Pm I, Pm II, Pm III and Pm IV). This coexistence challenges traditional ecological competition theory, stating that competition will be most severe between closely related species, rendering coexistence unlikely. Niche partitioning, where species coexistence is explained by differences in phenotype is a possible way to achieve such coexistence. Closely related sympatric species, despite only minor differences in morphology, can display different preferences for abiotic conditions. So if cryptic species differ in their response to ecological heterogeneities, their coexistence may be facilitated and the outcome of competition will depend on fluctuations in the abiotic environment. Studying these preferences and more broadly the ecology of cryptic species can lead to a better insight in the origin of cryptic speciation and the geographical distribution of these cryptic species.

*Rhabditis (Pellioditis) marina* is a common bacterivore associated with decomposing macro-algae in the littoral zone of coastal and estuarine environments. One of the possible factors shaping the distribution patterns and coexistence of the cryptic species is salinity, one of the most conspicuous environmental factors causing heterogeneity in tidal environments. The effect of salinity on the coexistence of cryptic species was studied in a lab experiment, where population structure between competition cultures (with equal abundances of four cryptic species together) and monospecific cultures (where the four cryptic species cannot affect each other's population development) was compared at two different salinities. The results showed an effect of competition and salinity on the population structure with (1) an increased time-averaged abundance of Pm III at the low salinity in monospecific cultures, (2) a negative effect of competition on the abundance of two cryptic species (Pm II and Pm IV) and (3) stronger competition at lower salinity. Lower salinity has mostly an intensifying effect on the outcome of the competitive interactions and besides competition, complete exclusion (Pm IV) and facilitative interactions occurred (Pm I and Pm III at high salinity). These results show that changes in the abiotic environment (in casu salinity) can shift the outcome of competition between and hence the possibility of the coexistence of different cryptic species of *Rhabditis (Pellioditis) marina*.

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# AFLP-BASED GENETIC MAP OF BRINE SHRIMP *ARTEMIA FRANCISCANA*

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Brine shrimps of the genus *Artemia* are small planktonic crustaceans found in about 500 natural salt lakes and salterns around the world (Lavens & Sorgeloos, 1996). *Artemia* is the most common live food in aquaculture activities, specifically for larval growth of >85% of the marine species reared in aquaculture (Kavim *et al.*, 2010). The aquaculture industry is the fastest growing food industry today.

*Artemia* has many features of interest for genomic research:
*Artemia* has a short life cycle (2-4 weeks). Levels of genetic variability for *Artemia* are among the highest within crustaceans (Abatzopoulos *et al.*, 2002; Bossier *et al.*, 2004). *Artemia* species are extremophiles, genes underlying these extreme phenotypes might be of utmost interest (Clegg, 2005; Robbins *et al.*, 2010). *Artemia* species are used as a model for the metabolism of crustaceans, biodiversity studies, toxicity testing, for *Vibrio* resistance in shrimps and for the interactions between sexual and parthenogenetic populations.

So far, only the mtDNA of *Artemia* has been sequenced completely and no *Artemia* linkage maps are currently available (Valverde *et al.*, 1994). *Artemia* linkage maps would provide basic information for further linkage studies on *Artemia* and other crustaceans, and construction of the maps is a first step towards creating genetic breeding programs. The development of genetic linkage maps is the base of mapping of quantitative trait loci (QTLs) and for marker-assisted selection (MAS). Genetic linkage maps have been reported for many aquaculture species.

A genetic map of the *Artemia franciscana* genome is being constructed with AFLP markers, using a F1 mapping population derived from a cross between two heterozygous strains (San Francisco Bay male x Vinh Chau female) (Vos *et al.*, 1995; Vuylsteke *et al.*, 2007). The phenotypic sex of each individual from the 113 heterozygous F1 offspring has been determined. With 42 primer combinations, we have found around 500 markers, of which two thirds are AFLP markers, segregating 1:1 (BC markers), the rest of the AFLP markers segregate 1:2:1 (F2 markers). Among the BC markers, 13 female markers co-segregate with sex. Based on AFLP markers co-segregating with sex, the genomic region containing the sex locus (or loci) will be identified. All found markers are being used for constructing a genetic map with the software package Joinmap 4 (Kyazma). Published *A. franciscana* SNPs will be put on the completed genetic map.

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# BURCHTSE WEEL: REDUCING THE TIDE DIFFERENTLY

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Originally the Schelde Estuary was one big area of mudflats and marshes. Along the entire course of the Schelde, big planes were present with a gradual slope from water to land. Throughout the centuries the economic importance of the river has grown. Due to the narrowing and deepening of the Schelde, the tidal volume has changed resulting in larger tidal differences and stronger currents. These changes have an impact on economy, ecology and safety. One of the possible answers to these problems is the construction of Flood Controlled Areas (FCAs) and Controlled Reduced Tides (CRTs), a solution that combines safety with ecology.

In Lippenbroek, the FCA-CRT technique is implemented for the first time, with success. With high inlet and low outlet sluices the flooding regime of natural marshes is reproduced in an enclosed polder area. Based on the results of this pilot project, many other FCA-CRT are planned, designed or under construction.

Inspired by Lippenbroek, also in Burchtse Weel tidal influence will be restored by 2011. However, here another sluice design will be implemented, using a low inlet and low outlet. Burchtse Weel is situated at the outskirts of the city of Antwerp and has a total surface area of approximately 50ha. It is a part of the 'Oosterweel'-project. The totally different approach of the sluice construction, compared to previously built CRTs, makes this area interesting for monitoring: will the same ecosystem goals be achieved using this different approach?

Here we present a comparative study of Burchtse Weel and Lippenbroek. We looked into abiotic parameters which have direct or indirect impact on the overall picture of the landscape. The nutrient contents of the Schelde River at Hamme-Lippenbroek and Burchtse Weel have been evaluated based upon their influence on the future vegetation.

Based on the tidal curves and the topography of both areas, inundation frequencies were calculated. These are one of the most important factors for the development of mudflats and marshes. Based on these inundation frequencies, maps of different ecotypes are made.

Finally a forecast of the expected vegetational development was made, based on different vegetation models, taking into account salinity and tidal characteristics. This allows us to present maps with probabilities for a certain vegetation cover.

# TRANSIENT BENTHIC FORAMINIFERAL ASSEMBLAGE FLUCTUATIONS DURING EARLY EOCENE HYPERTHERMALS AT DSDP SITE 401, BAY OF BISCAY, NORTH EAST ATLANTIC

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During the early Paleogene "hothouse" (60-50 Ma), earth experienced the warmest conditions of the Cenozoic (Zachos *et al.*, 2008). Tropical temperatures were slightly higher than today, but middle and high latitude temperatures were much higher. For instance, the sedimentological and paleontological record suggests sea surface temperatures of ~20°C near the Arctic (Weijers *et al.*, 2007). Superimposed on this warm climate mode was a series of transient periods (<200 kyr) of extreme global warming, known as hyperthermals (Thomas and Zachos, 2000). The most prominent and best documented hyperthermal is the Paleocene-Eocene Thermal Maximum (PETM; ~55.5 Ma), during which global temperatures rose by an additional ~5°C. This event left a major mark on the biogeosphere evolution: many protists flourished, floral communities changed (Wing *et al.*, 2005) and mammals experienced an accelerated evolution (Gingerich, 2006). However, the benthic foraminifera suffered: up to 50% of all species went extinct (Thomas, 2007). The deep-sea record shows that this climatic anomaly is associated with changing oceanic circulation and a severely disrupted carbon cycle. In early Eocene deposits worldwide, additional smaller hyperthermals have been detected, primarily based on stable isotope records and physical properties of sediment cores (Cramer *et al.*, 2003). Yet the biotic aspects remain largely unexplored, up till now.

The focus of this study is to investigate whether or not these recently discovered hyperthermals (Lourens *et al.*, 2005; Nicolo *et al.*, 2007) display similar biotic patterns as during the PETM, specifically concerning benthic foraminifera. Lower Eocene deep-sea sediments from DSDP Site 401 in the Bay of Biscay (paleodepth ~2000m) show a well-developed cyclicity in sediment color and carbonate content in calcareous nannofossil Zone NP11. In this interval, several darker, marly levels stand out in the otherwise grayish-brown calcareous chalks. The $\delta 13C$ and $\delta 18O$ records on *Nuttallides truempyi* and *Oridorsalis umbonatus* and on bulk material clearly show the iconic isotopic excursion of the PETM and five additional negative excursions of up to ~0.85‰ throughout Biozone NP11.
Some of these isotopic excursions can be correlated to short-lived, yet strong benthic foraminiferal assemblage changes. A rapid shift to impoverished faunas and the replacement of bathyal species with abyssal species suggest a severe disruption of the trophic regime at this location. On a longer time scale, a small but significant assemblage shift remains. Also, the fact that only the largest carbon cycle perturbations and temperature rises are associated with these faunal changes implies the existence of certain climatic thresholds.
The lithological, isotopic and quantitative foraminiferal data appear to confirm the idea that these early Eocene hyperthermal events produce similar, yet smaller, biotic changes as observed for the PETM worldwide.

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# EVOLUTION OF MACROECOLOGICAL NICHES IN THE MARINE MACROALGAE *DICTYOTA* (*DICTYOTALES*, PHAEOPHYCEAE)

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Macroalgae are important contributors to primary production and ecosystem functioning in shallow coastal marine habitats. Their macroecological niche is determined by a combination of biotic and abiotic factors, temperature, nutrients and salinity tolerances playing a very important role. In the absence of a reliable fossil record, comparative phylogenetics may shed light on the diversification, historical biogeography and the evolution of ecological preferences of these organisms.

We focus on the brown algal genus *Dictyota*, which is widely distributed in tropical to temperate regions and investigate how ecological preferences have evolved in this genus since the Cenozoic. To do so we apply niche modeling techniques.

To map the distribution of the respective *Dictyota* species, specimen lists from trusted literature have been geo-referenced and inserted into a database already containing several thousand observations. By correlating these distribution records with a set of macroecological parameters (www.bio-oracle.ugent.be) niche models are created using Maxent. Subsequently, using ancestral state reconstruction, we model the evolution of ecological niches and interpret these findings in relation to the geological and paleoclimatic record.

# OPERATIONAL EFFICIENCY AS KEY TO DESIGNING OSERIT, AN INTERVENTION SUPPORT TOOL IN CASE OF OIL POLLUTION

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Major oil pollution in the North Sea could cause serious environmental and socio-economic damages. In case of oil pollution, it is therefore crucial to decide and organize the response strategy as quickly as possible and in a way that it minimizes the damages. Since January 20$^{th}$ 1999, the Belgian Marine Environment Protection Law imposes the choice of this response strategy to be supported by a documented and scientifically-based method. In that sense, the OSERIT project has been set up to assess the short-term environmental impacts of oil pollution at sea and to what extent the use of dispersants can help in reducing these impacts. By means of information on oil spill, OSERIT will be able to quickly deliver a 3D forecast of the drift and fate of oil spill, a list of possible oil-sensitive environmental targets that could be damaged by the pollution, the risk of beaching, and a first/rough estimate of the environmental and socio-economic impacts.

This whole project revolves around the needs of the end-users (i.e. the Agencies involved in the Belgian Operational Intervention Plan for Pollution Response). The first major axis of the project consists in developing a user-friendly web-based interface that gathers relevant pieces of information to quickly perform a net environmental benefit analysis (NEBA). The second major axis includes designing and developing a new 3D Lagrangian/Eulerian model that can simulate the drift and fate of oil at the sea surface and in the water column. The end-users will be able to make a 'baseline' simulation of the oil pollution evolution (assuming no particular response action will be undertaken) and compare it with simulations of chemically dispersed oil.

Here, we briefly introduce the project and discuss how operational efficiency has constrained the design of the OSERIT tool.

# SHOULD ANTHROPOGENIC INFLUENCES BE INCORPORATED IN MARINE HABITAT SUITABILITY MODELS?

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Marine habitat suitability models typically predict the potential distribution of organisms based on environmental characteristics such as salinity, oxygen concentrations, temperature fluctuations or sediment class information. Although the anthropogenic pressure on the marine environment has been exponentially increasing during the last century, global effect of human activities on the distribution of marine organisms remains largely unknown. This research aims at (1) determining to what extent contamination/pollution data can be used to predict the occurrence of marine organisms and (2) evaluating whether the incorporation of anthropogenic chemicals in habitat suitability models increases the performance of these models.

A suite of habitat suitability models, e.g. Classification and Regression Trees and Generalized Linear Models, were used to predict the presence of three marine species from environmental characteristics only. Next, the models were extended with ten anthropogenic chemicals as additional predictors and it was examined if this extension significantly increased model performance.

The modelling techniques proved to be useful to reveal the most important predictors for the occurrence of the selected species. The models with the highest performance were those combining environmental characteristics with anthropogenic chemicals. We conclude that contamination/pollution data increase the performance of habitat suitability models, compared to the use of environmental characteristics only.

# HYDRO-METEO INFLUENCE ON SUSPENDED PARTICLE SIZE DISTRIBUTIONS

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In the vicinity of Zeebrugge suspended particulate matter (SPM) concentration and particle size distribution (PSD) have been collected during almost 200 days at about 1km from the shore line. Optical (OBS) and acoustic (ADP) backscatter sensors were used to estimate SPM concentration. The aim of the study was to assess flocculation and particle dynamics during different meteorological events. The PSDs measured with a LISST 100X have been classified using entropy analysis (Mikkelsen *et al.*, 2007) and assembled in three cases based on the low-pass filtered alongshore velocity component (Baeye *et al.*, 2010).

The PSDs during tide dominated conditions showed distinct multimodal behaviour. Multimodal flocculation occurs due to differences in particle bindings between primary and secondary bindings, resulting in more resisting microflocs and fragile macroflocs. The macroflocs were constant in size (350µm), in contrast with microfloc sizes (mode between 30m and 180µm). The microfloc population was characterized by a gradual shift of the PSD towards bigger size classes when turbulence decreases and by the occurrence of two microfloc populations, possibly caused by the heterogeneity of components within the SPM. Microflocs are partially disrupted into primary particles during peak flood velocity.

Analysis of the PSDs together with the interpretation of acoustic and optical derived SPM concentration revealed that storms from SW result in different PSD than storms from the NW. It was astounding to see that during SW storm no primary particles were detected and that the PSD was unimodal with an almost constant D50 of 40µm. The SW storm was characterized by lower SPM concentration derived from OBS than from ADP backscatter suggesting that the flocs where transported away from the measuring location and replaced by sand resuspended by waves. During NW storms the PSD were similar as during flood indicating that most SPM consisted of flocs.

As a conclusion, meteorological events have distinct influences on suspended particle size dynamics. The advection of the coastal turbidity maximum during storms may result in an increase of cohesive SPM concentration, the formation of fluid mud and the armouring of sand (NW storm) or in a decrease of cohesive SPM concentration, no fluid mud formation and increase of sand and silt in suspension (SW storm).

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# FLORAL DIVERSITY AND DISTRIBUTION IN THE MANGROVES AT MATANG, WEST PENINSULAR MALAYSIA, AFTER A CENTURY OF SUSTAINABLE FORESTRY

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Mangroves are important in protecting shorelines against tidal waves and erosion, and also support a range of wildlife species. In Malaysia, the mangroves occupy 564,606ha, with a nearly 16% (91,779ha) distributed along the west coast of peninsular Malaysia. Mangroves are more prevalent here due to the sheltered environment, in comparison to the east coast (mangrove extent = 5,738ha), which is entirely exposed to the South China Sea. Although Malaysia possesses the second largest mangrove cover (about 11.7%) in Southeast Asia (FAO, 2007), the scientific literature on these mangrove forests remain scanty. While Matang mangrove forest on the west coast has been under a concerted scientific management since the beginning of 20th century (Shamsudin and Nasir, 2005), the efforts to evaluate its floral diversity and distribution through the ground inventory techniques like PCQM (cf. Cintron and Schaeffer Novelli, 1984; Dahdouh-Guebas and Koedam, 2006) are almost nil. This present investigation brings out valuable information on this aspect in a well-managed and ecologically important location on the west coast of Peninsular Malaysia. The aim of this poster is to report the ongoing research, which is expected to lead to conclusions on the state of mangrove forest evolution.

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# THE HARBOUR PORPOISE *PHOCOENA PHOCOENA* IN THE BELGIAN PART OF THE NORTH SEA: TRENDS IN ABUNDANCE AND DISTRIBUTION

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The harbour porpoise *Phocoena phocoena* is once again an important component of the ecosystem in the Belgian part of the North Sea (BPNS), after decades of virtual absence. The basic analysis of strandings and bycatch data over four decades clearly demonstrate its return, with only few animals between 1970 and 1998, an increasing number between 1999 and 2004 (8 to 40 per year), and a high number between 2005 and 2009 (62 to 94 per year). The combined results of aerial surveys, passive acoustic monitoring and strandings monitoring reveal a seasonal pattern, with harbour porpoises being typically abundant from late winter to April, while being scarcer from May to early winter. Average densities in 2008 and 2009, as estimated by aerial monitoring, ranged from a maximum of 1.11 animals per km², or in total about 4,000 animals in the BPNS during spring, to a minimum of 0.06 animals per km², or in total about 200 animals in the BPNS during summer. In late winter and early spring porpoises occur throughout the BPNS, including in waters very close inshore, while they are restrained to more offshore and northerly waters between late spring and early winter. Erratic invasions of harbour porpoises in the BPNS however blur the general seasonal spatio-temporal pattern, which complicates our understanding of its spatial distribution and migration behaviour.

# THE ART NOUVEAU OF BIOLOGY: EXHIBITING SEAWEED-BACTERIAL SYMBIOSES

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Symbiosis highlights the beauty in biology. The symbiotic 'two become one' principle defines no longer a concept in biology; it basically is biology covering diverse forms of in nature widespread relationships among multiple partners and supporting fundamentally important processes. This essential significance of symbiosis is well outlined in the 'endosymbiotic theory' which claims that eukaryotic organelles like mitochondria and chloroplasts evolved by symbiogenesis. In the masterpiece of evolution algae and bacteria certainly take the leading part. As for their ancestors, marine macroalgae (seaweeds) form the modern-day canvas for heaps of bacterial symbioses ranging from beneficial, harmful or neutral, over obligate or facultative, to ecto- or endophytic interactions. Elaborating the latter, endobiotic associations between marine macroalgal hosts and bacteria have been reported over the past 40 years. Only in the siphonous (single celled, multinucleate) marine green alga *Bryopsis*, however, endogenous bacteria have been electron microscopically visualized in the cytoplasm at every stage of development, including the gametes, suggesting vertical transmission of the endosymbionts (Burr and West, 1970). This indicates a more stable and specific relationship between the algal host and its symbionts in which both partners may provide mutualistic ecological benefits. Although this remarkable algal-bacterial partnership was noticed in the early '70s, little or no research has been performed to explore the specificity and ecological significance of this alliance. To bring a new élan to this symbiosis-study, bacteria inside *Bryopsis* algae were visualized with fluorescent probes (FISH) and the endophytic bacterial diversity was analyzed by means of Denaturing Gradient Gel Electrophoresis (DGGE) and clone libraries. Sequencing results covered e.g. Rhizobiales, Rickettsiales, Rhodobacterales, and Bacteroides species with well-known symbiotic features. Moreover, when the identified endobacterial diversity was analyzed in regard to the *Bryopsis* samples' phylogeny and geographic distribution, some patterns could be observed: Rhizobiales and Rhodobacterales species seem widespread in *Bryopsis* plants, whereas Rickettsiales and Bacteroides species are restricted to *Bryopsis* algae from, respectively, temperate and tropical seas. Also the phylogenies of the bacterial partners themselves indicate a more facultative life style of the Rhizobiales and Rhodobacterales species in contrast to a more obligate nature of the Bacteroides and Rickettsiales symbionts. These and additional results on the potential function and the host-, time- and site-specificity of the bacterial partners show *Bryopsis* algae harbor host-specific endobacterial communities which (1) are distinct from the epiphytic and surrounding seawater populations, (2) differ with geographic distribution of the algal samples, (3) have the potential to fix nitrogen in situ and (4) can vary over time indicating the presence of both facultative and obligate endosymbiotic bacteria. Future investigations will include quantitative PCR and FISH experiments with species-specific probes to fine-tune the bigger *Bryopsis*-bacterial symbiosis picture.

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# A MUDDIFICATION OF THE BELGIAN COASTAL WATERS?  SHIFTS IN THE DISTRIBUTION OF 12 NUMERICALLY ABUNDANT BIVALVES OVER THE TWENTIETH CENTURY

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Knowledge on the macrobenthic communities of the Belgian part of the North Sea has been increasing since the early 1970s. In the frame of the EU 'Water' and 'Marine Strategy' Framework Directives, ecosystem health indices are being developed and it is now necessary to define 'reference conditions' against which human-induced impacts can be evaluated. It is however acknowledged that most impacts are much older than the 1970s and it can be questioned whether knowledge acquired since then can provide accurate information on the baseline situation. The historic collection of G. Gilson, held at RBINS, Department of Invertebrates, was investigated for the period 1899-1908 and compared to a data-set of the period 1994-2008 ('Macrodat-ILVO databank'; Degraer *et al.*, 2009) for 12 numerically abundant coastal bivalves. Despite restrictions resulting from different data distributions and sampling gears, our analysis evidences important distribution shifts, with a regression of clean sand species and a clear expansion of mud-tolerant species. The results are in line with an increased influence of suspended particulate matter in the sediment, which could be linked to maritime access works (Fettweis *et al.*, 2009), bottom trawling and/or the eutrophication of the Southern Bight of the North Sea. They show the importance of historic data gathering and processing to decide upon management targets and to tentatively predict the probable effects of action plans.

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# GENETIC AND MORPHOLOGICAL DIFFERENTIATION OF THE CRAB *DISSODACTYLUS PRIMITIVUS*, ECTOPARASITE OF TWO SYMPATRIC ECHINOIDS

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At Discovery Bay (Jamaica), *Dissodactylus primitivus* is a parasitic crab of two urchin species, *Meoma ventricosa* and *Plagiobrissus grandis*. *D. primitivus* uses asymmetrically its sympatric hosts. Indeed, all post-metamorphic stages (juveniles, adults) are present on *M. ventricosa* but only adults are found on *P. grandis*. Furthermore, the fecundity of female crabs varies between occupied hosts: it is greater on *P. grandis* than on *M. ventricosa*. These urchins present also great differences in morphology and behavior. These characteristics raise the question of the specialization of crabs suiting a particular host species. The aim of this work is to test the genetic differentiation (microsatellite analysis) and the morphological differentiation (shape analysis) between crabs originating from different hosts. Our results indicate the lack of genetic differentiation between crabs parasitizing *M. ventricosa* and *P. grandis*. In addition, genetic homogeneity between infra-populations (occupying one individual host) of crabs has also been detected, and is probably explained by the mobility of adults ("host-switching behaviour"). A morphological differentiation linked to host species and sampling year has been detected. This phenotypic plasticity is presumably related to differences in environmental pressures met by the crabs on their two host-species. In this context (no genetic differentiation), *P. grandis* could appear as an alternate host.

# THE HIDDEN LIFE OF *GWYNIA CAPSULA* (JEFFREYS, 1859) (BRACHIOPODA, TEREBRATULIDA) A MINUTE ARTICULATE BRACHIOPOD NEW TO THE SOUTHERN NORTH SEA

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We report on the occurrence and habitat in Belgian marine waters of the minute brachiopod *Gwynia capsula* (Jeffreys, 1859). Living specimens were found attached to the inside of empty shells and shell fragments collected in the coarse sediments of the Westhinder area. We herewith document the presence of a recent brachiopod for the Southern North Sea fauna. Prior to our observations, this species had not been found alive and its status in the North Sea was unclear. Our findings in an overlooked biotope (gravel grounds with coarse sands) suggest that *G. capsula* is probably not uncommon and that the species might have a wider distribution in suitable habitats throughout the North Sea.

# SUCCESSIVE CAMBIA IN THE MANGROVE *AVICENNIA*: A STUDY ON THE THREE-DIMENSIONAL STRUCTURE OF THE CAMBIA AND THE FUNCTIONING OF THE INTERNAL PHLOEM TISSUE

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Mangrove forests grow in conditions which must be considered extreme for woody angiosperms: high and changing salinity, frequent inundation with associated hypoxia, low relative humidity of the air and high temperatures. As 'marine formations', mangrove ecosystems are characteristic for the intertidal area of estuaries, creeks, sheltered bays and coastlines in tropical and sub-tropical areas worldwide. The genus *Avicennia* has been shown to be eurytopic as regards the above mentioned environmental conditions. Locally, *Avicennia* can often be found at the seaward as well as at the landward side (Disjunct zonation pattern) of the mangrove forest, sites with highly contrasting environmental conditions, while globally it has the largest latitudinal range in both the Eastern and the Western biogeographic mangrove regions (*i.e.* Indo-West Pacific and East Africa *vs.* America and West Africa respectively). The question is how *Avicennia* copes with this large and varying range of environmental conditions? It already has been proven that the wood anatomy of *Avicennia* is especially adapted to harsh environmental conditions. Properties of the wood (transport tissues) were suggested to be adapted to reduce cavitation events, defined as air bubble formation in the xylem sap. Inside vessels, those air bubbles can enlarge and therewith block the water transport (*i.e.* vessel embolism) so that cavitation and subsequent embolism is highly influencing the functionality of the hydraulic system. Amongst mangrove trees, the genus *Avicennia* L. (Acanthaceae) stands out by its successive cambia (*i.e.* having not one cambial layer but subsequent active cambia possibly conferring many sites of active growth in the stem). Secondary growth by successive cambia can offer *Avicennia* ecological advantages since (1) the internal phloem tissue can store water that could be used in refilling air-filled vessels with water and (2) the special, patchy growth can offer the tree woody tissue that is well-adapted to the conditions of the moment. In this study we investigate the organization of the successive cambia in *Avicennia* in three dimensions in order to complete the already investigated three dimensional network of transport tissues (phloem and xylem). Small stems (max. diameter: 3 cm) and branches of *Avicennia marina* (Forssk.) Vierh. and *A. officinalis* L. were sampled from the Rekawa lagoon in Sri Lanka, where the two species encounter spatially and temporally varying conditions as regards salinity, inundation. Serial sections and microscopic observation of the samples allow the reconstruction and visualization of the three-dimensional organization of the successive cambia. The working hypothesis of the research is: 'successive cambia are important for *Avicennia* to survive in extreme high environmental conditions and explains the genus eurytopic nature as compared to other mangrove genera'.

# THE IMPACT OF THE NORTH SEA MARPOL SPECIAL AREA DESIGNATION ON OIL DISCHARGES BY VESSELS: AN ANALYSIS OF 20 YEARS DATA FROM BELGIAN AERIAL SURVEILLANCE

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Operational oil discharges by vessels is a global environmental problem. Many regulations on different levels were set up as an attempt to diminish chronic oil pollution. Examples are the international MARPOL 73/78 Convention (1983) and the Bonn Agreement (1989), committing North Sea Coastal States to carry out regular surveillance. However, the number of oil discharges remained unacceptably high, leading to chronic oiling of seabirds and sensitive coastlines. In 1999, the North Sea was designated as Special Area under MARPOL 73/78 Annex I, where the most stringent oil discharge regulations apply. The aim of this research is to quantify the impact of the designation of the North Sea as a MARPOL Special Area.

Belgium initiated an aerial surveillance programme in 1991. The Belgian surveillance area (BSA) is adjacent to the Dover Strait, one of the busiest shipping zones of the world. Its marine ecosystem is characterised by shallow waters with many ecologically important sandbanks. The collection of data in the BSA since 1991 provides an excellent opportunity to quantify and analyse annual operational oil discharges. The effectiveness of the regulations following the designation of the North Sea as a Special Area was tested by comparing the periods before and after 1999.

A statistically significant decrease was found for number, surface and volume of oil slicks between 1991 and 2009.  This is in agreement with results for the Dutch surveillance area and for oil discharges in the European North Sea region. Furthermore, a significant difference between the periods before and after 1999 was found for number (-55%), surface (-51%) and volume (-64%). These results indicate the effectiveness of increased legislation in the BSA, in particular the designation of the North Sea as a MARPOL Special Area in 1999 and the special measurements that were taken to meet the requirements. However, the problem is not solved and alertness needs to be retained. Vessels are still discharging oil and even the smallest amount of oil can have a large ecological impact.

# MARINE RESEARCH: A SCIENCE WITH NO BOUNDARIES…

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As material for discussions during this day devoted to young researchers, I shall discuss the major boundaries I faced during the last decades of my already long career… Some will appear now to you rather obsolete whilst some others are still valid and might help young scientists to define their research field.

As a woman scientist, I shall begin to tell you my first steps in a world dominated during the seventies by men, especially onboard research vessels…

The second boundary was essentially linked… almost fifty years ago, to the partitioning between various fields of science. As a matter of fact, we used to talk about oceanography by analogy to geography seen as a descriptive science. Only later, the term of oceanology was introduced and become more process-oriented, and with this, slowly appears the need of an interdisciplinary approach. First, this involved the main fields of so-called 'hard sciences' such as physics, chemistry, biology etc. but more recently social sciences and economy have been considered essential for most research projects, especially those launched as support to sustainability development. In parallel to that, marine sciences become predictive with the development of more and more sophisticated mathematical models able to address the complex problems that the society has to face.

Another boundary was 'geographical'; in the past, marine scientists studied the ocean *sensu strictu* without considering its interaction with its major boundaries, such as the air-sea boundary and the land-sea interactions; this later being of special relevance for coastal zone studies. As an example, the Belgian coastal zone cannot be understood without considering the watersheds of the main rivers discharging to the area etc. i.e. involving not only the whole Belgium but also large parts of France, the Netherlands… This also points out the need of European Cooperation.

Most of these changes benefit from societal and political evolutions but also from the information revolution that more and more drive the world today. However, the most important issue, once a problem has been identified is to think about it, to design the best methodological and scientific approach, and to implement it. Solid science imbedded in an earth system vision is needed to find solutions to our nowadays 'under pressure' Planet.

# MULTIMODALITY OF A PARTICLE SIZE DISTRIBUTION OF MARINE SUSPENDED SEDIMENTS: SIGNIFICANCE AND APPLICATION

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Particle Size Distributions (PSDs) of suspended particulate matter are log-normal and multi-modal in general. The log-normality describes a more or less skewed distribution toward small size particles, and the multimodality describes a distribution consisting of multiple peaks. In a coastal environment suspended sediments consist often of flocs. The multimodality is caused by mixing of several floc classes which are different in size and physicochemical property. Those floc classes have undergone different fates in marine environments, and so are able to show their record of floc dynamics under flocculation and transport. Therefore, this research was purposed to develop and test a new experimental method of decomposing multimodal PSDs of suspended particulate matter and tracking decomposed floc classes for investigating floc dynamics. A time series of multimodal PSDs and flow characteristics (velocity and turbulence) measured near Zeebrugge were selected for testing the new method. An automated peak decomposing software (DistFit, Chimera Technologies Inc.) decomposed a measured multimodal PSD to three unimodal PSDs, consisting of clay particle (2 ~5µm), microflocs (size varying), and macroflocs (300~400µm), and estimated the mass fractions of the constituent particles and flocs.

Among many findings from decomposing a multimodal PSD and tracking decomposed PSDs, it is important to note that the volume fraction of macroflocs was maximized at the slack of a tidal cycle due to flocculation. This agrees with the previous finding in that floc size becomes a maximum under aggregation at the lowest turbulence but a minimum under breakage at the highest turbulence (Winterwerp, 2002). Furthermore, noteworthy is that the volume fraction of macroflocs consistently appeared during the ebb period of a tidal cycle but disappeared during the flood period. This is explained by the general lower ebb currents resulting in more efficient flocculation and the stronger flood currents limiting the growth of flocs. During maximum flood currents the PSDs indicate local resuspension of non-cohesive sand-sized particles, which agrees with finding of Baeye *et al.* (2010).

In conclusion, the new method of decomposing a multimodal PSD and tracking decomposed PSDs was proven to be a useful tool for investigating floc dynamics in a turbulent flow field of a marine environment. Deposition or erosion of a mud layer, which can be either beneficial or detrimental for a local marine environment, could be estimated by applying the new PSD-tracking method in a long-term and systematic way. Also, simulating interactions between two or three decomposed PSDs (e.g. aggregation and breakage) and re-superposing PSDs can be an easier numerical method to simulate flocculation of a fully continuous multimodal PSD in a large-scale marine system.

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# IDENTIFICATION AND CHARACTERIZATION OF SEX-SPECIFIC PROTEINS AND GENES IN THE BROWN ALGA *ECTOCARPUS SILICULOSUS*

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Fertilization patterns in seaweeds are of great interest from a molecular and ecological perspective. Successful reproduction in many species depends on a delicate equilibrium between biotic and abiotic conditions. Among the factors affecting fertilization rate, we find these triggering gamete release (including water movement and light) and those affecting gamete viability, but the first and crucial step of successful reproduction is gamete recognition.

Gamete recognition in sexual eukaryotes is mediated by sex-specific proteins that are unique to the gender and species, which assures that the mating occurs between correct individuals. The sex-recognition genes show outstanding divergence, suggesting a unique selection pattern acting upon them during the speciation process. Therefore studies of the sex-specific proteins and their evolution may provide a useful insight into species isolation and diversification.

*Ectocarpus siliculosus* is a brown, filamentous alga that can be found in all temperate climate zones. Small size, easiness of culturing in laboratory conditions, completion of life cycle in less than 3 months and its high fertility makes it a model organism for brown algae. The life cycle of *Ectocarpus* includes both, asexual and sexual reproduction. Sexual reproduction appears in the form of isogamy, where flagellated gametes are morphologically, but not physiologically, identical. The gamete recognition in *Ectocarpus* is known to be mediated by lectin-glycoprotein complexes associated with gamete outer membranes.

The aim of this study is to isolate and characterize sex related agglutinins and explore the differences between male and female gametes on a gene expression level. We apply chromatography techniques to isolate lectins and glycoproteins basing on their specificity and Mass Spectrometry measurements to identify retained proteins. To study differential expression patterns, we have prepared a transcriptome library for both male and female gametes, using Next Generation Sequencing platform. The analysis of obtained data revealed many gender-specific and sex-regulated transcripts. Combining the two approaches mentioned above will help better understand the complex matter of sexual reproduction and speciation in brown algae.

# EVALUATION TOOLS FOR AN ESTUARINE ECOSYSTEM

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The Schelde Estuary, with its tidal mudflats and marshes along a continuous gradient from fresh to marine water, is almost an unique ecosystem in Europe. Within this estuary several aspects of the ecosystem are being monitored regularly. To determine ecosystem health and functioning an evaluation method is prerequisite. Currently, only the Water Framework directive provides an evaluation method, yet it concerns water quality, not ecosystem functioning. In this study indicators of the physical-chemical key parameters for ecosystem functioning, i.e. dissolved oxygen and nutrient concentrations, are identified. Starting point was not a historical or pristine reference. Instead preconditions of these indicators are investigated in consideration of the ecological functioning. The specification of these preconditions implies boundaries between which the indicators may fluctuate so that the ecosystem functioning is not hampered. Not only the functioning in the estuary is considered, but also the coastal sea needs to be taken into account. The ecological functioning of the coastal sea is to a large extent depending on the delivery from estuaries. Conditions in the Schelde must be such that delivery from the estuary is sustaining a good ecological status in the coastal zone.

Oxygen is of vital importance for all (estuarine) life and a crucial indicator of the quality of an ecosystem. The amount of dissolved oxygen is a result of physical aeration and primary production on the one hand and consumption by respiration and oxidation processes on the other hand. Minimum values of dissolved oxygen concentrations were set, based on the minimal requirements for different organisms or processes. When oxygen concentrations do not reach minimum preconditions, this will affect the whole ecosystem. These values may vary in space and time. A surplus of nutrients in the estuary may cause eutrophication problems within the estuary itself or in the coastal zone. High concentrations of nutrients and especially aberrant nutrient ratios may lead to oxygen depletion and switches in phytoplankton composition. In this study these consequences are the main determinants for setting indicators and preconditions.

# INVESTIGATING THE ROLE OF PHYTOPLANKTON IN FLOCCULATION OF SUSPENDED MATTER IN ESTUARIES

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Pure cultures of *Scenedesmus obliquus* and sediment suspensions (kaolin and estuarine sediments) were incubated in rolling cylindrical tanks to study the influence of phytoplankton on the flocculation of sediments. The sets of experiments performed included: 1) varying concentrations of phytoplankton (0, 0.5, 2.0 and 6.0mg DW l -1) and sediments (30, 100 and 200mg DW l -1) and 2) treatments investigating the effects of phytoplankton on sediment flocculation (at a given phytoplankton and sediment concentration), and modification of flocculation by EDTA and salinity. The floc size and the number of flocs were estimated using image analysis. Factorial regression was used to analyse the first sets of experiments while one way ANOVA was used to determine significant difference between groups for the second. Post hoc comparisons (Scheffe test) were done for significant ANOVA results. Our results showed that roller tank incubations and image analysis may be a useful tool to study the effects of phytoplankton on flocculation of clay or sediment suspensions. *Scenedesmu*s seems to have an influence on flocculation of kaolin clay suspensions, although this influence was difficult to demonstrate due to the poor experimental control over kaolin flocculation in control treatments. In the estuarine sediment suspensions, *Scenedesmus* had no or only a weak effect on flocculation, probably because estuarine sediments were already rich in organic matter, which stimulates flocculation. EDTA had no significant effect on flocculation of kaolin and estuarine sediments, although floc size tended to be slightly lower in the presence of EDTA. Salinity significantly increased the number of flocs in both kaolin and estuarine sediment suspensions.

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# THE ROLE OF MEIOFAUNA IN ENERGY TRANSFER IN A MEDITERRANEAN SEAGRASS BED (CALVI, CORSICA)

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Meiofaunal communities of the endemic Mediterranean seagrass, Posidonia oceanica, were sampled in five different habitats characterised by different degradation level of macrophytodetritus. In terms of abundance, harpacticoid copepods represent half of the community followed by nematodes and polychaetes. Two meiofauna communities were distinguished: (1) a benthic community of meiofauna, living in the sediment or on highly fragmented macrophytodetritus, and (2) a foliar, epiphytal community associated with seagrass leaves and low fragmented macrophytodetritus leaves. They differed significantly in their harpacticoid copepod family composition. The benthic community consisted mainly of families like Tisbidae and Miraciidae, while the epiphytal community was dominated by families like Thalestridae and Laophontidae. These differences in composition may also imply a differential functional diversity.

Trophic biomarkers (stable isotopes, fatty acids) were used to identify the major sources of organic matter contributing to the copepods diet and hence to gain insight in the overall carbon flux. Harpacticoid copepods showed preferences to feed upon the epiphytal biofilm community composed of bacteria, diatoms, fungi and microalgae. Copepods used the seagrass and detritus material merely as substrate, but were attracted to the biofilm rather than the plant material which is rich in structural carbohydrates difficult to assimilate by animals (i.e. lignin, cellulose, …).

Since harpacticoid copepods showed to use different sources of carbon, unravelling the contribution of each of them and the role of the degradation level of the detritus for food selectivity is the next step forward.

# CONNECTIVITY OF *SCYLLA SERRATA* IN KENYA AND THE INDIAN OCEAN

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Few studies were conducted on the genetic population structure and gene flow of marine organisms. Some were carried out in different places in and around the Indian Ocean, including Indonesia and the Red Sea (Froukh and Kochzius 2007, Khalaf and Kochzius 2002, Kochzius and Nuryanto 2008, Fratini and Vannini 2002). All these studies have been conducted on the basis of genetic analyses of mitochondrial markers. Some species like Tridacna crocea (Indonesia) or Larabicus quadrilineatus (Red See) show very strong genetic population structures indicating restricted gene flow and isolation. The same species, present in different isolated areas could evolve into different populations. Thereby, the study of genetic population enables us to identify the population structure and could help to infer the population movement and connectivity between remote sites. For instance, Nuryanto and Kochzius (2008) found 4 different populations of giant clam in the Indian Ocean, west Pacific and Red Sea: (1) Red Sea, (2) Eastern Indian Ocean and Java Sea, (3) Indonesia through-flow and seas in the East of Sulawesi, and (4) Western Pacific. Even though the sample site in the Western Pacific is geographically closer, the haplotypes from there (3) are more divergent from the ones found in the central Indo-Malay Archipelago (1) than the haplotypes from the much more distant Red Sea (4). This could be explained by the low sea level during glaciations, which lead to a strong ecological barrier between the Indian Ocean and the west Pacific, and by the oceanic currents that restrict gene flow in that direction. To better understand the population structure and the gene flow in and around the Indian Ocean, we propose to take more samples in a place where there were none: eastern African coast and more particularly in Kenyan coast. In addition, these samples allow studying the connectivity and the genetic structure of Kenya's marine organisms and could be related to the structure and to the distance of mangrove forests, on which these species are known to depend for food and refuge. In addition, the samples could be linked with a Kenyan mangrove GIS to infer the connectivity of marine organisms. The starting hypothesis that we will check is that there is some genetic diversity amongst the organisms. In other words, some different haplotypes and therefore different isolated populations exist along the coast. The methodology consists in taking samples by fishing, diving or snorkeling in different places along the Kenyan coast. Collaboration with local fishermen is also considered. The results of this study will help to understand the dispersal behaviour of the Mangrove mud crab Scylla serrata at two different scales: a small scale (Kenya) and a larger scale (in and around the Indian Ocean).

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# THE FISH SPECIES COMPOSITION AND VARIATION OF CATCH FROM THE ARTISANAL FISHERY IN THE PEMBA CHANNEL OF THE WESTERN INDIAN OCEAN

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In the Western Indian Ocean coastal zone, where highly diverse fish communities occur, it is important to study the artisanal fisheries exploiting these communities. Forty-three (43) species of fishes were caught by drifting gillnet, longline, handline, traps and gillnet during October 2008, January 2009, January 2010 and June 2010. A catch of 6,873.2kg from sampled fishing crafts was landed in which the sub-sample weight of 4,920.6kg was measured to biological level. A total of 64 species was observed, whereby the higher CPUE of 55.1kg/boat/day was obtained from sharknets (drifting gillnet) dominated by *Thunnus albacores* (86.9%). The Handline was the next which contributed 4.9% which was dominated by emperor group (*Lethrinus lentjan*) and the least catch was from trap fishing which contributed 4% of the total catch dominated by *Leptoscarus vaigiensis* and *Siganus sutor* (3.8%). Sharknet dominated in terms of catch rates compared to other two fishing gears because it caught large pelagic fishes. Furthermore, this study showed the higher percentage composition by number was contributed by gillnet whereby the catch was dominated by *Lethrinus lentjan* (62.3%). There were considerable differences in the species composition and variation in terms of gear types and sampling periods. Based on the sampling period it was observed that *Thunnus albacares* and *Katsuwonus pelamis* are caught more during October while other species had little variations. This paper discusses in detail their catch variation and abundance between gears and sea condition.

**Keywords:** artisanal fisheries; fishing crafts; CPUE; species composition and catch variation.

# MOLECULAR SYSTEMATIC OF GROUPERS (SERRANIDAE) IN THE INDO-WEST PACIFIC

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Groupers are bottom-associated fishes found in the tropical and subtropical waters of all oceans. Most species occur on coral reefs, but some live in estuaries or on rocky reefs. They are generally associated with hard (rocky) bottoms, although juveniles are found in seagrass beds, and adults of a few species prefer sandy or silty areas. Groupers are usually the most expensive fishes in the local markets, separate catch statistics are not reported for most species, and landings are often summarized as 'serranids' or 'groupers.' This lack of species-specific catch data is due, to the difficulty of identifying many of the species. This study focuses on the molecular phylogeny of several species of the family Serranidae. Phylogenetic analysis will be done on samples from Tanzania, Indonesia, Malaysia and Japan. Fish were identified at species level and fin clip, muscle and gill tissues were sampled and preserved in 96% ethanol. Analysis will be done at the Plant Biology and Nature Management (APNA) Laboratory at the VUB Etterbeek campus from October 2010 to February 2011 and will involve DNA extraction from samples according to the Chelex method of Walsh *et al.* (1991). Fragments of the mitochondrial cytocrome *b* and 16S rRNA genes will be amplified by PCR and sequenced. This will be followed by a phylogenetic analysis in special computer programs to obtain cladograms and phylogenetic trees for biological systematics.

# ORGANISMS AS ECOSYSTEMS ENGINEERS: THE CASE OF AMPHIPOD GRAZERS FROM *POSIDONIA OCEANICA* MEADOWS

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*Posidonia oceanica* is a seagrass endemic to the Mediterranean Sea, and is able to form large monospecific areas, called meadows. These meadows shelter high biomasses and biodiversities of amphipod crustaceans. Moreover, It is now established that several species of these amphipods feed on the macro-epiphytes present on the leaves of the seagrass.
Here, we performed in situ experiments to assess whether this grazing activity could impact the dynamics of the leaves' epiphytic cover, and thus influence the functioning of the meadow as an ecosystem. We used microcosms containing monospecific populations of 3 amphipods taxa (*Apherusa chiereghinii*, *Dexamine spiniventris* and *Gammarus* spp.), and placed them directly in the meadow, at a depth of 10m.

Biomasses of erected macroalgae and erected animals (hydrozoans, bryozoans) were lower in all grazed treatments. However, none of the studied taxa seemed to consume encrusting epiphytes, either vegetal or animal. This selective grazing pressure by amphipods may release encrusting epiphytes from competition for space, light and/or nutriments with the fast-growing erected algae, and could thus play an important role in the structuring of the epiphytic cover from *P. oceanica* leaves. Moreover, this top-down control might keep erected algae biomass to a normal, sustainable level, therefore also benefiting the seagrass itself.

Our results also indicate that amphipod trophic activity caused nitrogen enrichment in both grazed (erected algae) and non-grazed (encrusting algae & seagrass leaves) vegetal tissues. A plausible interpretation could be that sloppy feeding and excretion by the grazers enhanced availability of this nutrient, which is typically limiting for photosynthesis in shallow *P. oceanica* meadows. This emphasizes the fact that grazing is not a simple negative interaction, but that it can also benefit the primary producers.

Our results thus indicate that amphipods from *P. oceanica* meadows seem to be bound to the epiphytic cover of the leaves by complex and multilateral trophic interactions, and have an indirect influence on the seagrass itself. Amphipods may therefore play an important part in the functioning of the epiphyte/seagrass/grazer system of these meadows, and thus act as ecosystems engineers.

This abstract is dedicated to the freshly born Adèle and Côme.

# GENETIC STRUCTURE AND LIFE HISTORY AS BASIS FOR MANAGEMENT UNITS IN TURBOT *PSETTA MAXIMA*

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Many commercial marine fisheries have strongly declined or even collapsed due to the synergy between a changing climate and anthropological influences, such as habitat degradation and overfishing. Therefore, policy makers request management advice about a growing number of species that were not subject to analytical assessments of stock size and composition in the past, leading to the definition of Total Allowable Catches and the fishing quota. However, there is often a discrepancy between management units and biological populations for these 'new species', since management units were originally defined for the main commercial species (e.g., sole and plaice) and often reflect convenient geographic boundaries rather than biological entities of the new species. Furthermore, marine fishes are also strongly influenced by environmental oscillations, leading to an unpredictable reproductive success, high mortality and unclear population delineation. A good description of biological units within a species, and knowledge of the dispersal capacity and the realised genetic connectivity, are therefore important for the management of exploited fish populations. Turbot *Psetta maxima* is such a valuable commercial species for which the European Commission requests management advice. This species inhabits the entire northeastern Atlantic region, including the Baltic, Mediterranean and Black Seas, but analytical advice has not yet been provided in the past. In our research, information on the genetic structure and life-history traits of turbot from different areas is evaluated for its potential application in defining biologically relevant management units, and to obtain insights in population connectivity.

# FROM BATHYMETRY TO BIOSHIELDS: A REVIEW OF POST-TSUNAMI ECOLOGICAL RESEARCH IN INDIA AND ITS IMPLICATIONS FOR POLICY

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More than half a decade has passed since the December 26th 2004 tsunami hit the Indian coast leaving a trail of ecological, economic and human destruction in its wake. We reviewed the coastal ecological research carried out in India in the light of the tsunami. In addition, we also briefly reviewed the ecological research in other tsunami affected countries in Asia namely Sri Lanka, Indonesia, Thailand and Maldives in order to provide a broader perspective of ecological research after the tsunami. A basic search in ISI Web of Knowledge using keywords 'tsunami' and 'India' resulted in 127 peer reviewed journal articles, of which 39 articles were pertaining to ecological sciences. In comparison, Sri Lanka, Indonesia, Thailand and Maldives had, respectively, eight, four, 21 and two articles pertaining to ecology. In India, bioshields received the major share of scientific interest (14 out of 39) while only one study (each) was dedicated to corals, seagrasses, seaweeds and meiofauna, pointing to the paucity of research attention dedicated to these critical ecosystems. We noted that very few interdisciplinary studies looked at linkages between pure/applied sciences and the social sciences in India. In addition, there appears to be little correlation between the limited research that was done and its influence on policy in India. This review points to gap areas in ecological research in India and highlights the lessons learnt from research in other tsunami-affected countries. It also provides guidance on the links between science and policy that are required for effective coastal zone management.

# WHO BENEFITS AND WHO LOOSES? ESTIMATING THE VALUE OF ECOSYSTEM GOODS AND SERVICES IN THE WATAMU MARINE PARK AND RESERVE, KENYA

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Coral reefs, seagrass beds, mangrove forests and other marine ecosystems provide a wide range of ecosystem goods and services that support the well-being of the human population. However, apart from natural causes, these ecosystems have been threatened by conversion to other land uses and increasing degradation through overexploitation, pollution among other human activities that result from poor management. This is coupled with the fact that marine ecosystem goods and services are often undervalued. Marine Protected Areas have been established with a purpose of conserving biodiversity and promoting ecotourism. The purpose of valuation is to assist in sustainable management decisions and conservation. This ongoing study estimates the value of ecosystem goods and services within the Watamu Marine Park and the Mida reserve in Kenya, the conservation costs of the ecosystem goods and services and how the benefits and costs are shared among different stakeholders. The hypotheses include: 1) the benefits from conservation are more than the opportunity costs; 2) the benefits are not equally distributed among different stakeholders; 3) the further the village from the mangrove ecosystem, the less value the resource is given. Using key informant, focus group discussions and surveys, at least 30 stakeholders including fishermen, fishmongers, mangrove harvesters, curio vendors in villages surrounding the park and reserve were interviewed to estimate the use values and non-use values. Interviews were carried out after every one homestead and at landing sites targeting respondents who derive their livelihood from marine related activities. Numbers of fishermen and fish catch data and mangrove exploitation data will be obtained from the fisheries and forestry departments respectively while park operation data will be obtained from the Kenya Wildlife Service records. Data analysis will be done according to the responses from the respondents in relation to distance from the sea and mangroves. Market prices will be estimated for the goods including mangrove products and fish. For biodiversity conservation, Contingent Valuation Method (CVM) will be used to estimate the non-use value, while travel cost method will be used to estimate the ecotourism function. For other services that could not be estimated in time such as the protection and carbon sequestration values the benefits transfer method will be used. The data will be compared with studies from other parts of the world.

# POTENTIAL OF COASTAL VEGETATIONS IN CARBON SEQUESTRATION FOR MITIGATING THE CLIMATE CHANGE

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Climate change is a great global risk to biodiversity, productivity and functioning of ecosystems. Of which, coastal ecosystems are of great significance for their vulnerability to climate change and capability to mitigate the change as well. Mangroves, seagrasses and coral reefs are the major tropical coastal ecosystems and their coastal vegetations play a major role in $CO_2$ mitigation. The mangrove forests and seagrass beds are as high as 20 times more efficient in carbon sequestration than tropical forests. Occupying just 0.7% of coastal zone, the mangrove forest ecosystems contribute to 10% of the total net primary production and 25% of carbon burial in the world coastal zone. Therefore, the coastal vegetations serve as potential sink for the major green house gases and help to slow down global warming. They are capable of trapping carbon in their sediment and biomass; hence are recognized as key for the extreme long-term potential to sequester atmospheric carbon. However, due to the increasing rate of deforestation, harvesting and forest degradation, the world's forests including coastal mangroves are estimated to be a net source of carbon. Due to destruction of coastal vegetation, there is an annual reduction of about 30 trillion grams of carbon in the global coast. The annual primary production of global mangroves is 218 trillion grams of carbon; and about 50% of the carbon fixed by mangrove vegetation is unaccounted for. Mineralization in mangroves is largely underestimated, and that the majority of carbon export from mangroves to adjacent waters occurs as dissolved inorganic carbon. Carbon dioxide efflux from sediments and creek waters and tidal export of DIC appear to be the major sinks. In spite of all these facts, the role of mangroves and other coastal vegetations in carbon budget and climate change mitigation is neglected from accounts of the global ocean carbon cycle for the main reason that the marine vegetation occupies only less than 2% of the oceanic surface. A combination of reducing deforestation, coupled with restoring the coverage and health of the coastal vegetations could reduce the emissions of the $CO_2$. Thus the protection and restoration of coastal vegetations, through comprehensive approach and integrated management would have significant impact.

# QUORUM SENSING INHIBITORS FROM MICRO-ALGAE COMMONLY USED IN AQUACULTURE

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Quorum sensing, bacterial cell-to-cell communication with small signal molecules such as acyl-homoserine lactones, regulates the virulence of many (aquatic) pathogenic bacteria (Schauder and Bassler, 2001; Waters and Bassler, 2005). Therefore, interfering with quorum sensing is currently being explored as a novel biocontrol strategy to fight bacterial infections. In this study, the effects of different marine and freshwater micro-algal strains on acyl-homoserine lactone-regulated phenotypes of three reporter strains were investigated. Two freshwater micro-algae inhibited violacein production of quorum sensing reporter strain *Chromobacterium violaceum* CV026. Further tests using *Escherichia coli* JB523 showed that micro-algal extracts inhibited or stimulated quorum sensing, depending on the algal strain. One freshwater and 5 marine algae showed quorum sensing inhibitory activity, whereas two algae stimulated quorum sensing-regulated gene expression. Micro-algal strains that showed inhibitory activity in the previous assays also inhibited acyl-homoserine lactone-regulated bioluminescence in the aquaculture pathogen *Vibrio harveyi*. The growth of all reporter strains was found to be unaffected by the micro-algal samples. The most promising micro-algal strain was found to be *Chlorella saccharophila* CCAP211/48, as its extracts inhibited quorum sensing-regulated gene expression in all three reporter strains. This study revealed that micro-algae are able to act as a biocontrol agent against pathogenic bacteria in aquaculture.

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# MANGROVE FOREST STRUCTURE ORGANISATION IN A MONOSPECIFIC STAND OF THE BLACK MANGROVE *AVICENNIA GERMINANS* (L.) STEARN IN THE CAMEROON ESTUARY

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One of the major components of forest stand structure is the spatial arrangement of tree positions and the distribution pattern of species. *Avicennia* (Acanthaceae) is considered an important colonizer of new areas. This genus comprises about eight species of which only one, namely the Black mangrove *Avicennia germinans*, occurs in Cameroon mangrove forests. Through extension its complex of pneumatophores this species causes solidification of the soft substrate, hence facilitating the stabilization of coastal zones. In spite of this ecological importance, little is known about the patterning of *A. germinans* forest stands. In this contribution, we characterized the stand structure of this species in the Wouri Estuary (Cameroon). We located two sites in the landward margin and one on the seaward edge. There, we established 20 plots of 40m×40m along belt transects, and subdivided each plot into 16 subplots of 10m×10m. We measured the diameter, height and spatial coordinates of all *A. germinans* stems and finally determined the type of spatial arrangement of trees based on the number of stems counted in each subplot. Our results showed that the mean tree diameter, basal area and height were considerably higher on the seaward edge than in the landward margin, and with few exceptions, the spatial arrangement of *A. germinans* trees was commonly clumped. These different patterns were consistent with the map resulting from the recorded spatial coordinates. On one hand, the clumped spatial arrangement of trees could be due to the fact that seedlings of *A. germinans* are often dispersed over greater distances by tidal action (seaward edge), while on the other hand, the same pattern might be attributed to their capabilities of settling close to the senescent tree in less flooded areas (landward margin). Moreover, when seedlings are trapped by the pneumatophores, this can lead to a random distribution sometimes recorded in the two different locations. In addition to our findings, it is important to develop a more complete characterization of the stand structure of *A. germinans*. We believe this objective can be achieved by analyzing endogenic organisation processes that occur within the growing environment of this species.

# ECOLOGICAL RELATIONSHIP BETWEEN FISH FAUNA AND CORAL REEF BENTHOS IN KIUNGA MARINE NATIONAL RESERVE, KENYA

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Kiunga Marine National Reserve (KMNR) is located at the northernmost stretch of the Kenyan coastline (40° 07' E, 2° 00' S). The reserve was designated as such in 1979 under the Wildlife Conservation and Management Act of 1976 and it is under the authority of Kenya Wildlife Service (KWS). KMNR is unique for its 'interconnected environments' from coastal dunes, island biota, mangrove forests, seagrass beds, and coral reef to the open ocean. Being at the southern end of the Somali Upwelling, it is believed to be at the margin of the coral reef ecotone. Artisanal fishing is the main economic activity, contributing to more than 70% of the household income.

The study seeks to enhance the management of Kiunga Marine National Reserve and adjacent area through incorporation of scientific information to guide decision-making. The study aims to identify the ecological status by relating coral reef benthos with fish census data and use survey data to describe the artisanal fishery.

To conduct the data analysis, a time series dataset spanning 2004-2009 has been collected. The data include underwater visual census (UVC) for fish and invertebrates identified to species level, line intercept transect (LIT) for coral benthos, coral species diversity and recruitment identified up to genus level.

The analysis of ecological monitoring data will be done primarily with the statistical software PRIMER (Plymouth Routines In Multivariate Ecological Research).

# EVALUATION OF ECOSYSTEM SERVICES OF A FRESH WATER TIDAL RESTORATION PROJECT

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All over the world estuaries are considered to be economically very important ecosystems that provide ecosystem services (Costanza *et al.*, 1997) which for their part contribute to human welfare (Fischer *et al.*, 2009). To compensate for losses of estuarine habitat and accompanying services, costly investments are often needed. However, not all ecosystem services are replaceable causing a decrease in human welfare. World-wide restoration projects and nature development of estuarine ecosystems take place to restore the delivery of ecosystem services. Disfunctioning of ecosystems corresponds with the reduction or standstill of the delivery of several ecosystem services. To determine and evaluate these deliveries an evaluation of the ecosystem is a prerequisite. The functions or ecosystem services of intertidal restoration areas were already described in literature (De Groot *et al.*, 2002; Cox et al., 2006) and even used as conservation goals of the Schelde (Adriaensen *et al.*, 2005). However, the quantification of these services was not performed before. In this study three ecosystem services of intertidal habitats, i.e. aeration, nitrogen retention and silica delivery, were quantified to evaluate these services. Our study site is a former agricultural area that was turned into a flood controlled area with a controlled reduced tide (Cox *et al.*, 2006). Since four years, fresh water intertidal mudflats and marshes are developing. Due to the controlled in- and outflow through a system of sluices, this site is perfect for mass balance studies. During tidal campaigns dissolved oxygen, nitrogen and dissolved silica concentrations were measured several times a year after which mass balance studies were performed. The results of these mass balance studies show that the study area provides in two functions: aeration and nitrogen retention. Also silica delivery was observed when estuarine silica concentrations were limiting.

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# STUDY OF SAND DYNAMICS AT SMALL SCALE ON THE BELGIAN CONTINENTAL SHELF TO EVALUATE THE RISK OF MINE BURIAL

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The Belgian Continental Shelf is affected by sea mines from the World Wars. It is not uncommon that fishermen carry one of them with their net, sometimes with heavy consequences.
The Belgian Navy makes an effort to solve this problem. It supports several researches involved in this topic and this project is one of them.

After years of researches considering and improving the best methodology to find and pick them up from the sea bottom without consequences, the Belgian Navy wanted to also better understand the environments surrounding these objects and the causes-effects due to their interaction.

More over the Belgian Navy wishes to develop a method to evaluate the most appropriate techniques usable considering different geo-morphological scenarios.

This research tries to answer all these problematics focusing on sand dynamics at small scale in well defined research areas in the Belgian Continental Shelf.

Based on previous studies (Wever, 2003), the bedforms named 'megaripples' with an height up to 1.5m and a cross section of 30m are considered as the most important bedforms for episodic mine burial on operational time scales. Areas where these bedforms can be formed and where they have certain dynamics are selected for the investigation.

The Wandelaar region, the Vlakte van de Raan region and the Gootebank region next to the anchorage zone are the three areas of interest for the project. First of all, they all show this geomorphologic characterization and secondly they are areas densely populated by ships and fishermen with a high economic value.

Different methodologies of investigation are thought to evaluate the changing in time and space on the bedforms on the seafloor: multibeam measurements for new bathymetrical maps are performed in the last three years, time series of side-scan sonar measurements were monthly planned but due to bad weather conditions and technical problems on the instrument, only some recordings are available, boxcores for very detailed sediment analysis at the experimental sites are taken, instrumented objects able to record the height of the sediments around the object itself during short and long times (property of the German Navy, FWG) are deployed to investigate small-scale variability of sand dynamics over 3 to 12 months. The use of these instrumented objects is essential to have long periods of measurements without interruptions; unfortunately the operations for their recovery give some difficulties.

These different techniques are used to have comparable and compatible results, to deal with different logistic problems and to evaluate different methods of investigation with their degree of uncertainty. Significant results of the interaction between the object and the surrounding environment are already available.

At the end of the project a method for prediction of partial or total burial of objects will be developed and risk maps for the BCS will be provided to identify areas at low, medium or high risk of mine burial.

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# A CLOSE LOOK AT MARINE SPATIAL MANAGEMENT IN THE SOUTHERN NORTH SEA

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The European seas are home to a wide range of marine habitats and have to support a variety of marine industries. 'Multi-usage' can cause frictions between socio-economic interests and ecological conservation requirements, but also between the different user groups. The increasing pressures upon the European seas and coastal areas (mostly leading to a degradation of the marine ecosystem) call for a well-planned approach of the spatial (and temporal) use by and the development of the different sectors. MESMA (Monitoring and Evaluating Spatially Managed Areas) is an EU-FP7 project (2009-'13) with 21 partners from 13 countries, which aims to produce integrated management tools (concepts, models and guidelines) for the monitoring and evaluation of spatially managed marine areas. The main goal is to streamline the spatial management of the marine environment in Europe at different levels. During the first year of the project, the existing literature on spatial management, tools and indicators was reviewed. Another major task was the development of a 7-step generic framework, including the setting of operational objectives, the identification of existing data, pressures and management measures, the selection of indicators, risk analyses, the evaluation of the current management plans, and the formulation of recommendations. For the coming years, a toolbox will be assembled and the framework will be tested (including a thorough governance analysis), through 9 case-studies within five geographical regions (North Sea, Atlantic, Baltic, Mediterranean, and Black Sea). This approach makes it possible to compare pressures on an inter-regional level (e.g. offshore wind farms in the North Sea, Black Sea and Baltic), or on a multi-pressure level for a specific region (e.g. MPAs, fishing, wind energy, geo-hazards and tourism in the Black Sea). The complexity of the Southern North Sea (SNS) case-study (including 4 sub-case areas) is reflected in a huge variety of biotopes, human activities and regulations. Moreover, there are remarkable spatial differences in human uses and governance arrangements within the case-study area. In the SNS case-study, the framework will be tested through a nested approach, at first instance to monitor and evaluate whether the current management plans are able to cope with an operational objective of producing and using 20% of "green" energy (partly through windmills at sea) by 2020.

# IMPACT OF PHYTOPLANKTON BLOOM DEPOSITION ON MICROBIAL COMMUNITIES AND METAL FLUXES IN CONTAMINATED NORTH SEA SEDIMENTS: A MICROCOSM STUDY

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Metal contamination and eutrophication are two interrelated problems affecting many coastal zones, including the Belgian Continental Zone (BCZ) of the southern North Sea. High concentrations of heavy metals, such as Cd, Cu, Pb, Zn, Hg and Ni, have been reported, especially in muddy subtidal sediments. Furthermore, eutrophication due to the input of nutrients and organic matter from adjoining estuaries results in recurrent spring algal blooms. Sedimentation of these algae and algae-derived organic matter results in intense remineralization in the sediments. This can cause significant changes in the redox state of the benthic ecosystem, affecting benthic microbial community structure and metal behavior. This study investigated the benthic response of phytoplankton bloom deposition on microbial communities and metal fluxes in a muddy, heavily contaminated subtidal station (130) from the BCZ. We used microcosms to evaluate the deposition of high concentrations (3µgl$^{-1}$ chl a) of *Skeletonema* sp. and *Phaeocystis globosa* on microbial community structure. Sediments were sampled after 0, 2 and 7 days. Changes in microbial eukaryote community composition and activity were analyzed using molecular methods (18S rDNA and rRNA based DGGE respectively). These data were complemented by monitoring of the benthic metal fluxes and other geochemical variables (a.o. $O_2$, pH, chlorophyll and DOC), and changes in composition and activity of benthic prokaryotes. The interaction between organic matter deposition, microbial community structure and activity, and metal dynamics will be discussed.

# QUORUM SENSING-INTERFERENCE TO REDUCE MORTALITY DURING BLUE MUSSEL (*MYTILUS EDULIS*) LARVICULTURE

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In 2005, blue mussel (*Mytilus edulis*) was the primary cultured bivalve in Europe. Mussels are cultured by capturing larvae or by fishing young mussel seed from the wild and on-growing these to marketable size. Unfortunately, the production is extremely variable due to uncertain availability of natural spat. Hatchery production of mussel larvae is one solution to this problem (Galley *et al.*, 2010). However, mass production of mussel seed in hatcheries is hampered by outbreaks of diseases, caused by pathogenic bacteria. In the past, diseases were combated with antimicrobial drugs (ADs). This led to the emergence of AD-resistant pathogens (Martinez, 2009). Therefore, alternatives to the use of antibiotics are necessary. The technique of quorum sensing-interference is a new field of research that deserves considerable attention. Quorum sensing (QS) is a type of bacterial cell-to-cell communication that regulates the pathogen's virulence. Blocking QS can result in decreased virulence (Defoirdt *et al.*, 2004).

A gnotobiotic test system is being developed for blue mussel larvae. This system will be used for challenge tests during which the interactions between selected quorum sensing-using pathogens (i), selected quorum sensing-interfering bacteria (ii) and mussel larvae (iii) will be determined. The survival, growth and immune status of gnotobiotic mussel larvae will be monitored as well as the composition of the bacterial communities associated with the mussel larvae and present in the medium. In parallel, the effect of the quorum sensing-interfering bacteria on microalgae cultures will be determined. Selected bacteria will be screened for their positive effects on algal growth. Subsequently the microalgae that are co-cultured with the bacteria will be administered to the mussel larvae of which growth rates and survival will be measured. The aim is to identify bacteria that have a beneficial effect on both microalgae and mussel larvae.

Understanding the role of QS will enable the development, evaluation and commercialization of quorum sensing-interfering bacterial mixtures, which will increase considerably hatchery mussel larvae production without the necessity to use antibiotics. A stable and predictive supply of high quality mussel seed is a pre-condition to develop commercial mussel farms when natural supply becomes unreliable. Also integrated multi-trophic aquaculture (IMTA) projects (Troell *et al.*, 2009) and offshore projects (e.g. windmill parks) (Michler-Cieluch *et al.*, 2009) can be supplied with hatchery seed, supporting the worldwide concern to develop sustainable aquaculture practices.

Hatchery production of mussel seed also permits genetic breeding programs and the generation of triploid seed, which can lead to mussels containing more meat with a better taste and/or mussels that are resistant to certain bacterial diseases or parasites (Beaumont *et al.*, 2007).

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# ESTIMATING SPATIAL AND TEMPORAL VARIABILITY OF MARINE SPECIES FROM OPPORTUNISTIC DATA: A NORTH SEA PLAICE CASE STUDY

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Major concerns have been raised regarding the state of living resources and the ecosystem they live in (Halpern *et al.*, 2008). Ecosystems are affected by a variety of human activities. Management and conservation of species in this changing environment requires a profound understanding of spatial ecosystem properties and trends.

However, most sampling programs measuring biological processes have either a good coverage in space, or a good coverage in time. Examples are marine mammal or fish surveys that occur only annually or even less frequently, and single spot continuous monitoring such as the 'Helgoland Roads' time series (Wiltshire *et al.*, 2010). If we are to understand the dynamic and spatiotemporally heterogeneous processes, intensive sampling in both space and time is required, especially in the marine environment where biological survey sampling is generally a logistically complex, expensive, and time consuming operation (e.g. see Schiermeier, 2008). As a result, regular monitoring of relevant components in the marine environment is often lacking.

Complementary to the use of research vessels, sampling on board commercial vessels of opportunity can be a powerful strategy to monitor the distribution of species. Our objective is to estimate population distribution in space and time using such opportunistic data. In particular we use data on North Sea plaice (*Pleuronectes platessa*) caught and subsequently discarded on commercial fishing vessels (Catchpole *et al.*, 2005), estimated from discard sampling programs of the Dutch and Belgian fisheries. The limitations of these opportunistic data can be accounted for by employing spatial interpolation methods. Within-vessel or small scale residual spatial autocorrelation is accounted for by including a random effect of the intercept and incorporating a spatial correlation function into the error structure. This statistical method successfully reconstructs the spatio-temporal distribution based on opportunistic spatially non-uniform sampling.

Our results indicate that the discarded plaice are small juveniles, representing crude spatial abundance indices. Although the haul-specific observations of juvenile plaice appear highly variable in space and time, our results show a simple pattern of the gradual offshore movement of recruits from the nursery areas, corroborating earlier observations in the nursery areas (Bailey 1997).

The spatial distribution of the different age groups in our results clearly differs from that observed in the first half of the previous century (Beverton and Holt, 1957). The causes for the changes in migration patterns of juvenile plaice are unknown, but likely linked to changes in temperature, food availability, competition, or predation (Teal *et al.*, 2008).

The statistical model presented here could be used to combine data coming from annual research vessel surveys and vessels sampling opportunistically, covering a large part of the coastal waters in the eastern North Sea. Combining such data could lead to further insight into the seasonal spatial distribution of marine species.

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# CLIMATIC REQUIREMENTS FOR MANGROVES: WHAT DOES ECOLOGICAL NICHE MODELLING REVEAL? – PRELIMINARY RESULTS

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Mangroves are forests in the intertidal zone along (sub)tropical coastlines. This vulnerable ecosystem is under threat of increasing coastal human population and land-use changes. Global warming has a major impact on the mangrove distribution as sea level is rising and the position of the intertidal zones is moving landwards. Next to this, an increase of temperature creates the possibility for mangroves to move polewards beyond their current distribution. By investigating the temperature at the mangrove latitudinal range limits, we found that (1) there is not one isotherm that coincides with mangrove latitudinal limits: monthly air and sea surface temperature are highly variable among congeneric mangrove limits, (2) the larger distribution of the genus *Avicennia* compared to the genus *Rhizophora* is reflected in the temperature requirements: *Avicennia* limits are colder than *Rhizophora* limits (Quisthoudt *et al.*, submitted).

In a next step towards the understanding of the climatic requirements of mangroves, we are investigating the climatic niche of the whole mangrove distribution. Because the mangrove distribution is mirrored by the equator, the first hypothesis is that the mangrove ecosystem has the same climatic niche in the northern and southern hemisphere. The second hypothesis is that the climatic niche of the mangrove forests in the Indo West Pacific Region is the same as in the Atlantic East Pacific mangrove forests, indicating that the species differentiation of congeneric species between the two biogeographic regions is due to vicarance. Up-to-date information about the mangrove distribution is recently published in the mangrove atlas on country and species level. Spalding *et al.* (2010) and Giri *et al.* (2010) published a new world map of the mangrove distribution based on satellite images. Climatic variables are mean minimum temperature of coldest month, yearly mean temperature, growing degree days above 18°C, yearly precipitation, yearly potential evapotranspiration and water balance, all derived from WORLDCLIM database (Hijmans *et al.*, 2005). We are applying an OMI analysis (Doledec *et al.*, 2000) to find out the niche of the mangrove species of the genera *Avicennia* and *Rhizophora*.

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# INVESTIGATING EFFICIENCY OF GREENBELTS FOR THE PROTECTION OF SRI LANKA'S COASTS AGAINST OCEAN WAVE SURGES

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## Aim of the study

After the tsunami of 26 December 2004, we discovered that some villages close to the coast were less affected by the destructive wave than others (Dahdouh-Guebas *et al.*, 2005; Feagin *et al.*, 2010). This was explained by the presence of a 'greenbelt' between the village and the ocean which was wide or/and strong enough to decrease the catastrophic nature of this event.

## Study area

The objective of our ongoing research is to classify greenbelts (forests, sand dune with or without vegetation) all along the Sri Lanka coast using remote sensing and fieldwork in order to qualify the vulnerability of the Sri Lanka coast. The land field survey was done in the southern part of Sri Lanka between Matara and Tampaddai.

## Methodology

We selected areas where the impacts of tsunami were less than that in other places. To identify these areas we created an index based on percentage of deaths in each Grama Niladari (i.e. village officer) or GN division (smallest administrative unit in Sri Lanka). In addition we used the status of the area after the event. These two indicators are not perfect but together they give us complete information about the impact of the event.

## Ongoing research

The ongoing part of the research aims not only at identifying the vulnerable areas but also to provide recommendations and guidelines on the establishments of greenbelt barriers. Different greenbelts can be suggested when knowing the features of the coastal area such as topography, distance from the ocean, presence of sand dunes or coastal forests.

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# *IN SITU* AND EXPERIMENTAL STUDY OF TROPHIC RELATIONSHIPS AND DIVERSITY OF MACRO-INVERTEBRATES ASSOCIATED WITH DEAD *POSIDONIA OCEANICA* LITTER

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*Posidonia oceanica* meadows are highly productive ecosystems in Mediterranean coastal waters. A variable but generally important part of this primary production forms *P. oceanica* dead leaves litter which can accumulate in the meadow or be exported outside, to sandy patches, deep systems or even terrestrial places. This exported detritus litter has very poor nutritional qualities, but it supports a wide assemblage of micro and macro-invertebrates. Even if partial information is available for a few species, trophic relationships between these macro-invertebrates and carbon transfers are still poorly known in this ecosystem.

In this context, this research project will fill in this gap. We will use several traditional tools to determine accurately these trophic links: gut content analysis, bulk stable isotope analysis, fatty acid composition, and a much more innovative and far less used technique which is compound specific stable isotope analysis (CSIA). These are recognized as powerful tools in coastal trophic ecology.

In order to try to improve the use of fatty acid composition in trophic ecology, we'll also conduct a laboratory experiment. We'll try to find fatty acid tracers of some potential food sources that are transferred through more than one trophic level because this could provide a very innovative way to use fatty acids in Mediterranean trophic ecology.

We'll also try to determine how some ecological factors affect the trophic relationships between the leaf litter macro-invertebrates, and so we'll take our samples at every season, at sites presenting different litter fragmentation, composition and constancy characteristics.

Resource pulses may have strong effects on ecosystems in which they happen. Even if *P. oceanica* leaf litter ecosystem often faces that kind of event, no study ever tried to determine the impact of detritus pulses on leaf litter macro-invertebrates or on trophic links between them. We'll conduct an *in situ* experiment to try to assess the impact of a litter pulse on the litter macro-invertebrates assemblage.

In conclusion, this research project will provide important information on macro-invertebrate trophic structure and on *P. oceanica* leaf litter ecosystem, which could play a central role in carbon cycle and recycling in the Mediterranean sea.

# ASSESSMENT OF ELECTRIC PULSE FISHING AS AN ENVIRONMENT FRIENDLY FISHING METHOD IN THE NORTH SEA

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Brown shrimps (*Crangon crangon*) are of great commercial importance as the third greatest marine production in the North sea. They are caught with bottom trawls, operated by approximately 600 vessels. The application of the small meshed nets leads to high amounts of discards. Additionally the heavy bobbin rope, used to startle the shrimp, might cause damage to vulnerable habitats in coastal areas and estuaries.

The adoption of electric pulses is a promising alternative. The bobbin rope is replaced by electrodes to aim at a stricter selectivity and to reduce seabed contact. Extensive commercial testing of the prototype revealed an average by-catch reduction of 35% in volume and a reduction of bottom contact by 75% while catch efficiency is preserved. Therefore electric pulse fishing has high economic potential, while reducing environmental impact. At the moment electric fishing is banned in the EU because of its unknown effects. Additional information is crucial to lift the standing ban.

The effects of those low intensity pulses on marine organisms are poorly documented. Preliminary studies indicate no immediate effects, but they lack information on the various life stages of the exposed organisms. Impact on stress levels was not investigated and exposures were limited to one specific electric pulse. Whether electric pulse fishing is ecologically justifiable in the marine ecosystem will be examined by the following steps:

1) A multifunctional pulse generator will be constructed to determine the safety margins within which no health risks occur. Electrical field parameters such as pulse shape, amplitude, duration, frequency and polarity will be tested. A founded selection of marine organisms will be subjected to homogeneous pulse fields under controlled laboratory conditions, this allows altering one pulse variable while keeping all others constant.

2) Different life stages of three invertebrate species and three demersal fish species, that often occur in the catches of the crangon and that can easily survive in captivity will be selected for the experiments. After an adaptation period the organisms will be exposed to a specific pulse characteristic combination. Some of them will be followed up and others will be immediately euthanized for the examination.

3) The impact of the electric fields will be assessed using a multidisciplinary approach with the following parameters: mortality, behaviour, reproduction, tissue lesions (macroscopic and microscopic) and stress indicators. Information on the latter is scarce and in a first series of experiments, the response to acute stress will be characterized.

The present study constitutes the essential basis of all future work in this field and will avoid applying harmful pulse fields.

# SITE FIDELITY AND MOVEMENTS OF COD (GADUS MORHUA) AT A WIND FARM USING ACOUSTIC TELEMETRY

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A substantial expansion of offshore wind farms in the Belgian part of the North Sea (BPNS) has been planned, inducing a growing interest in the possible effects of these artificial habitats on the marine environment. To date however, little research has been done to consider the possible effects on the ichthyofauna. Reubens *et al.* (in press) demonstrated that wind turbines built at sea may attract fish populations considerably, possibly related to the enhanced provision of resident food items on the turbines. However, no information is available on migration patterns or residency of fish species. This study, which is the first in the BPNS using passive acoustic telemetry, aims to improve our knowledge of cod (*Gadus morhua*, Linnaeus 1758) site fidelity and movement within a wind farm in the BPNS.

Passive acoustic telemetry is an often used technique to investigate small scale movement patterns, habitat selection and activity patterns of fish over an extended period of time (Jadot *et al.*, 2006; Collins *et al.*, 2007; Bellquist *et al.* 2008). A VR2W Positioning system (VPS) study provided by Vemco was set up. The VPS is a low cost, non-real-time underwater acoustic fine-scale positioning system. An array of 11 acoustic hydrophones was deployed at the C-Power wind farm in August 2010 to track movements of 19 cod. Data were uploaded manually from the hydrophones every 2-3 months.

The first results indicated a variable residency, depending upon the specimen. The variability in detection rates between individuals indicated that there were no consistent behavioural patterns for day/night preferences. The study however clearly revealed habitat preferences. Most detections of all specimens were closely related to the artificial hard substrates, indicating the aggregation effect of the windmill artificial reef on cod.
Recording is currently going on and longer term investigation may reveal possible seasonal migration patterns.

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# THE ROLE OF SUSPENDED PARTICULATE MATTER IN THE DISTRIBUTION AND STRUCTURE OF MACROBENTHIC COMMUNITIES IN THE BELGIAN PART OF THE NORTH SEA

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The Belgian part of the North Sea (BPNS) is one of the most well known marine areas in the world. It has a surface area of 3600km$^2$ and comprises a wide variety of soft sediment habitats. Recent studies have shown that median grain size and sediment mud content strongly correlate with the distribution of macrobenthic communities in the BPNS. However, physical variables other than those strictly associated to the sediment, might play an important structuring role as well. As such, suspended particulate matter (SPM) is considered one of the major components in the North Sea waters and its distribution and concentration is expected to structure the macrobenthos in the BPNS, in a sense that is directly linked to food availability and respiratory and filtering capacity thresholds. The aim of this research framed within the Belspo QUEST4D project, is to quantify the importance of SPM in structuring the macrobenthos in the BPNS, using existing macrobenthos and environmental data abundantly available in the BPNS. Our findings contribute to the discussion on thresholds for Good Environmental Status under the EU Marine Strategy Framework Directive.

# ON THE OCCURRENCE AND HABITAT OF *TELMATOGETON JAPONICUS* TOKUNAGA (DIPTERA; CHIRONOMIDAE) IN THE SOUTHERN BIGHT OF THE NORTH SEA

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Prior to the construction of offshore wind farms, high densities of *Telmatogeton japonicus* Tokunaga, 1933 (Diptera: Chironomidae) larvae were present on navigational buoys situated off the Belgian coast. Low numbers of pupae and adults were living on these buoys throughout the year. Soon after the installation of offshore wind farms *T. japonicus* colonised the splash zone of the new structures. The midge was also identified from the fouling assemblage on the hulls of research ships and military vessels operating in Belgian waters, which may explain how it was able to rapidly colonise the new habitats. Despite being widespread and abundant on offshore hard substrates, *T. japonicus* larvae were not found in samples taken in the intertidal and splash zone of coastal hard substrata such as groins, pilings and harbour structures. The failure of *T. japonicus* to similarly abundantly colonise these artificial constructions in Belgium may be due to more intensive predation.

# INFLUENCE OF TRACE METALS POLLUTION ON THE COMMUNITY STRUCTURE OF SOFT BOTTOM MACROFAUNA IN INTERTIDAL AREAS OF THE DAR ES SALAAM COAST, TANZANIA

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Dar es Salaam is the largest and a major industrial city in Tanzania with a population of about 2.5 million people. Due to rapid increase in population, most open spaces have been converted to residential and industrial areas, resulting in uncontrolled disposal of domestic and industrial sewage.  Because sewage is rarely treated, pollution is usually transported by rivers and streams to coastal areas. Despite efforts undertaken to assess the level of pollution in sediments and or fauna of the Dar es Salaam coast, very little efforts have been made to try to address the influence of these pollutants on faunal community structure in Dar es Salaam coastal areas. Thus the main objective of the present study is to assess the influence of trace metal pollution on the community structure of soft bottom macrofauna in intertidal areas of the coast.

Samples for this study were collected during a field trip in summer, 2010. Six stations along the coast were selected and at each station three replicate samples of sediments were collected by using a frame with surface area $0.0962m^2$ and height 0.20m. The sediments were well mixed and a small fraction of it placed in small plastic bottles for analysis of heavy metals, organic matter content and grain size distribution. The remaining sediments were sieved through a 0.5mm sieve and retained organisms preserved in plastic bottles with ethanol. Salinity of water at each station was determined by using a refractometer. The samples were transported to the Vrije Universiteit Brussel (VUB) for analysis. Currently, sediment samples are analysed in the Analytical and Environmental Chemistry Lab of the VUB and identification of macrofauna is going on in the APNA (Algemene Plantkunde en Natuurbeheer) Lab. After sediment analysis and species identifications, the total number of organisms, species number, and Shannon-Wiener diversity index will be calculated for each station. Statistical significance tests will be conducted in order to compare different stations. If the data show a normal distribution, a one way ANOVA (Analysis of Variance) will be conducted. Otherwise, a non parametric Kruskal-Wallis ANOVA by ranks will be used. A multivariate analysis of the community structure will be done with the software PRIMER 6.0. Samples will be compared using cluster analysis and multidimensional scaling (MDS). ANOSIM will be used to test for significant differences. Abiotic parameters will also be analysed with the same methods used for analysis of community structure. A BIOENV correlation analysis will be performed to determine which abiotic parameters best explain the changes in the assemblage of macrofauna.

# MARINE SCIENCE AND TECHNOLOGIES FOR HEALTHY AND PRODUCTIVE SEAS: WHAT IS THE EU DOING?

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Seas and Oceans are a critical source of food, energy, mineral and biological resources, as well as the medium for the most efficient mode for transport of goods. They are also submitted to increased pressure from human activities and climate change. Pollution, contaminants, eutrophication, destruction of habitats, acidification are profoundly affecting the marine environment. As more and more activities are developed or pushed offshore, this situation is compounded by an increasing competition for marine space.

The EU maritime policy is intended to be an integrated answer to these challenges. The Marine Strategy Framework Directive sets the ambitious objective of defining and reaching Good Environmental Status for our regional seas. We are in a situation where legislation is ahead of science. With a growing demand for food and energy and in times of financial crisis and budgetary constraints, policy makers expect marine science and technologies to provide answers and help reconcile sometimes conflicting objectives.

It is clearly a big challenge for marine science and technologies. But it is also an opportunity to be identified as a key factor to help address such societal challenges. In the face of such challenges, marine scientists might have to be more engaged with society. Marine science and technologies might not hold answers to all questions and challenges. But it is clear that without marine science and technologies, and new ways to undertake them, no solutions to our 'seas and oceans' challenges are possible.

# FATE OF THE PREDICTIONS IN GALLE-UNAWATUNA MANGROVES, SRI LANKA: A VALIDATION AFTER 10 YEARS USING SATELLITE (IKONOS) AND GROUND-TRUTH DATA

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Validation of earlier predictions is a challenging but significant contribution to ecological research. The present study tests the predications made 10 years ago by Dahdouh-Guebas *et al.* (2000) on the evolution of mangrove forest in Galle-Unawatuna, Sri Lanka. The ground inventory carried out in five Sectors covering the entire forest (Point Centred Quarter Method - PCQM) (Cintron and Schaeffer Novelli, 1984) revealed that the adult species composition is dominated by *Rhizophora apiculata*, *Excoecaria agallocha*, *Bruguiera gymnorrhiza* and *B. sexangula*, with their total density of 216-267 stems $0.1ha^{-1}$ and basal area $1.19-1.44m^2$ $0.1ha^{-1}$. However, both young and juvenile vegetation in the most Sectors was dominated solely by *B. gymnorrhiza* (128-869 stems and 356-1482 propagules $0.1ha^{-1}$). According to Dahdouh-Guebas *et al.* (2000), the transition of an *E. agallocha* forest into a *B. gymnorrhiza* dominated one or at least their co-dominance in the Sectors 1 and 2 is possible, whereas Sector 3 being dominated by adult and juvenile *R. apiculata* will persist. Overall, the possible transition to a *Bruguiera* dominated forest in Galle-Unawatuna area was forecasted. The recent decadal changes between 1994 and 2004 through the integration of IKONOS satellite imagery of 2004 with ground-truth information confirmed many of the predictions and showed dynamic shifts in young/adult vegetation by *B. gymnorrhiza*. Both *E. agallocha* and *R. apiculata* continue to be dominant in Sectors 2 and 3, although the adult turnover by *B. gymnorrhiza* has not yet occurred, probably due to the small time interval between the two investigations. Confirming in part with the earlier prediction on *R. apiculata* in Sector 3, present study also revealed the abundance of *B. gymnorrhiza* as young and juvenile vegetation. Viewing the present dynamic shifts and sheer dominance as young vegetation by *B. gymnorrhiza* with a mean height of 5.8m in most Sectors, it is still possible to anticipate the mangroves being dominated by this species, and actually now validates the predictions made 10 years ago. Because of apparent changes in the mangrove vegetation structure, it could be concluded that the 'moving mosaic' pattern of mangrove species distribution reported earlier for Galle-Unawatuna still persists.

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# THYROID HORMONE DISRUPTING CHEMICALS IN SEA BASS (*DICENTRARCHUS LABRAX*) FROM EUROPEAN COASTS

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Polychlorinated biphenyls (PCBs) and organochlorine pesticides like Dichloro-Diphenyl-Trichloroethane (DDTs), Hexachlorocyclohexanes (HCHs), aldrin, dieldrin and trace elements (Cd, Cu, Se, Pb, Zn and Hg) were analysed in the muscle of sea bass (*Dicentrarchus labrax*) sampled in coastal regions near several important European river mouths (Gironde, Charente, Loire, Seine and Scheldt). These potential endocrine disrupting chemicals were present in European coastal waters. Even if their concentrations were well below the Maximum Residue Limits set by the governments, they induced alterations of the endocrine system.

We established correlations between contaminant concentrations and effects on the thyroid system in sea bass. The contaminants induced modifications of the metabolic pathways of thyroid hormones and enhanced thyroid hormone synthesis. The activity of T4 Outer Ring Deiodinase was increased, that leads to an intensified conversion of thyroxine (T4) to its more biologically active form triiodothyronine (T3). Meanwhile, the activity of T4 sulfatation was reduced, that leads to a lowered biliary excretion of thyroid hormones. The modified metabolic pathways of the thyroid hormones can be interpreted as a tool to homeostatically maintain the thyroid hormone status. Of all tested compounds, the higher chlorinated PCBs seemed to be the most implicated in this perturbation.

The nature of thyroid hormone synthesis, signalling and regulation is highly conserved among vertebrates. Although we cannot extrapolate thyroid toxicity data directly from one species to another, these environmental factors may well affect thyroid function in other species, including humans.

*The first author dedicates this abstract to the freshly born Adèle and Côme. Congratulation to the parents!

# THE ABIOTIC GRIM REAPER: DETERMINING THE SURVIVAL OF SALT MARSH VEGETATION

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The colonization and spreading behaviour of marsh plants is strongly linked to their interactions with the abiotic environment. The outcome of these interactions forms the basis to evaluate, explain and predict distribution patterns and therefore the ability to support policy makers in the decision making processes for tidal wetland management.

The aim of this study is to evaluate the influence of abiotic parameters (hydrodynamic and sediment properties) on the survival and lateral expansion of two salt marsh pioneer plants (*Spartina alterniflora, Scirpus mariquter*), in order to find mechanistic explanations for patterns observed on a larger scale. These two species co-occur in the lower pioneer zone of salt marshes in the Yangtze Estuary, China; differing through their morphology does the native species *Scirpus mariqueter* exhibit a small and flexible habitus, the invasive species *Spartina alterniflora* a stiff and tall.

Different size classes of dispersal units (seedlings, rhizome fragments and tussocks) were planted at three different locations in the salt marsh pioneer zone of eastern Chongming Island, Yangtze Estuary, China. The planting date and period was chosen, to have a sufficient size and number of dispersal units (right after the growth spurt in early spring) on the one hand, and to include a period of high precipitation and strong winds (disturbed scenario: plum rain, around July) on the other. The locations were chosen accordingly to different sediment and hydrodynamic properties, which at the spot resulted in different patterns of the developing vegetation front.

Our results indicate the existence of a size threshold enabling these two ecosystem engineers to survive the disturbed scenario and therefore forming a selective mechanism. Further, we were confronted with an unexpected lower survival of the stronger ecosystem engineer *Spartina alterniflora*. This indicates that even though *Spartina alterniflora* constitutes the stronger ecosystem engineer (higher growth rate, earlier start-, longer vegetation period and higher sediment trapping ability) the stiffer aboveground parts and, compared to *Scirpus mariqueter* the lower investment in the belowground parts are exhibiting a serious viability disadvantage.

The implications of these findings not only help to explain the vegetation distribution patterns on Chongming Island, but also give important insights in the interaction mechanisms between plants and their abiotic environments including the perspective to explain patterns on a larger scale.

# MORPHOLOGICAL MANAGEMENT FOR THE SCHELDT ESTUARY COMBINING SAFETY, PORT ACCESSIBILITY AND ECOLOGY

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This study will investigate the possibilities to optimize and harmonize three important estuarine functions by morphological management: port accessibility, safety against flooding and ecology. With morphological management we mean the modification of bed morphology by strategic dredging and disposal of sediment, and construction, adaptation or removal of hard structures such as groynes, dike-protection measures and dikes. The aim is to identify those morphological modifications that can have a combined positive effect on flood defense, port accessibility and ecology.

The impact of different kinds of morphological modifications will be studied by hydrodynamic modeling. A new hydrodynamic Telemac 2D model of the Scheldt Estuary will be built. The Telemac model uses an unstructured grid that allows refining calculations in areas of interest and roughening the grid in other areas to increase calculation time. The bed morphology is an important input for hydrodynamic models, while the output consists of a spatial pattern of water levels and current velocities that dynamically changes with the tide. For the analysis of the model output, we will focus on a number of specific hydrodynamic parameters at specific scales, depending on whether we want to assess the impact on flood defense, port accessibility, or ecology:

1) In terms of flood defense, the study will focus on the relationships between bed morphology and simulated high water levels along the whole estuary, especially for extreme storm surges. In this way the impact of bed morphological features on tidal flood wave and storm surge propagation or attenuation are assessed.

2) In terms of port accessibility, the study will focus on current velocities and patterns and bed shear stresses that are calculated at the sills. For example, the duration of bed shear stresses that exceed the critical thresholds for erosion and sedimentation during an average spring-neap tidal cycle, is a measure for the self-eroding capacity at the bars. If necessary, the hydrodynamic computations may be coupled with sediment transport modeling for more detailed subsections of the model grid that concentrate on sills.

3) In terms of ecology, the study will focus on water depths and current velocities that are simulated on the undeep subtidal and intertidal flats. Intertidal benthic communities (and vegetation) are known to be closely related to tidal inundation, flow velocities, and sediment composition (Ysebaert et al., 2002). The water levels and flow velocities that are simulated with the hydrodynamic model will be translated into the impacts on benthic organisms by coupling with ecological models on the spatial distribution of benthic organisms in the Westerscheldt.

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# PHYLOGEOGRAPHY AND POPULATION STRUCTURE OF THE BROWN SEAWEED *DICTYOTA DICHOTOMA* (DICTYOTALES, PHAEOPHYCEAE) ALONG EUROPEAN COASTLINES

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The population structure of the common brown seaweed species *Dictyota dichotoma* along European shores was explored employing one newly developed mitochondrial marker. *D. dichotoma* belongs to a warm-temperate phytogeographic group with north-eastern extension. Its geographical distribution covers the northeast Atlantic, the Mediterranean and the Macaronesian archipelago with exclusion of Cape Verde. Analysis of a total of 281 individuals from 19 sampling locations revealed a reasonable level of polymorphism. A first exploration of the phylogeography of *D. dichotoma* is presented. Diversity was highest for the southern distribution area, but unexpectedly several private alleles were found in the northeast Atlantic. Analysis of molecular variance reveals that Atlanto-Mediterranean populations are comparable but clearly distinct from Canary Islands populations. Mismatch distribution analysis on the Atlanto-Mediterranean samples did not reject the hypothesis of sudden expansion. Our data suggest a postglacial recolonization of the northeast Atlantic from a potential southern glacial refugium located near the Iberian Peninsula. Future research aims to analyze a multilocus dataset (including mitochondrial, chloroplast and nuclear markers) by model-based phylogeography based on coalescent theory.

# LARGE SCALE EXPERIMENTAL INVESTIGATION ON WAVES-VEGETATION INTERACTION

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In their natural environment, seagrasses are exposed to wind-driven currents, waves and wave-driven currents. The effects of marine/estuarine submerged vegetation on unidirectional flows has been studied at a variety of scales in the field (Neumeier and Ciavola,2004; Prager and Halley,1999) and in laboratory flumes (Dubi,1995; Ciraolo et al., 2006), while much less is known about the interaction between seagrass and waves. Wave attenuation due to vegetation and flow conditions over and within vegetation fields have been experimentally (Fonseca and Cahalan, 1992; Ota et al., 2004; Augustin et al., 2009) and numerically (Li and Yan, 2007; Suzuki and Dijkstra, 2007) examined.

In this work, experiments using artificial vegetation have been conducted at full scale, simulating *Posidonia oceanica*, a seagrass species endemic to the Mediterranean Sea included in the Barcelona convention list of protected species. This marine plant forms large underwater meadows which are considered to be of high importance to the environmental conservation of the region that is occupied, supporting a highly biodiverse habitat and protecting from coastal erosion. Those seagrass meadows are distributed in shallow areas from the surface to a depth of 30-40m in clear conditions, colonising sandy substrata, rocky shores and old matte reefs.

The research was carried out in the CIEM wave flume at UPC (Universitat Politècnica de Catalunya) in Barcelona, Spain. Objectives of the experiments were the measurement of wave attenuation, transmission and energy dissipation over artificial *Posidonia oceanica* in intermediate and shallow waters. The effects of submergence ratio hs/D (hs=height of seagrass, D=water depth) and seagrass density (number of stems per square meter, stems.m$^{-2}$) on the above characteristics were investigated. A meadow with a total length of 10.7m was constructed by polypropylene artificial plants, selected for the most similar physical properties to real *Posidonia oceanica* leaves (Folkard, 2005). Each plant was modeled by four stripes: two stripes 55cm long and two stripes 35cm long. Two different seagrass densities, which represented densities of *P. oceanica* found in nature, and two shoot arrangements, were produced: 360 and 180 stems.m$^{-2}$ in staggered and non-staggered configuration, respectively.

Experiments with regular waves, taking measurements of wave height at different locations along the meadow (seaward, front, middle, end and shoreward of *P. oceanica* field), indicate attenuation of waves along the meadow for various wave conditions and three different submergence ratios hs/D (0.500, 0.423 and 0.323) as discussed in Stratigaki et al. (2009; 2010a; 2010b), while results for irregular waves are presented in Manca et al. (2010).

Results from spectral wave propagation over vegetation have been analyzed in the present study. Bradley and Houser (2009) found that the rate of spectral wave energy dissipation by a mixed seagrass bed under low energy conditions is frequency-dependent, and Lowe et al. (2007) found that, within a rigid canopy exposed to irregular waves, the flow attenuation varies among the different wave components. Here, spectral analysis was performed for estimating wave height attenuation and wave induced velocities and for determining the effects of seagrass density, submergence ratio on wave characteristics along the meadow.

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# STUDY OF WAVE REGENERATION BY WIND IN THE LEE OF A FARM OF WAVE ENERGY CONVERTERS USING THE MILD-SLOPE WAVE PROPAGATION MODEL, MILDwave

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The increasing energy demand, the need to reduce the greenhouse gasses, and the shrinking reserves of conventional energy have enhanced the interest in sustainable and renewable energy sources, a.o. wave energy. Many concepts for wave power conversion have been invented, a.o. Wave Energy Converters (abbreviated as WECs). In order to extract a considerable amount of wave power, single WECs will have to be arranged in arrays or 'farms', using a particular layout. As a result of the interaction between the WECs of a farm (near-field effects), the overall power absorption is affected. Moreover, the wave height behind a large farm of WECs is reduced, possibly influencing neighboring farms or other users in the sea or even the coastline (far-field effects). In general, the incident waves are partly reflected, transmitted and absorbed by a single WEC. Those devices can be distinguished in two main types: type (i) (different cases of floating bodies) and type (ii) (fixed or slack moored overtopping devices that capture the overtopped waves).

The present study refers to the development of the numerical modeling of the above mentioned wake effects of a WEC farm in a mild-slope wave propagation model, MILDwave. Here, the effect of wind input is introduced in order to investigate the effect of wave growth by wind on the reduced wave heights in the lee of single WECs and WEC farm layouts.

The numerical wave propagation model MILDwave has been recently used to study wake effects and energy absorption of farms of WECs (Beels *et al.*, 2010a; 2010b; Troch *et al.*, 2010; Baelus and Keppens, 2010) by using a sponge layer technique. MILDwave is a mild-slope wave propagation model based on the equations of Radder and Dingemans (1985) and developed by Troch (1998). This phase resolving model is able to generate linear water waves over a mildly varying bathymetry and to calculate instantaneous surface elevations throughout the domain. Wave transformation processes such as refraction, shoaling, reflection, transmission, diffraction and wave breaking can be simulated intrinsically. Other typical applications of the model are the study of wave penetration in harbours, e.g. Zeebrugge and Ostend in Belgium (e.g. Stratigaki and Troch, 2010; Stratigaki *et al.*, 2010), the harbour of Hanstholm in Denmark (Margheritini *et al.*, 2010), wave transformation studies, e.g. in the Norwegian coast (Kofoed *et al.*, 2008) and in the Belgian coast for the Thorntonbank, etc.

The physical process of wave regeneration by wind in a phase resolving model has been developed. The wakes behind single WECs and WEC farms are investigated for various wave conditions under the effect of wind. The evolved technique is applied on farms composed by hypothetical WECs with basic dimensions 36mx36m exhibiting a certain amount of absorption and on WECs known as Wave Dragons. Results in the lee of WEC farms when the wind effect is incorporated confirm that the available wave power increases when wind is applied. Moreover, taking into account wave regeneration by wind represents in a better way the actual wave and wind conditions in the field.

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# POPULATION GENETIC DIFFERENTIATION OF MUD CRAB, *SCYLLA SERRATA* IN INDONESIA

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*Scylla serrata* is a commercially important mud crab species that is widely distributed and commonly found in most estuarine habitat of Indonesian coastal waters. The plaktonic larval phase suggests high dispersal potential and possibility of extensive gene flow between population on a geographic mesoscale. This study investigates the phylogeographic distribution of *Scylla serrata* in Indonesia and further aims to compare its genetic population structure and connectivity pattern throughout Indo-West Pacific based on the previous existing studies. The samples used in this study were collected from several local fish markets in Indonesia from July to September 2010. Those selected sampling locations were namely: Sungai Liat (Sumatera Island), Pontianak (Borneo Island), Samarinda (Borneo Island), Labuan (Java Island), Tangerang (Java Island), Cirebon (Java Island), Pelabuhan Ratu (Java Island), Brondong (Java Island), Sidoarjo (Java Island), and Mataram (West Nusa Tenggara Island) (n = varies from 11 to 20). One cheliped was taken from each individual crab sample, then preserved in 95% ethanol solution and stored at 6˚C.  Mitochondrial DNA cytochrome oxidase subunit I (COI) gene will be used as a gene marker in this study. Molecular genetic analysis will be conducted in  Plant Biology and Nature Management (APNA) Laboratory at the VUB Etterbeek campus from October 2010 to February 2011.

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# LATE HOLOCENE CLIMATE VARIABILITY AS RECORDED IN AN ISOLATION BASIN IN THE LÜTZOW HOLM BAY REGION, EAST ANTARCTICA

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The past two millennia are of particular interest to the understanding of the Earth's Climate System, because the boundary conditions of the climate did not change dramatically. The Northern Hemisphere (NH) climate is in that timeframe characterized by three main periods of climate change, namely the Medieval Warm Period (MWP; 1100-700 yr BP), the Little Ice Age (LIA; 500-100 yr BP) and the recent temperature increase. For the Southern Hemisphere (SH), the occurrence and timing of these climate anomalies are however less consistent (Verleyen *et al.*, in press), probably due to relative paucity of proxy data (Mann *et al.*, 2008). We aim to reconstruct climate variability during the past two millennia in the Lützow Holm Bay region, East Antarctica by means of a multi-proxy analysis on lake sediments. The distinct zones in the cores, based on diatom, pigment and lithostratigraphic analyses, correspond to a shift from marine to lacustrine conditions with a clear transition zone in between. These different environmental conditions provide information on coastal oceanographic conditions between 1975 and 1280 cal. yr BP, and on limnological conditions between 1155 cal. yr BP and present. The marine part of the sediment cores likely reflects ecological changes such as a declining water depth causing changes in light climate and sea ice dynamics as a result of lake isolation rather than climate variability. Between 640 and 560 cal. yr BP, the relatively higher chlorophyll and carotenoid concentrations and higher diatom productivity, are linked to a higher primary productivity and hence point to the presence of a warmer period. This warm period shows a delayed response by c. 150 years compared to the NH MWP, which confirms the simulations by Goosse *et al.* (2004). There is no evidence for a LIA-like event in this region, similar to previous findings in East Antarctica (Verleyen *et al.*, in press). The data from the upper centimeters of the core point to only very small direct and/or indirect changes in snowfall during the recent decades and are in agreement with a relatively modest warming in East Antarctica, probably related to a buffering effect of the ozone hole (Marshall *et al.*, 2009). We conclude that there still is a strong need for additional well-dated high-resolution records to test the apparent interhemispherical differences in paleoclimate variability.

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# EVALUATING THE RIVER DE-EUTROPHICATION GAIN ON THE MAGNITUDE OF *PHAEOCYSTIS* BLOOMS IN THE SOUTHERN NORTH SEA BETWEEN 1985 AND 2005: A MODEL STUDY

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High-biomass blooms of undesirable Phaeocystis colonies occur each spring in the eutrophied eastern English Channel and Southern North Sea area (including the Belgian coastal zone, BCZ) as a result of excess river nutrient loads. Over the last 60 years, nitrogen (N) and phosphorus (P) delivery to the coastal sea has shown up and down variations related to human activity. After 1950, an accelerated increase of nutrient loads was reported due to a combination of increased human population, socio-economic development and intensive agriculture that cumulated in the mid-1980s (eutrophication period). After this period, nutrient reduction measures were slowly implemented (de-eutrophication period), leading in particular to an important decrease in P loads subsequent to the removal of phosphates in washing powders. Today the P delivery has decreased to earlier values of 1960 while the N decrease is less important leading to an imbalanced N:P enrichment of the receiving coastal waters, yet characterized by elevated spring blooms of Phaeocystis colonies.

Biogeochemical models which are based on chemical and biological principles and describe ecosystem carbon and nutrient cycles as a function of environmental forcing are ideal tools to investigate the link between phytoplankton blooms and changing environmental conditions. An updated version of the existing MIRO model (Lancelot et al., 2005) describing diatom/Phaeocystis blooms and related nutrient cycles in Phaeocystis-dominated ecosystems has been implemented in the Eastern English Channel and Southern North Sea over the 1985-2005 period to investigate the link between the magnitude of Phaeocystis colony blooms and the decrease in nutrient loads. The analysis of model simulations focuses on the BCZ for which survey data are available for the 1988-2000 period. The maximum cell abundance reached by Phaeocystis in the BCZ shows no clear trend, being modulated by the up and down fluctuations of available N stocks. On the contrary a 35% decrease of the bloom duration is simulated for the period and is correlated with the decrease in P loads. These results suggest that a significant decrease in the blooms of this undesirable species would not occur without a further significant decrease in N loads. Accordingly, one can expect these significant changes to be delayed by the diffuse nature of the main N source, i.e. NO3 (mainly resulting from agricultural practice) which can be captured in water tables and then progressively restored with a memory effect.

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# BIO-ORACLE: A GLOBAL ENVIRONMENTAL DATASET FOR MARINE SPECIES DISTRIBUTION MODELING

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The oceans harbor a great diversity of organisms whose distribution and ecological preferences are often poorly understood. Species distribution modeling (SDM) could improve such knowledge and inform marine ecosystem management and conservation. Although marine environmental data are available from various sources, there are currently no user-friendly, high-resolution, global datasets designed for SDM applications.

We present Bio-ORACLE (Ocean Rasters for Analysis of CLimate and Environment), a global dataset consisting of 23 geophysical, biotic and climate rasters. This dataset was compiled using global coverage data, e.g. satellite based and *in situ* measured data, representing various aspects of the marine environment relevant for species distributions. The rasters were assembled at a resolution of 5 arcminutes (ca. 9.2 km) and a uniform landmask was applied.

The utility of Bio-ORACLE was evaluated by maximum entropy SDM of the notorious invasive seaweed *Codium fragile* subsp. *fragile*. This allowed us to predict the distribution of the species, to assess the predictive power of the distribution model and to illustrate the potential of the data package for SDM of shallow-water marine organisms in general.

The high predictive success of the presence-only model of *Codium fragile* subsp. *fragile* shows that the information contained in Bio-ORACLE can be informative about marine distributions and permits building highly accurate species distribution models. In conclusion, we recall that the availability of this global environmental data package has the potential to stimulate marine SDM.

# DISTRIBUTION AND BIOACCUMULATION OF MICROPOLLUTANTS IN AN ESTUARINE ECOSYSTEM

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Due to anthropogenic activities trace metals and organic micropollutants have been introduced in the aquatic ecosystem where they can accumulate and persist for many years. Those pollutants can become available for uptake by organisms and cause  toxic effects. Persistent pollutants have the ability to be transferred through food chains and even become a threat for human health.

Bioaccumulation of chemical substances depends on two main factors. First, pollutants must be available for uptake by organisms. This bioavailability is strongly influenced by the chemical properties of the pollutant, by several physical and chemical processes and by environmental characteristics of the surrounding water and sediment, which can be highly variable in certain environmental systems like estuaries. These characteristics determine the chemical speciation and distribution of pollutants over the environmental compartments.
Secondly, bioaccumulation is influenced by the exposure route. Which exposure route is important for an aquatic organism is highly dependent on its physiology, habitat preference and feeding strategy.

This project aims to determine the exposure route most responsible for bioaccumulation in organisms with different feeding strategies and trophic level, and this for various pollutants. Therefore we conducted passive as well as active biomonitoring studies in the Scheldt Estuary. We related accumulated levels of micropollutants (trace metals, organic pollutants) in caged and free living animals to levels in environmental compartments (water, suspended particulate matter, pore water, sediment).

# IMPACT OF BIVALVES ON CARRYING CAPACITY THROUGH NUTRIENT FEEDBACKS

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Bivalves are key species in many estuaries around the world, because of their large filter feeding capacity (Dame & Prins, 1998). They are also widely cultured for food. Ecological impacts can be analysed in terms of ecological carrying capacity. This refers to the maximum level of (in this case bivalve) production that an ecosystem can sustain without unacceptable ecological impacts (McKindsey *et al.*, 2006). The "acceptability" of impacts is determined within the political domain, but the role of science is to provide insight.

Bivalve filter feeders can influence the ecosystem in various ways. Besides removing plankton from the water column by filter feeding, they may also function as a feedback mechanism in terms of nutrient recycling, stimulating growth of particular functional groups (Newell, 2004). For example in the Netherlands, in a study by Prins and Smaal (1994) wild mussel beds in the Oosterschelde estuary increased nutrient availability in summer when phytoplankton was nutrient-limited. In a recent study using a modelling approach, Guyondet *et al.* (2010) also found that mussel culture may be able to alter ecosystem structure through changes in nutrient cycling. However, knowledge gaps remain, for example with regard to remineralisation rates of mussel faeces and pseudofaeces. The aim of this PhD research proposal is to improve understanding of the role of bivalves in nutrient cycling.

This subject is highly topical because of a new development in the Dutch mussel industry. The industry is currently undergoing a transition whereby wild seed catch is gradually being replaced by seed collector systems. These comprise seasonally introduced artificial substrate in the water column which is then colonised primarily by mussels. The mussel seed is harvested at the end of the season and entered into the regular culture cycle. The additional mussel load seasonally imposed on the ecosystem presents questions with regard to its effects on carrying capacity by influencing nutrient fluxes and stoichiometry. The seed collector systems in the Oosterschelde estuary and the Dutch Wadden Sea will be used as the model for this study because of their novel ecological significance, and their novel properties in terms of (age) structure and seasonality. Moreover, the peak of their activity is in summer when the impact of nutrient release on primary producers may be greatest (e.g. Prins and Smaal, 1994).

This study will culminate in a nutrient budget for seed mussel collector systems, which can be used in the assessment of carrying capacity impacts. Elements contributing to this budget include investigation of the growth of mussels and other life on the collectors, effects of crowding, and the fate of excretion products of the mussels. One of the main challenges will be the integration of levels of scale, from individuals to the ecosystem.

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# POTENTIAL IMPACTS OF SEA LEVEL RISE ON MANGROVES IN CA MAU CAPE, SOUTH VIETNAM: AN APPLICATION OF REMOTE SENSING TECHNIQUES FOR ASSESSMENT

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In Vietnam, the Ministry of Natural Resources and Environment reported that projected sea level is expected to rise about 30cm and 75cm respectively in 2050 and 2100 (MONRE, 2009). In a comparative analysis, the World Bank concluded that Vietnam ranks among the top 5 countries that will experience the adverse impacts of sea level rise (Susmita *et al.*, 2007). Being aware of climate change impacts, especially sea level rise, the Government of Vietnam approved a 'National target program to respond to climate change' (NTP) (NTP, 2008). One of the strategic objectives of the NTP is to assess climate change impacts on sectors and regions in specific periods and to develop feasible action plans to efficiently respond to climate change in the short-term and long-term to ensure sustainable development of Vietnam. Within the context of sea level rise due to climate change, Ca Mau cape is considered as the most vulnerable place in Vietnam. In order to assist the province in the development of their action plan to respond to climate change, this study will play an important role in attempts to provide scientific implications and appropriate solutions for integrating climate change issues into the action plan toward sustainable development.

Based on aerial and satellite images this study tried to estimate the changes in the sea level and the impacts on mangrove biodiversity and local communities in the mangrove area located in the Ca Mau cape, a natural mangrove ecosystem with high value of biodiversity, socio-economic importance and scenic beauty. Geographic Information Systems were used to make forecasts about the proposed scenarios on sea level rise and to identify critically endangered areas. Major technical constraints had however been foreseen: quality of images, spatial and temporal coverage of images, insufficient topographical data and basic projection opportunities of sea level data in combination with climate models.

The sea level of Ca Mau Cape has already risen with more than one meter during the last 60 years. Since the area is under the influence of both the East Sea and the Gulf of Thailand, a combined influence of erosion and accretion events causes a strong dynamic evolution in the mangrove forest. The erosion rate is about 22.2m per year while the accretion occurs with a rate of 47.1m per year. Projections of the difference in sea level between the past and the present, towards the future indicated that sea level in 2090 will increase 57cm, 64cm and 86cm respectively in the low emission scenario B1, medium emission scenario B2 and high scenario A1FI (relative to the period of 1980-1999). The results of the projections for the migration trends of the mangrove area in the future show that Ca Mau Cape will gain 14.2km², 16km² or 21.5km² mangrove forest depending on the emission scenario (B1, B2 or A1FI respectively). The interpretation of this result must however be combined with the further research on the amounts of mangrove area that will inundate when sea level will rise.

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# ASSESSMENT OF PRIMARY IMPACTS OF GLOBAL CLIMATE CHANGES AT THE BELGIAN PART OF THE NORTH SEA

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The North Sea ecosystem is characterised by a high productivity and highly diversified habitats but also by heavy ship traffic, intensive fishery, tourism and a number of offshore activities. This intensive use has as a consequence that the vulnerability of the ecological, social and economic community is high for climate changes. This calls for a sustainable approach when addressing climate change issues in our North Sea.

In the framework of the CLIMAR project, financed by the Belgian Science Policy Office, the primary and secondary impacts of the climate changes for the Belgian Continental Shelf are being assessed on the different socio-economic activities (harbour activities, tourism, wind energy, sand mining, etc…). Different adaptation strategies are being developed, which will be relevant on medium term (2040) or long term (2100) time scales.

In the first phase of the research, the primary effects of climate changes were determined. These results are presented here.

Time series of water level at Ostend from 1927 to 2006 were analysed. A sea level rise of 1.69mm/year was found, which is higher than the values previously reported. These time series further indicate a possible sea level rise acceleration over the last decade(s).

Measurements of significant wave height (1978 till 2007) and of wind speed (1980-2007), together with meteorological forecasts of the Norwegian Meteorological Institute from 1955 till 2006, were analysed. No clear trend was found in the data. A small decrease might be observed in the significant wave height at Westhinder (offshore the Belgian coast) but the time series are too short to give conclusive answers. Also the wind speed for the Belgian coast show a small decrease, certainly since 1990-1995. This seems to agree with recent research, showing an indication of decrease in storminess for the southern North Sea.

Analysis of sea temperature data from the World Ocean Database 2005 show an increase of sea water temperature varying between 0.023°C/year in the North to 0.053°C/year in the southern and central North Sea.

Based on a literature study, the data analysis and climate change scenarios set up by neighbouring countries, different climate change scenarios were set up for the Belgian Continental Shelf, ranging from moderate scenarios, with a sea level rise of 60cm, expected by 2100, to extreme, unrealistic scenarios with an expected sea level rise of 2m by 2100.

Finally, hydrodynamic models, wave models and sediment transport models were used to evaluate the impact of the climate change on different parameters, e.g. the maximum current speed in front of the harbours, the mud deposition in the fair channels or the wave attack on the beaches. For the different climate change scenarios, the models are being used to assess the impacts. Model results show that the impacts can be considerable.

# THE USE OF BENTHIC INDICATORS FOR ENVIRONMENTAL STATUS ASSESSMENT

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The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) are the European umbrella regulations for water systems. It is a challenge for the scientific community to translate the principles of these directives into realistic and accurate approaches (Van Hoey *et al.*, 2010). The ecological concept behind both directives is, in principle, very simple, and consists of comparing the current state of an area with that which would be expected under minimal or sustainable human use of that area and, in case of degradation, intervening to bring it back to the desired good status. To accomplish this environmental status evaluation, following principles were essential: the ecosystem-based approach, the development of indicators, de definition of 'pristine' or sustainable conditions, the detection and quantification of pressures and the development of monitoring programs. In Van Hoey *et al.* (2010), the strengths and weaknesses of these principles were discussed from benthic research point of view. Especially for benthic invertebrates, the accumulated knowledge is extensive, largely reflecting a long-standing preoccupation in benthic research with approaches to effective environmental assessment.

Due to the spatial extent of European marine areas and ecosystem complexity, the scope for identifying universal bio-indicators is limited. The implementation of well founded sampling strategies related to habitat types as well as spatially definable pressure gradients is an indispensable prerequisite for a reliable status assessment. The indicators deliver evidence-based information, but there are shortcomings and caution is always required concerning their use in environmental assessment. Therefore, expert involvement, beside objective approaches, in filling in these principles seems of vital importance.

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# IMPACT OF DIFFERENT FUNCTIONAL CRAB GROUPS ON PROPAGULE RECRUITMENT AND MANGROVE FOREST STRUCTURE

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The structure of the mangrove ecosystems is affected by various abiotic factors (temperature, salinity, nutrient availability, tidal range, topography, etc.) and biotic factors (intra and inter-specific competition, fauna, anthropogenic pressure etc.) (Lee, 1999b). Faunal impact is largely due to the crab activities (Cannicci *et al.*, 2008). Some authors refer to 'crabs' as mangrove ecosystem keystone species (Smith III *et al.*, 1991; Schories *et al.*, 2003). They contribute actively to the forest structure through two activities: the activity of 'engineering' (Bartolini *et al.*, 2010) and herbivory behaviour (Schories *et al.*, 2003). Burrows and galleries in hypoxic or anoxic soils allow a better soil oxygenation and increase the bioavailability of nutrients such as nitrogen and phosphorus (Smith III *et al.*, 1991). In addition, some families of herbivorous crabs are known to be a threat to natural and artificial mangrove regeneration (Dahdouh-Guebas *et al.*, 1998) and a regulator of competition in high stand density areas (Bosire *et al.*, 2005), both through consumption of mangrove propagules and juveniles. We focus this ongoing study on the interaction between herbivorous crabs (Sesarmidae), detritivorous crabs (Ocypodidae) and mangrove propagule settings and growth abilities in Gazi Bay, Kenya. Two hypotheses are central: herbivorous crabs influence the structure of mangrove forests by selecting and consuming propagules. Scavengers and herbivorous crabs lead to biogeochemical changes by the construction of burrows and the recycling of organic soil matter. These biogeochemical changes will profoundly influence the structure and the health status of the mangrove forests. We found that herbivorious crabs are not homogeneously distributed and that their distribution is correlated with vegetation structure. Although propagules pulled into burrows are considered predated and lost, we observed that part of these buried propagules did germinate after two days under *Avicennia marina* cover and after 6 days under *Ceriops tagal* cover. We found that one propagule out of five on average germinated despite its being below-ground. This prompts us with the question whether or not predation can also be a positive regulator of mangrove regeneration, rather than a negative.

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# BACTERIAL COMMUNITY STRUCTURE AND POTENTIAL CONTROLLING FACTORS ALONG A WATER COLUMN STRATIFICATION GRADIENT DURING MULTI-ANNUAL COCCOLITHOPHORID BLOOMS

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Future increases in sea surface water temperature are expected to have direct and indirect effects on the functioning of the biological pump in the world's oceans. Because marine microbial communities drive biogeochemical cycles of global importance, a better knowledge of the structure of these microbial communities, their interactions, and the factors controlling them is needed to understand ecosystem function and how environmental changes will affect it.

Our study is the first comprehensive, multi-annual account of the dynamics of bacterial community structure during spring coccolithophorid blooms along the continental shelf break of the North East Atlantic Ocean. We investigated bacterial community structure using DGGE fingerprinting and clone libraries from samples from different water layers, stratification degrees, biochemical composition, productivity levels, and phytoplankton regimes during three consecutive spring phytoplankton blooms. A combination of ordination, discriminant function analysis and distance-based partitioning of variation was used to untangle physicochemical factors structuring the bacterioplankton community which often relate to those that shape the phytoplankton assemblage.

Water column stratification was identified as the main factor shaping the bacterial community structure and, together with environmental variables such as TEP and dissolved silicate concentration, total alkalinity anomaly and water oxygen saturation, as well as the phytoplankton composition, accounted for the observed inter and intra-annual differences in bacterioplankton assemblages. The overall inter-annual similarity of bacterial community composition substantiates the notion of a certain predictability of bacterial assemblages, in the same way size structure and succession patterns of phytoplankton functional groups can be linked with particular environmental settings.

Future increases in sea surface temperatures are expected to lead to increased stratification, and will therefore, as our results suggest, strongly affect bacterial community composition. Linking the latter with the functioning of the biological pump remains one of the key issues to be resolved in order to more accurately predict the effect of climate change on the functioning of the world's oceanic ecosystems.

# IMPLEMENTATION OF A SUSTAINABLE PROJECT IN THE TANBI WETLAND COMPLEX, BANJUL (THE GAMBIA)

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The aim of this on-going study is creating a design for a boardwalk that is part of an ecotouristic project in the Tanbi Wetland National Park (TWNP). This mangrove area is located adjacent to the capital of The Gambia, Banjul. The nature reserve was listed as a Ramsar site in 2007 (an "Area of International Importance") but it is under great human pressure, such as through the dumping of municipal waste in the mangrove swamps, the erosion of banks by speedboats from tourist water sports, etc. In this way, the mangrove habitats are degraded and can even be destroyed.

The entire project is supported by the City of Ostend, which has a city link with Banjul since 2003. As the City of Ostend co-finances the entire project, a cost calculation will be carried out.

The boardwalk project aims at creating awareness, both for the people of Banjul and for tourists visiting Gambia. Eco-education also plays an important role in this process; local students can visit the TWNP and learn about the mangroves and their importance. The TWNP is located close to hotels and tourist areas in Banjul. The local boats could be used for excursions in the small creeks, combined with the boardwalk-excursion. Guided tours by local inhabitants make visitors aware of the problems affecting the nature reserve.
The project includes a pedestrian walk-on bridge with a length of approximately one kilometer, two observation towers that can be used by birdwatchers, a platform where oyster women can prepare local products for visitors, a pontoon for moor canoes, etc. Another proposition is to build an open-air museum, the "Sea Life Center", located in seven different huts across the entire boardwalk. It portrays the different habitats and their ecological and socio-ecological components present in and around the mangrove.

During the calculation of the wood structure the *Belgian standards* (NBN) and *Eurocode* (EC) were followed where possible. The *Australian standards* (AUS) were also consulted, in contrast to the Belgian standards, they have standards specifically for boardwalks. These standards are used when

designing constructions. Design values were obtained from tests carried out according to the standard. We drew every boardwalk model using *Google Sketchup Pro 7.1*, a 3D software tool.

During a 5-week stay in Banjul in January-February 2011, the mangrove area will be mapped using a surveying device. The *Trimble Pathfinder Pro XRT* equipped with an *OmniSTAR* license allows measurements with an accuracy up to 20 centimeters. Based on the maps that were made, implementation plans are composed, making construction possible by the inhabitants of Banjul.

# MOLLUSCS IN THEIR ELEMENT? AN X-RAY VIEW INSIDE

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Some mollusc species like oysters and mussels can have a wide geographic distribution. As such different populations of these species are exposed to different types of environmental stress: pollution, temperature changes, eutrophication… The physiology of molluscs is an important factor determining the toxicity of different pollutants acting on the ion regulation. The distribution of different chemical elements within organisms can be visualised and quantified at a very high spatial resolution with state of the art micro-X-ray fluorescence (XRF) techniques (De Samber *et al.*, 2010).

In this study, these methods were applied to determine the (trace) element composition of larvae of the Pacific oyster *Crassostrea gigas*, exposed for 48h in copper spiked or clean seawater. The results demonstrate and visualize significant changes in the ion regulation of this species. These preliminary results indicate that this technique can be used to assess the homeostatic status of marine species under stress.

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# SELF-SAMPLING: A STEP IN THE RIGHT DIRECTION?

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Most of the data on commercial catches, landings as well as discards, are collected during commercial surveys by seagoing observers. However, they can collect those data only during a few trips a year onboard of a few vessels. Fishermen on the other hand, can provide haul-based data on catch compositions and discard quantities or can collect biological information throughout the whole year. Thus, a Fisheries Science Partnership (FSP) programme i.e. a self-sampling programme, based on a strong co-operation between the scientists and the fishing sector, would allow a serious increase in spatial and temporal coverage and reduce problems of very large raising factors based on scientific observer data only. In other words, self-sampling could provide valuable information on the abundance and distribution of commercial species and improve the quality of the data available to scientists and managers. The ultimate objective of this FSP programme is two-folded: on the one hand to contribute to more accurate stock assessments and advice by ICES and on the other hand to complement and strengthen fisheries science programmes and engage the industry in the collection of fisheries data. On request and initiative of the Belgian fisheries sector, the Institute for Agricultural and Fisheries Research (ILVO), in close cooperation with the fisheries sector, started a self-sampling programme to identify the impact of the Belgian beam trawl fishery on the Celtic Sea (areas VIIf and VIIg) cod stock. Fishermen of several vessels are participating in the pilot project on a voluntary basis. The skippers and crew were trained by scientists of ILVO to follow a standard sampling protocol for collecting and recording data. This FSP Celtic Sea cod programme aims to gather robust, accurate and detailed information on catches (landings and discards) of cod and to promote a better relationship between scientists and fishermen.

# ECOLOGICAL MONITORING OF THE BEACH NOURISHMENT PROJECT LOMBARDSIJDE

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During the last decade, climate change has become a much debated topic. An increase in storms and rising sea levels are particularly problematic for low lying countries like Belgium. Moreover, every kilometer of our coastline is intensively used and needs protection against coastal erosion and flooding. Despite intensive monitoring and maintenance actions, some parts of our coastline do not achieve the required safety level. Soft coastal defence techniques like beach nourishment might help solve the problem. Beach nourishment consists of mechanically or hydraulically placing sand directly on top of an existing beach. As it safeguards the natural dynamics of the coast, beach nourishment has rapidly become a widely applied protective measure in Europe. However, its effect on the soft-sediment macrobenthos remains unclear. Macrobenthos are classified as the seafloor inhabiting benthic forms larger than one millimeter. These organisms play a key role in the wider beach ecosystem. They make up a large part of the diet of intertidal birds and fish and they act as good indicators of pollution and stress. Our research focuses on Lombardsijde beach as it was nourished from March until September 2009. Approximately 650,000m³ of sand was deposited on top of the beach over a distance of around 1,200m. The sand (grain size: 200-250μm) originated from the new fairway to Oostende.

The scientific evaluation of ecological effects of any anthropogenic influence can only be performed by comparing the status of the environment before (t0 situation) and after (t1 situation) the influence has taken place. The soft substrates of Lombardsijde beach have been and are being extensively monitored (Welvaert, 2005; Van Ginderdeuren *et al.*, 2007; Vanden Eede *et al.*, 2008; Vanden Eede *et al.*, 2010; Vanden Eede *et al.*, 2011, in progress). To distinguish the effects of beach nourishment from those of natural variation, we include reference sites in our studies. These sites have comparable species composition and physical-chemical characteristics to the impact sites but are located out of reach of the investigated anthropogenic influence. The reference site for Lombardsijde beach is the beach in front of Nieuwpoort-Bad.

The 2009 study (Vanden Eede *et al.*, 2010) showed no notable changes on Lombardsijde beach over the period 2006-2009. We did find a rougher median grain size during autumn 2009 compared to previous years. The beach profile of Lombardsijde was altered in such a way that it now resembles the one of Nieuwpoort-Bad almost perfectly. No other distinct negative trends for the macrobenthos were found. The nourishment was in full progress during the 2009 study. A clear overview of the ecological situation after completion of the works (t1 situation) remains to be obtained. Further research is needed to discover the real effects of the Lombardsijde beach nourishment on macrobenthos (Vanden Eede *et al.*, 2011, in progress), especially since the aim of the Flemish government is to declare part of Lombardsijde beach as a nature reserve for both birds and seals.

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# CHEMICAL WARFARE BETWEEN MICROALGAE: BIOGENETIC BROMINE CYANIDE (BRCN) CONTROLS BIOFILM FORMATION AROUND A MARINE BENTHIC DIATOM

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Biofilm formation in marine habitats is a ubiquitous process and nearly all surfaces are covered with a complex community. If technical surfaces such as ship hulls are concerned in this process, termed as fouling, it can cause severe economic damage and therefore intense efforts are undertaken to control such processes (Yebra *et al.*, 2004). Among the early settlers, microalgae play a key role in the development of biofilms and especially diatoms are able to settle on even the most fouling resistant surfaces. Fundamental processes during marine biofilm formation might be regulated by chemical factors released by settling organisms in this habitat. Especially around benthic microalgae fine-scale spatial variations in species composition are often observed (Saburova *et al.*, 1995). This spatial distribution of species is characterized by non-overlapping areas of maximal density and negative correlation of species densities (Saburova *et al.*, 1995) Since these occur even in the absence of abiotic heterogeneity, species interactions mediated by allelochemicals might play a key role.

We demonstrate that a marine benthic diatom biosynthesizes and exudes novel halogenated allelochemicals with strong effects on naturally co-occuring diatoms. Using a bioassay-guided approach, we demonstrate that the diatom *Nitzschia* cf *pellucida* produces a diverse mixture of iodinated and brominated metabolites including the new natural products BrCN (Bromine cyanide) and ICN (Iodine cyanide) which exhibits pronounced allelopathic properties. Allelopathic activity is highest shortly after daybreak and the labile compound obviously acts as short term signal, leading to "cleaning" daily events around the algae which suggests a highly effective novel strategy for biofilm control. We show that the production of all halogenated metabolites detected is hydrogen peroxide dependent and therefore link BrCN and ICN production to haloperoxidase enzymes (Butler and Sandy, 2009). Halogenated low molecular weight hydrocarbons are ubiquitously released from marine micro- and macroalgae (Sturges *et al.*, 1992; Paul and Pohnert, 2011) but their function is often controversially discussed. Micro and macroalgae contribute significantly to the atmospheric halocarbon budget and local maxima are often observed in coastal regions. Here we provide a novel explanation for the poorly understood role of halogenated low molecular weight molecules from microalgae (Sturges *et al.*, 1992).

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# CREATING A REGIONAL, MULTI-YEAR ARCHIVE OF SATELLITE-DERIVED SEA SURFACE TEMPERATURE, CHLOROPHYLL A AND TOTAL SUSPENDED MATTER CONCENTRATIONS

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For the JELLYFOR project  a project aimed at setting up jellyfish forecasting based on in situ and remote sensing data  existing BELCOLOUR procedures were adapted to process a large number of OceanColor MODIS Aqua L2 files, for custom regions of interest.

Three regions were defined for JELLYFOR: the Belgian Coastal Zone (BCZ, *51˚51'N, 1˚48'E ; 51˚48'N, 4˚00'E*), the Catalan Coast (CTL, *40˚08'N,0˚36'E ; 42˚07'N, 3˚29'E*) and the Northern Irish Coast (NOI, *54˚15'N, 5˚21'W ; 55˚37'N, 8˚53'W*). All MODIS Aqua images for a seven-year period (01/01/2003 – 31/12/2010) were processed for these regions, creating a dataset containing chlorophyll *a* concentration (chl), sea surface temperature (sst) and total suspended matter concentration (tsm). In theory, for each location one MODIS image is on average available every day, but cloud cover influences the usefulness of the data archive, especially on short timescales.

Daily bins – composites that combine the data of best available quality for one day – were averaged per month.  Next, a climatological mean was created by combining monthly bins over the seven years. By comparing the climatological mean with the data from each year individually, anomalies such as high summer temperatures and early chlorophyll *a* peaks can be detected.

In BCZ, well-known patterns are found in the dataset: the spring phytoplankton bloom, the faster increase and decrease of sst in the shallow near-coast zone and the onshore-offshore gradient of tsm, with a concentration maximum during winter. By analyzing time series and monthly maps, it can be concluded that MODIS has a detection limit for chlorophyll *a* concentrations in turbid waters.

A latitudinal increase of sst is found in CTL. A shelf edge front, caused by salinity differences between coastal and offshore waters (Sabates and Pilar Olivar, 1996), can be observed in the chl, sst and tsm datasets. Associated with the front is the colder, less saline Catalan Current (an extension of the Ligurian Current), which can be traced along the shelf edge. For chl and tsm, high concentrations are found near-shore, and low concentrations offshore, especially during summer.

In the chl, sst and tsm datasets of NOI, a front can be observed, situated approximately at Malin head, where colder and less saline waters from the Northern Channel of the Irish Sea meet the warmer and more saline waters of the North East Atlantic (Gowen *et al.*, 1998). The differences between the two water masses are most clear in summer for sst, and in winter for chl and tsm.

In a multi-year MODIS dataset, known oceanographic features are apparent. Using monthly composites, the inter-annual changes and the evolution throughout the year can be analysed. The methodology was created generically, so a similar archive can easily be created for any region in the world. The archive can be used for a wide range of applications in marine biology, sediment transport, coastal management, etc. In conclusion, a long-term remote sensing dataset is a useful tool for understanding the oceanography of any region, be it a well-studied or a relatively unknown one.

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# ASSESSING PALEOTEMPERATURE AND SEASONALITY DURING THE EARLY EOCENE CLIMATIC OPTIMUM (EECO) IN THE BELGIAN BASIN BY MEANS OF FISH OTOLITH STABLE O AND C ISOTOPES

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During its past, Earth has known long-lasting periods characterized by a significantly warmer climate and higher $CO_2$ levels compared with today. The nature of these so-called greenhouse periods has become a major research domain within the field of paleoclimatology. Interestingly, according to recent research the early Paleogene greenhouse period appears to be highly variable, challenging paleoclimatologists to modify their current knowledge about the functioning of the climate system. The Belgian Basin, part of the southern North Sea bight, comprises a fairly continuous Paleogene sedimentary record. It is dominated by mid-shelf to coastal fossiliferous sands and clays, which have suffered only minor deformation. This marginal setting presents an opportunity to link deep-sea and continental paleoclimate records, increasing our understanding about the impact of climate changes on local marine ecosystems.

The use of fish otoliths – calcareous ear stones comprising seasonal growth rings – as (paleo)environmental indicators is still increasing. In our study, otolith $\delta^{18}O$ signatures are measured to assess their potential as an early Paleogene paleotemperature and paleoseasonality proxy. The $\delta^{18}O$ of otolith aragonite precipitates in equilibrium with sea water temperature, although this relationship seems to be taxon-specific. Otoliths of several levels and locations within the early Eocene climatic optimum (EECO) interval have been polished, drilled with a micromilling apparatus for bulk and incremental microsamples, and subsequently analyzed by isotope ratio mass spectrometry. The selected species are non-migratory bottom-dwellers belonging to the families Congridae and Ophidiidae, and hence should reflect bottom water temperatures. To calculate temperatures, the paleotemperature equation of Thorrold *et al.* (1997) was used. The isotopic composition of the ambient sea-water $\delta^{18}O_w$ was chosen at -1.0‰, taking into account current knowledge about the isotopic composition of northeastern Atlantic ocean waters during the EECO.

A cross-plot of bulk otolith $\delta^{18}O$ vs. $\delta^{13}C$ results shows significant offsets between both families used (10°C when expressed in temperature). Ophidiid data probably represent true bottom water temperatures of the Belgian Basin. The more negative Congrid data on the other hand, suggests that this taxon probably thrived in more coastal waters, influenced by freshwater influx. Based on Ophidiids, the mean annual temperature (MAT) of the EECO is calculated at 27.5°C, which is in line with other proxy results. However, variations in MAT up to 6°C suggest a more pronounced expression of climate variability in mid-latitude marginal basins than in tropical areas. Incremental analyses revealed a ~9.5°C mean annual range of temperatures, similar to modern seasonality in the same region. These results suggest that otoliths from early Paleogene mid-latitude marginal marine environments such as the Belgian Basin are well suited to infer paleoclimate variability at seasonal and long-term time scales.

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# THE IMPACT OF THE INVASIVE COMB JELLY *MNEMIOPSIS LEIDYI* IN THE NORTH SEA

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Although the Belgian part of the North Sea (BPNS) is a very well studied ecosystem, the knowledge on jellyfish and more specifically ctenophores is poorly documented. Zooplankton research in the BPNS shows that several ctenophore species are facilitated by higher summer and autumn water temperatures. Recently it became obvious that these 'primitive' invertebrates are able to alter and control complete food webs.

The American comb jelly, *Mnemiopsis leidyi*, is one of the most notorious invasive species in the world. It caused massive ecological and economic damage to the Black Sea ecosystem. In the BPNS, it was observed for the first time in 2007.

To assess the impact of *M. leidyi* on different human activities (fisheries, energy providing industries and tourism) a detailed study will be carried out on the spatial and temporal distribution and the role of *M. leidyi* in the food web of the BPNS and the Westerschelde Estuary. A standard Operational Protocol for sampling, conserving and fixating these fragile species for different analysing purposes, will be further developed.

*M. leidyi* is known to predate on fish eggs and larvae and zooplankton. As such, it can be seen as a potential competitor and predator of zooplanktivorous fish. The position of *M. leidyi* in the food web will be assessed using stable isotopes and fatty acid analyses, and through the use of a genetic probe to identify *M. leidyi* at a larger North Sea – North Atlantic Ocean scale.

The obtained information will be useful to formulate national and international policy advice towards various sectors, including fisheries, energy providers and tourism.

# THE BLAST DECISION SUPPORT SYSTEM BASED ON INDICATORS FOR CLIMATE CHANGE

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The coastal zone environment suffers from an increasing pressure from economic activities, urbanization and population growth. Climate change with effects such as sea level rise, increased flood risk and changing temperature and rainfall patterns has even more consequences for this area. Policy makers are forced to make both long term and short term plans for climate change and sea level rise.

The Interreg IV B BLAST project (www.blast-project.eu) has a primary focus on "Bringing land and sea together", by harmonizing and integrating data between land and sea. The project aims to improve the Integrated Coastal Zone Management and Planning (ICZM & P) and maritime safety in the context of climate change.

Work package 6 of the BLAST project aims to develop new common policies and a web based decision support system (DSS) supporting ICZM under the emerging climate change. To achieve this aim, a methodology has been worked out based on a conceptual model, an indicator approach and an innovative architecture for the DSS.

The conceptual model frames in the context of the well-known DPSIR (driving force – pressure – state – impact – response) approach from the European Environment Agency. This model describes the role of ICZM under the pressure of climate change.

Based on this model, user requirements have been carried out among stakeholders in the countries around the North Sea. These requirements have been translated into a selection of ICZM indicators, giving a signal of climate change. Erosion of a sandy coast could be signal of sea level rise. The DSS will offer specific tools for six of these indicators being erosion, flooding due to sea level rise, potential of renewable energy, geological stability, urban indicators and tourism.
The DSS will have an innovative architecture using state of the art GIS spatial data infrastructure components. The DSS will support Open Geospatial Consortium standards such as web map services, web feature services, web coverage services, but also the more advanced web processing services. This DSS will offer the policy makers and planners specific tools to make decisions on mitigation (e.g. energy production from alternative energy sources) and adaptation (e.g. sea defence) measures.

# THE COGS FROM DOEL – MULTIDISCIPLINARY RESEARCH ON TWO MEDIEVAL SHIPWRECKS

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In 2000 and 2002, two wooden wrecks were found in the harbour of Antwerp during the construction of the Deurganckdock. Specialists soon identified these wrecks as medieval cogs. Cogs are the typical large merchantmen from the time in which the Flemish cities had their economic height. The first cog, is one of the most complete of all medieval shipwrecks ever found in Europe. At the time of the finding there was very limited time to do research on site. Therefore every plank and timber had to be disassembled and was put in a container with water to prevent it from rotting. In total 455 timbers of both cogs were placed in 33 containers. The Flemish Heritage Institute (VIOE) started its multidisciplinary research in the summer of 2010 at the Flanders Hydraulics Research (Waterbouwkundig Laboratorium) in Borgerhout, Antwerp.

The entire analysis of all timbers consists of a multidisciplinary approach. After removing all sediment, each timber needs to be photographed. All interesting details are recorded. A digital drawing arm was purchased with which the objects can be drawn in 3D with an accuracy of up to 1000th of a millimetre. When each timber has been drawn in detail the construction of the ship can be analysed in its entirety.

In order to date the ship, a dendrochronologist works on the project. He can date every timber based on the growth rings in the wood. Moreover he is able to give an idea about the provenance of the wood as well. Several planks show that they come from a tree that has been chopped in the winter of 1325/26 in a forest in northern Germany.

Moss that was used to make the planked hull watertight can also be analysed. Moss can serve as a trap for pollen and can therefore give an idea about the vegetation that grew in the area where the moss was plucked in those days.

In this way the researchers hope to get a good idea about the date, provenance and trade route it was sailing on, almost 700 years ago.

The VIOE, as a governmental agency, also gives a lot of attention to public outreach. Therefore the work on the cogs can be followed on a variety of social media as well.

# RESTORING FISH HABITAT ON EMBANKED SITES

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The Schelde Estuary is one of the last genuine estuaries in Western Europe, with a complete longitudinal salinity gradient ranging from Vlissingen near the mouth to Gent, where the influence of the tides is stopped by sluices. The result of this gradient is a wide diversity of typical estuarine habitats. Intertidal habitats (mudflats and marshes) make up a significant proportion of the estuarine habitat available to fish (Stevens, 2006).

The transitional position of the intertidal zone, between the marine and terrestrial environments, makes it vulnerable to human interference in the estuarine system and climate induced sea level rise. In the Schelde Estuary more than 50% of the intertidal habitat was lost by dike building, dredging and embankment over the past century (Meire *et al.,* 2005). To compensate this loss of intertidal habitat, several studies were made and induced in the Sigma-plan. One of the goals of this plan is to increase the amount of intertidal habitat.

To achieve this, reclaimed land is being returned to the river through managed realignment. Another option is to restore tidal influence through a sluice system called Controlled Reduced Tide (CRT). A CRT has high inlet and low outlet to achieve an optimal tidal range.

A pilot-project for CRT was created at Lippenbroek. After the implementation of this CRT in 2006, there has been a monitoring study of the fish community in this area (with fykes and electro-catchment systems). A comparison was made between the communities before and after the induction of the CRT. The results of this comparison showed that there was a bigger diversity of the fish population after the induction (from 7 species before the induction to 14 species after the induction). Simultaneous with this monitoring study, a study was done on the mudflats in the estuary next to the CRT, to see which species should be expected in the CRT. A comparison of these results show that almost all of the species caught in the estuary where also caught in the CRT (Simoens *et al.*, 2007). These results indicate that fish have no problem passing the sluice system and use this area on a species specific base as a spawning - , nursery – and foraging habitat.

In the oligohaline zone of the estuary, the connection between Burchtse Weel and the estuary will be restored. The pond and the estuary will be connected through a large sluice, allowing tidal influence in the area. A monitoring scheme is worked out to evaluate the use of this restored habitat by fish, and to compare it with CRT systems.

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# THE USE OF AN ECOSYSTEM ENGINEER IN COASTAL DEFENSE

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Ecosystem engineers, or more precisely physical ecosystem engineers, are organisms that change the abiotic environment by physically altering structure. As a consequence they often, but not always, have effects on other biota and their interactions, and on ecosystem processes. The physical ecosystem engineering concept interconnects a number of important ecological and evolutionary concepts and is particularly relevant to environmental management. In this study the use of ecosystem engineers (Pacific oysters), for the reduction or prevention of tidal flat erosion in the Oosterschelde Estuary, is investigated.

Erosion of tidal flats represents a serious problem in the Oosterschelde Estuary. Intertidal areas are disappearing due to the construction of a storm surge barrier (finalized 1987) and the building of compartmentalization dams. These construction works caused a reduction of the tidal amplitude and tidal currents, which resulted in large-scale morphological changes. As tidal channels are now oversized with respect to the tidal volume, channels are filling in with materials from the adjacent tidal flats (so-called 'sandhunger'). Reduction in tidal flat area and elevation results in a loss of valuable habitats, and poses a threat to coastal defense.

Pacific oysters [*Crassostrea gigas* (Thunberg)] were introduced in the Oosterschelde Estuary in 1964. They spread rapidly throughout the Oosterschelde expanding from 0 ha in 1975 to 775 ha in 2005 (Smaal *et al.*, 2009). On several intertidal areas large and dense oyster reefs can be found. These reefs can influence tidal flow and wave action and, in doing so, modify patterns of sediment deposition, consolidation, and stabilization. The use of these ecosystem engineers could be an innovative, cost-efficient and sustainable method for conservation of estuarine tidal habitats and coastal defense.

The application of oyster reefs is mostly needed in places subjected to severe erosion. As most of these places lack natural oyster reefs, artificial reefs can be constructed, using empty oyster shells, which provide suitable substrate for natural oyster settlement. The use of such artificial reefs as coastal defense will be successful, when the reefs become living and self-sustainable structures (i.e. support all life stages: settlement, growth, and survival) and stabilize tidal flats. Therefore, artificial oyster reefs have been constructed in the Oosterschelde to monitor and evaluate the effectiveness of the concept. At the same time, environmental constraints for the development of oyster populations are determined and natural oyster reef formation is studied to better understand the ecosystem engineering capacity of this species. Furthermore, the effect of oysters on the surrounding morphology and the impact they have on the surrounding biota are investigated.

First results show that artificial reefs indeed can reduce erosion and provide suitable substrate for oyster larvae, but the success of these reefs will depend on local environmental conditions (e.g. hydrodynamic conditions, inundation time). This study is part of the innovation programme Building with Nature (www.ecoshape.nl).

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# PERSISTENT ORGANIC POLLUTANTS IN HARBOUR PORPOISES FROM THE NORTH SEA FROM 1990 UNTIL 2008: YOUNG WILDLIFE AT RISK?

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In the European North Sea, harbour porpoises (*Phocoena phocoena*) are top predators with relatively long life spans and a limited capacity for metabolic biotransformation of contaminants compared to some other marine mammal species. As such, they are exposed to a mixture of persistent pollutants, such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), DDT and metabolites (DDXs), hexachlorobenzene (HCB) and chlordanes (CHLs) that bioaccumulate in their tissues. We report here on the levels of persistent organic pollutants in blubber, liver and kidney of harbour porpoise neonates (n=3), calves (n=15), juveniles (n=6) and adults (n=4) of the southern North Sea. Concentrations of almost all contaminant classes decrease slightly in all age groups over the period 1990–2008. For some classes (e.g. PCBs and DDXs) however, levels seem to increase little in harbour porpoise calves. In all animals, blubber had the highest concentrations, followed by liver and kidney, whereas liver and kidney were the preferred tissues for several compounds, such as octa- and deca-PCBs. Our data suggest that harbour porpoises calves are exposed to higher or comparable concentrations of POPs and somewhat different patterns of selected POPs than adults, potentially placing them, and the entire population, at a disproportionate risk for exposure-related health effects.

# DYNAMIC PROCESSES IN SEA ICE CAPTURED BY THE TEMPORAL EVOLUTION OF ITS BIOGEOCHEMICAL PROPERTIES

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One of the fundamental questions arising today in polar oceans in the context of climate change, is to understand how sea ice affects gas exchange between the atmosphere and the ocean. In this framework, a survey was carried out on first-year landfast sea ice in the Arctic (Barrow, Alaska), from January to June 2009. Several ice cores, brines and under-ice seawater were collected to investigate seasonal physical and biogeochemical sea ice processes and how they affect gas dynamics within the ice ($O_2$, $N_2$, Ar, $CH_4$).

Based on results obtained from key stations, with special focus on gas composition ($O_2$, $N_2$, Ar, $CH_4$), we observed four main stages in the evolution of physical and biogeochemical properties: (1) a winter stage characterised by a poor permeability in sea ice (apart from the basal part) and a relatively low concentration of chlorophyll a; (2) an early spring stage where the major part of sea ice is still below the permeability threshold, but with a higher chlorophyll-a content. The accumulation of ammonium and the concentration of nitrate and phosphate suggested development of remineralisation processes; (3) significant increase of temperature and induced higher permeability lead to dramatic changes: chlorophyll-a and Rayleigh numbers suggest brine drainage; analyses of nutrients, oxygen and hydrogen isotopes and gas concentration ratios ($O_2$:$N_2$, $O_2$:Ar) indicate a partial replacement of drained brines by seawater; (4) lastly, permeability increases further and induces a size discrimination on autotrophs: only the largest autotrophs remain in the ice porosity. Nutrients concentrations are below the dilution curve of seawater. The volume of total gas and the gas ratios show an increased gas exchange between sea ice and atmosphere/seawater, and $O_2$ production by photosynthesis.

Besides first measurements of $O_2$:Ar in sea ice, we also present first values of methane concentration in sea ice. They exceed the atmospheric concentration during the whole sampling period and suggest thus an important concentration in the seawater below the sea ice cover. Sea ice thus acts as a temporary storage for $CH_4$.

To conclude, sea ice is not an impermeable barrier as usually considered in current climatic models. It can be permeable in certain conditions as theoretically suggested by Golden et al. (2007). Moreover, our results show that sea ice does not only act as a barrier, but play an active role in carbon transfer due to both sea ice related processes: biological production by sympagic communities and potential oxidation of methane. Thus, sea ice appears to be a key component in carbon fluxes in polar oceans and then in the climate system that cannot be neglected in future model developments.

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# APPLICANTS
# VLIZ Thesis Awards Marine Sciences 2010

# NUMERIEKE MODELLERING VAN DE GOLFGROEI DOOR WIND IN DE ZOGZONE VAN EEN PARK VAN GOLFENERGIECONVERTOREN M.B.V. HET GOLFVOORTPLANTINGSMODEL MILDWAVE

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Begin 2008 stelde Europa haar ambitieuze 20-20-20 klimaatdoelstellingen voor, die intens gekoppeld zijn aan hernieuwbare energie. Eén veelbelovende en duurzame technologie is het opwekken van energie uit golven. Numerieke modellering van de golfenergie-convertoren is een belangrijk aspect in de verdere ontwikkeling van deze technologie. Dit artikel [1] beschrijft de implementatie van de golfgroei door wind in de hyperbolische mild-slope vergelijkingen die door het numerieke golfvoortplantingsmodel MILDwave gebruikt worden. Verschillende uitdrukkingen voor de energie-overdracht van de wind naar de golven, beschikbaar in de literatuur, worden beschouwd. De toepasbaarheid van deze uitdrukkingen voor MILDwave wordt onderzocht en gevalideerd, en de uitdrukking die de meest bevredigende resultaten levert, wordt weerhouden om de invloed van de wind op de zogzone van een park van golfenergie-convertoren te onderzoeken.

**Sleutelwoorden**: golfgroei door wind; MILDwave; hyperbolische mild-slope vergelijkingen; zogzone van GECs; golfenergieconvertoren; hernieuwbare energie; golfenergie.

## I. INTRODUCTIE

### A. Kadering van het onderzoek
Europa streeft naar een energie-efficiënte economie met een beperkte $CO_2$-uitstoot. Om deze ambitie te verwezenlijken werd begin 2008 een Europees klimaatplan opgesteĺd, dat gekend is als de 20-20-20 doelstellingen. Deze doelstellingen houden in dat een reductie van de uitstoot van broeikasgassen met 20% behaald moet worden tegen 2020 (in vergelijking met de statistieken van 1990). Eenzelfde afname wordt opgelegd aan het primair-energieverbruik. Daarenboven moet het aandeel van de hernieuwbare energie tegen 2020 opgetrokken worden tot minstens 20% van de totale energieconsumptie in de Europese Unie.
Het behalen van deze doelstellingen is rechtstreeks en onrechtstreeks gekoppeld aan de evolutie van de sector van de hernieuwbare energieproductie. De groei van deze sector is uiteraard afhankelijk van sociaal-politieke en economische factoren, maar niet in het minst ook van technologische innovatie. Hierbij is het belangrijk dat geïnvesteerd wordt zowel in de ontwikkeling van de bestaande technologieën, als in het onderzoek naar nieuwe technologieën. Eén veelbelovende technologie waarvan het potentieel wereldwijd erkend wordt en die op termijn een significante bijdrage kan leveren tot de productie van groene energie, is energie opwekken uit golven.

### B. Golfenergie - state of the art
Golfenergie is in essentie een geconcentreerde vorm van windenergie. Golven worden immers gegenereerd door de progressieve overdracht van energie uit de wind die over het wateroppervlak blaast. De totale hoeveelheid beschikbare energie voor alle kusten in de wereld wordt geschat op 2 TW, wat quasi gelijk is aan de globale energieconsumptie.
Ondanks de erkenning dat golfenergie significant kan bijdragen tot de globale energievoorziening, is de technologie van de golfenergieconvertoren (afgekort als GEC's) nog altijd niet kostenefficiënt. Dit dient geen rem, maar een stimulans te zijn voor verder onderzoek, indachtig dat golfenergie vandaag staat waar windenergie een dertigtal jaar geleden stond.
Inmiddels werden vele concepten voor golfenergie-conversie ontwikkeld en beproefd. De golfenergie-convertoren, die de beschikbare golfenergie omzetten naar elektrische stroom, worden in hoofdzaak ingedeeld in twee categorieën op basis van hun conversieprincipe. De GEC's van het oscillerende type, waarbij een lichaam of waterkolom oscilleert onder invloed van de zeegolven, vormen een eerste categorie. Een tweede categorie zijn de GEC's van het golfoverslagtype, waarbij golven overslaan in een bassin gelegen boven het gemiddelde zeeniveau.
De numerieke modellering van golfenergieconvertoren speelt een belangrijke rol in hun optimalisatie. Door het gebruik van golfvoortplantingsmodellen is het mogelijk om de lay-out van een GEC-park (meerdere GEC's samen die als één geheel functioneren) te optimaliseren, de impact

van de GEC's op het golfklimaat in hun zogzone te bestuderen, de golfenergieproductie te berekenen en optimaliseren, etc.

### C. Het numerieke model MILDwave

MILDwave is een dergelijk numeriek golfvoortplantings-model. Het werd ontwikkeld aan de Universiteit Gent [2] en is gebaseerd op de mild-slope vergelijkingen van Radder en Dingemans (1985). Het tijdsdomein model MILDwave kan lineaire golven genereren, en de voortplanting simuleren over variërende bathymetrieën met flauwe bodemhellingen door de golfverheffingen en de snelheidspotentiaal over het domein te berekenen. Hierbij is MILDwave in staat de belangrijkste verschillende golftransformatieprocessen te modelleren zoals refractie, shoaling, reflectie, transmisse, diffractie en golfbreking, en het model behoudt daarbij een beperkte rekentijd.

De evidente causale relatie tussen wind en golven, en de vaak significante invloed van de wind op de golfgroei, maakten een uitbreiding van het numerieke golfvoort-plantingsmodel noodzakelijk. De implementatie en de validatie van deze uitbreiding vormen het hoofddoel van dit onderzoek. Nadien wordt de geïmplementeerde windmodule gebruikt om de invloed van de wind na te gaan op de grootte van de zogzone van een park van GEC's.

## II. GOLFGROEI DOOR WIND

### A. Het fysische proces

De overdracht van energie van de wind naar de golven is een complex fysisch proces, dat tot op heden nog niet eenduidig beschreven is. Niettegenstaande de complexiteit zijn meerdere theorieën uitgeschreven, de ene al nauwkeuriger dan de andere. Op basis van theoretische en praktische overwegingen, is de voor implementatie in MILDwave meest geschikte theorie weerhouden, zoals hierna beschreven.

De negatieve dissipatieterm $W_g$ [3] is gebruikt voor zowel regelmatige als langkruinige onregelmatige golven (kortkruinige golven vallen buiten het bestek van deze thesis):

$$W_g = -\frac{2C_g}{H_s}\frac{dH_s}{dy} \qquad (1)$$

De gradiënt $dH_s/dy$ wordt berekend volgens de groeicurve van Wilson-Krylov [4], [5], waarvan de uitdrukking gegeven wordt door (2):

$$\frac{gH_s}{V_y^2} = \beta_v\left[1-\left(1+\alpha_v\sqrt{gy/V_y^2}\right)^{-2}\right] \qquad (2)$$

De bovenstaande uitdrukkingen worden in de hyperbolische mild-slope vergelijkingen geïmplementeerd.

### B. Parameters in uitdrukkingen voor golfgroei door wind

De berekening van de golfgroei door wind maakt gebruik van de significante golfhoogte $H_s$, dewelke ogenblikkelijk gesimuleerd dient te worden in MILDwave. Meerdere modules zijn ontwikkeld om deze parameter te schatten, en zijn onderling vergeleken op basis van nauwkeurigheid, én rekentijd. Het is immers belangrijk dat MILDwave zijn intrinsieke voordeel als snelle numerieke solver behoudt.

De parameters die voorkomen in de groeicurve dienen gekalibreerd te worden om een goede overeenkomst met de waarnemingen te bekomen. De waarden voorgesteld in [3] zijn als standaardwaarden ingesteld in MILDwave.

### C. Implementatie in MILDwave

De hyperbolische mild-slope vergelijkingen waarop MILDwave [2], [6] steunt voor de berekening van de golfverheffing $\eta$ en de snelheidspotentiaal $\varphi$ worden gegeven door (3):

$$\begin{cases} \dfrac{\partial \eta}{\partial t} = \dfrac{\omega^2 - k^2 CC_g}{g}\phi - \nabla \cdot \left(\dfrac{CC_g}{g}\nabla\phi\right) \\ \dfrac{\partial \phi}{\partial t} = -g\eta \end{cases} \qquad (3)$$

Door de dissipatietermen voor diepte-geïnduceerde golfbreking ($D_g/E$) [7] en de groeiterm voor de bijdrage van de wind ($W_g$) op te nemen, worden de vergelijkingen (3) uitgebreid tot (4):

$$\begin{cases} \dfrac{\partial \eta}{\partial t} = \dfrac{\omega^2 - k^2 CC_g}{g}\phi - \nabla \cdot \left( \dfrac{CC_g}{g}\nabla\phi \right) - \left( \dfrac{D_B}{E} + W_g \right)\eta \\[4mm] \dfrac{\partial \phi}{\partial t} = -g\eta \end{cases} \quad (4)$$

Implementatie in de MILDwave code is mogelijk na discretisatie in tijd en ruimte van (4).

## III. VALIDATIE VAN DE WIND-MODULE

De validatie van de module die de invloed van de wind op de golven simuleert, wordt in dit onderzoek verricht via een vergelijking met de groeicurve van Wilson-Krylov [4], [5], en is uitgevoerd zowel voor regelmatige als langkruinige onregelmatige golven. In Tabel I worden de golf-karakteristieken van een selectie uit de uitgevoerde testcases ter validatie weergegeven. In Figuren 1-3 wordt de vergelijking tussen numerieke (MILDwave) en theoretische (Wilson-Krylov groeicurve) resultaten weergegeven voor regelmatige (Fig. 1) en onregelmatige langkruinige (Fig. 2-3) golven. In deze figuren wordt de windgroei van de significante golfhoogtes gegeven langsheen een longitudinale snede van het numeriek bassin.

Tabel I. Golfkarakteristieken van de testcases besproken in Fig. 1-3

| test case | $H_{(s)}$ [m] | $T_{(p)}$ [s] | $U_{10}$ [m/s] | Golfgeneratie |
|-----------|---------------|---------------|----------------|---------------|
| 4-6 | 2.0 | 5 | 20 | Regelmatig |
| J-4 | 1.0 | 5.2 | 12.0 | Langkruinig onregelmatig JONSWAP ($\gamma$=3.3) |
| PM-4 | 3.0 | 7.6 | 25.0 | Langkruinig onregelmatig Pierson-Moskovitz |



Fig. 1. Testcase 4-6: Groei van de golfhoogte Hs langsheen een longitudinale sectie van het numeriek bassin: MILDwave resultaten (volle lijn), Wilson-Krylov groeicurve (puntlijn).
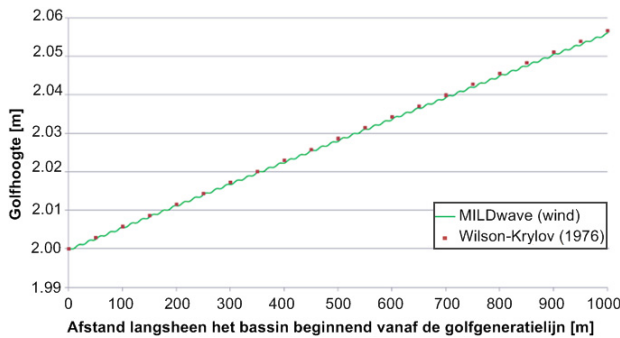


Fig. 2. Testcase J-4: Groei van de golfhoogte Hs langsheen een longitudinale sectie van het numeriek bassin: MILDwave resultaten (volle lijn), Wilson-Krylov groeicurve (puntlijn).
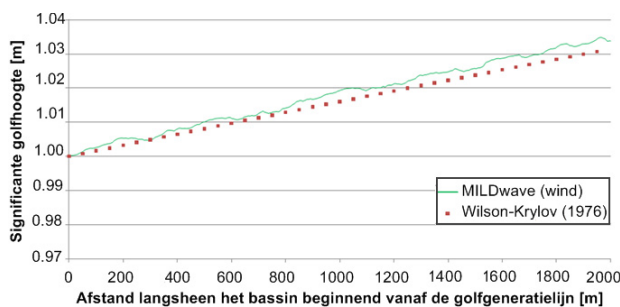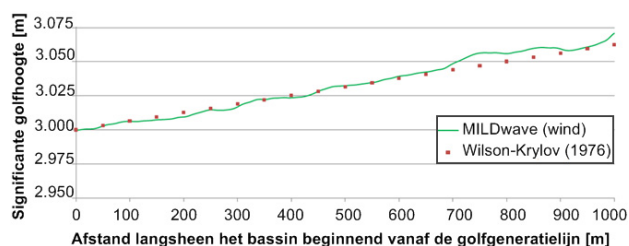
Fig. 3. Testcase PM-4: Groei van de golfhoogte Hs langsheen een longitudinale sectie van het numeriek bassin: MILDwave resultaten (volle lijn), Wilson-Krylov groeicurve (puntlijn).

De numerieke resultaten van simulaties in MILDwave met de windmodule actief, zijn in goede overeenstemming met de theoretische resultaten van de Wilson-Krylov groeicurve voor de regelmatige golven gegenereerd in 'Testcase 4-6' (Fig. 1). Deze testcase kan als karakteristiek beschouwd worden voor de volledige reeks uitgevoerde testen met regelmatige golven. Voor de langkruinige onregelmatige golven worden kleine afwijkingen t.o.v. de theoretische waarden geobserveerd (Fig. 2-3). Anderzijds zijn op de significante golfhoogte $H_s$ variaties van dezelfde grootteorde waargenomen voor simulaties waarbij de windmodule inactief is. De kleine afwijkingen zijn bijgevolg niet te wijten aan het effect van de windgroeimodule, maar het resultaat van onregelmatige golfvoortplanting. Hierop gebaseerd besluiten we dat de windmodule op een correcte en bevredigende wijze de invloed van de wind op de golven modelleert, ook voor langkruinige onregelmatige golven.

## IV. INVLOED OP DE ZOGZONE VAN EEN PARK VAN GEC'S

De uitgebreide MILDwave code wordt vervolgens toegepast om de invloed van de wind op de zogzone van één individuele, vrijstaande GEC, en vervolgens van een GEC-park te onderzoeken. Een reeks simulaties, met verschillende configuraties van de parklay-out van de GEC's, wordt onderzocht. Eén van de onderzochte types van GEC's is de 'Wave Dragon' (GEC van het golfoverslag-type). Observaties van de numerieke resultaten tonen aan dat de invloed van de wind onmiddellijk achter één GEC of een GEC-park zeer beperkt is, en vergroot met een toenemende afstand achter de golfenergieconvertoren.

Dit wordt geïllustreerd door een testcase waarbij een rij van drie GEC's (met een tussenafstand gelijk aan twee maal de breedte van één GEC) wordt beschouwd. De opgelegde golfkarakteristieken zijn: significante golfhoogte $H_s$ gelijk aan 3.0m, piekperiode $T_p$ gelijk aan 8.4m en windsnelheid $U_{10}$ gelijk aan 15.0m/s. De resultaten worden weergegeven m.b.v. van een contourplot van $K_d$-verstoringscoëfficiënten (Fig. 4), waar de waarde van de verstoringscoëfficiënt in een 'punt A' van het domein, $K_{d,A}$, gelijk is aan de gemeten golfhoogte in 'punt A', $H_{s,A}$, gedeeld door de opgelegde invallende golfhoogte langs de golfgeneratielijn $H_{s,i}$.
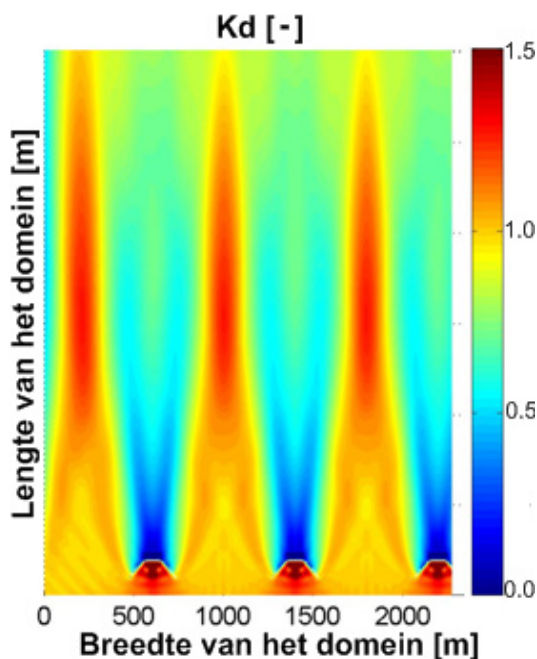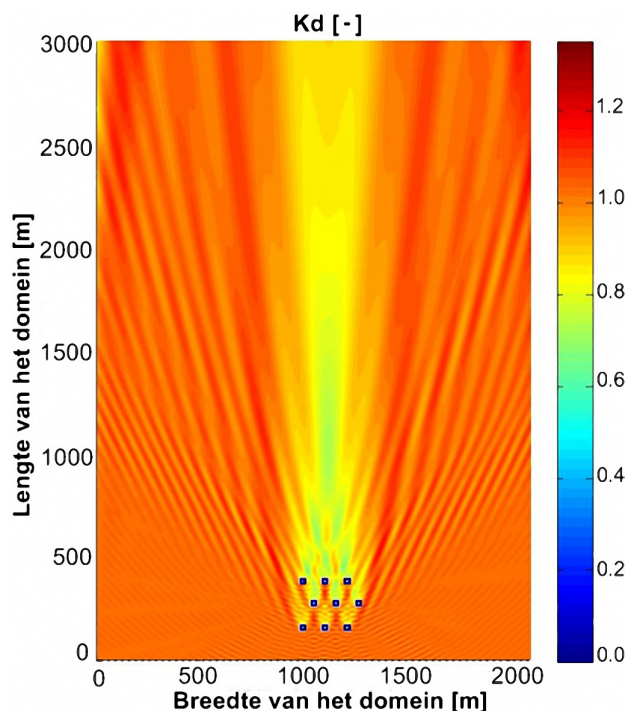
Fig. 4. Contourplot van de verstoringscoëfficiënten, $K_d$ [-], voor een rij van 'Wave Dragon'-GEC's (onregelmatige golven, $H_s$ = 3.0m, $T_p$ = 8.4 s, $U_{10'}$ = 15.0m/s).

Op een afstand van 100m achter een GEC, gepositioneerd op de buitenste positie van de rij, is de aanwezige golfenergie gelijk aan $144.10^4$ W, voor het geval waarbij geen wind wordt aangelegd over het wateroppervlak. Deze golfenergie wordt berekend over een oppervlakte van 1200m². Wanneer het effect van de wind in rekening wordt gebracht, wordt over dezelfde oppervlakte een licht verhoogde waarde van de beschikbare golfenergie teruggevonden: $146.10^4$ W (toename van 1.4%). Op een afstand van 500m achter de GEC wordt het effect van de wind belangrijker. De waarde van de aanwezige golfenergie stijgt van $549.10^4$ W tot $574.10^4$ W (toename van 4.5%) voor condities zonder en met het effect van de wind, respectievelijk.

Dezelfde windeffecten worden eveneens geïllustreerd door een studie van een park van negen hypothetische GEC's (GEC's met eenvoudige geometrie), geplaatst in een geschrankte (zogenaamde staggered grid) lay-out (Fig. 5). Deze hypothetische GEC's hebben dezelfde absorptie-eigenschappen als echte GEC's. Op de configuratie vallen regelmatige golven in met een golfhoogte, $H_{w'}$ gelijk aan 1.0m en een golfperiode, $T_{w'}$ gelijk aan 5.2 s. In Fig. 5 (onderaan) zijn de $K_d$-waardes in de zogzone van de GEC's groter door het effect van de windgroei. In Figuur 6 wordt de evolutie van de golfhoogte gegeven langs een longitudinale snede van het numerieke bassin en het GEC-park. Onder invloed van een windveld met een snelheid, $U_{10'}$ van 12.0m/s, treedt op een afstand van 2100m achter het GEC-park een golfhoogte-toename van 0.046m op t.o.v. de windstille situatie.
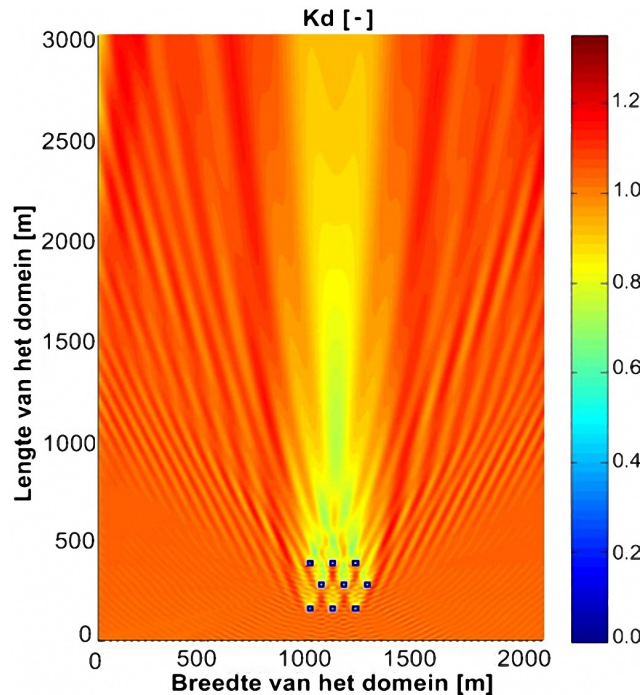
Fig. 5. Zogzone achter een park van hypothetische GEC's voor loodrecht invallende regelmatige golven ($H_w$ = 1.0m en $T_w$ = 5.2s). Contourplotten van de berekende verstoringscoëfficiënt $K_d$ [-] voor een staggered grid met de wind module inactief (bovenaan) en de windmodule actief (onderaan).
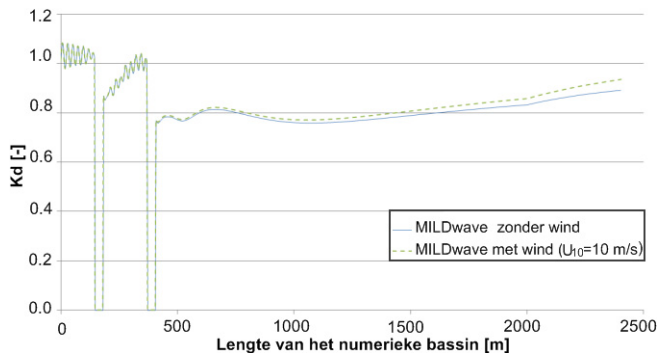


Fig. 6. Berekende verstoringscoëfficiënt $K_d$ [-] langs een parallelsectie t.o.v. de golfvoortplantsrichting op x = 1100m, voor loodrecht invallende regelmatige golven op een park van hypothetische GEC'S en voor een windsnelheid, $U_{10}$, gelijk aan 0.0m/s (origineel) en 12.0m/s.

## V. CONCLUSIES

Algemeen kan men besluiten dat uit de studie van zowel individuele convertoren als van verschillende park lay-outs is gebleken dat de invloed van de wind beperkt is over korte afstanden, maar significant is wanneer men grotere afstanden beschouwt. Het is dan ook voornamelijk bij de optimalisatie van de inplanting van meerdere parken van golfenergie-convertoren dat het in rekening brengen van de invloed van de wind op het golfklimaat een meerwaarde biedt. Ook voor de studie van de golfimpact op kustlijnen, windmolenparken, etc. gelegen in de schaduwzone van de GEC-parken is het effect van de wind significant, en kan het numerieke golfvoortplantingsmodel MILDwave met de windgroei-module een krachtig ingenieurstool zijn.

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# REDUCTIE VAN GOLFOVERSLAG BIJ EEN GLADDE DIJK: COMBINATIE VAN EEN BERM EN STORMMUUR

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## I. Inleiding
Verscheidene redenen liggen aan de basis van de steeds toenemende interesse in de kustveiligheid en de ermee gerelateerde aspecten. Vooreerst bestaat er sinds de publicatie van het rapport "Climate Change 2007" door het Intergouvernementeel Panel voor Klimaatverandering geen twijfel meer over het fenomeen van klimaatverandering. Gevolgen van deze mondiale klimaatverandering zijn ondermeer een stijging van de waterspiegel en een toename in intensiteit, frequentie en geografisch voorkomen van hevige stormen. Daarnaast zijn er ook sociologische factoren die beleidsmakers ertoe nopen meer aandacht te schenken aan de kustveiligheid. Voorbeelden hiervan zijn de hogere subjectieve waarde-inschatting van mensenlevens, het stijgende economische belang van zeehavens en de toeristische sector,...
De afnemende vrijboord (afstand tussen hoogste punt van de dijk en het stilwaterpeil) en de veranderende stormkarakteristieken vragen een permanente analyse en evaluatie van de bestaande kustinfrastructuur overal ter wereld. In het kader hiervan wordt in opdracht van de Vlaamse overheid momenteel nog volop gewerkt aan het "Geïntegreerd Kustveiligheidsplan" [1] dat dit jaar gepubliceerd zal worden. Het plan moet de Belgische kuststreek in de toekomst behoeden bij het optreden van een 1000-jarige storm (storm die statistisch gezien eens om de 1000 jaar voorkomt). In een ideaal scenario bouwt men daartoe een verdedigingsinfrastructuur die deze en andere (super)stormen volledig tegenhoudt. Om rekening te houden met economische en praktische beperkingen wordt bij de dimensionering ervan echter een zeker overslagdebiet (overstromende hoeveelheid water per tijdseenheid) toegestaan zonder dat hierdoor de globale of lokale stabiliteit van de constructie in het gedrang gebracht wordt, noch dat delen van het hinterland onder water komen te staan.
Het voorspellen van deze overslagdebieten wordt meestal gedaan aan de hand van empirisch bepaalde formules. Deze masterproef heeft tot doel het controleren en aanpassen van de in onze contreien meest gebruikte formules ter toepassing op de aan de Belgische kust typisch voorkomende dijkgeometrie zoals weergegeven in Fig. 1. Tevens wordt het effect nagegaan van enkele mogelijke ingrepen die naar voor geschoven worden in het kader van het Geïntegreerd Kustveiligheidsplan en van een combinatie van deze ingrepen. Hieronder wordt bijvoorbeeld verstaan: de installatie van een verticale stormmuur (al dan niet met parapet), aan de meest zeewaarts of meest landwaarts gerichte zijde van de wandeldijk.
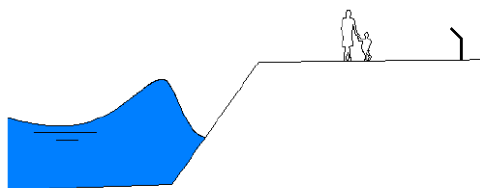


Fig. 1. Typisch aan de Belgische kust voorkomende dijkgeometrie: een hoge dijk met voldoende wandelruimte. In dit voorbeeld is de wandeldijk aan zijn meest landwaarts gerichte zijde voorzien van een stormmuur met parapet.

Het belang van de overspoelde hoeveelheid water kan niet onderschat worden. Zo maakt het nog te verschijnen Kustveiligheidsplan gewag van een potentieel levensbedreigende situatie voor om en bij de 4000 mensen indien een 1000-jarige storm vandaag de Belgische kust teistert. Oostende, net als verschillende andere badsteden langs onze kustlijn, is vandaag slechts beschermd tegen een 100-jarige storm en verdient extra aandacht omwille van zijn laaggelegen stadscentrum.

## II. Theoretische achtergrond
Een veelvuldig gebruikte, algemene formule ter voorspelling van het gemiddelde overslagdebiet is de volgende:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = A \cdot \exp\left(-B \cdot \frac{R_c}{H_{m0}}\right)$$

Formule 1

Hierin is $\dfrac{q}{\sqrt{g \cdot H_{m0}^3}}$ het gemiddelde overslagdebiet en $\dfrac{R_c}{H_{m0}}$ de dimensieloze vrijboord. De coëfficiënten A en B variëren naargelang de auteur. Als grondslag voor dit eindwerk werden de formules van J.W. van der Meer gebruikt, zoals voorgesteld in [2]. In [2] wordt een onderscheid gemaakt tussen brekende golfcondities en niet-brekende golfcondities. Alhoewel deze classificatie in eerste instantie werd ingevoerd om aan te duiden met welke formule het best gerekend wordt, bestaat er in de meeste gevallen wel een grote overeenstemming met het fysische verschijnsel van golfbreking. In het geval van niet-brekende golfcondities past de algemene formule zich als volgt aan:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \exp\left(-2.6 \cdot \frac{R_c}{H_{m0}} \frac{1}{\gamma_f \cdot \gamma_\beta}\right)$$

Formule 2

In het geval van brekende golfcondities wordt volgende formule voorgesteld:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.067}{\sqrt{\tan(\alpha)}} \cdot \gamma_b \cdot \xi_0 \cdot \exp\left(-4.75 \cdot \frac{R_c}{H_{m0}} \cdot \frac{1}{\xi_0 \cdot \gamma_b \cdot \gamma_v \cdot \gamma_f \cdot \gamma_\beta}\right)$$

Formule 3

In deze formules komen enkele parameters voor die de stormcondities aan de teen van de structuur vastleggen alsook enkele geometrische afmetingen van de dijkconstructie: $H_{m0}$ =de spectrale golfhoogte, $q$ = het gemiddelde overslagdebiet, $g$ = graviteitsversnelling, $R_c$ = vrijboord, $\xi_0$ = brekerparameter (getal van Iribarren) = $\tan\alpha / \sqrt{s_0}$ , $\tan\alpha$ = helling van de dijk, $s_0$ = fictieve golfsteilheid = $2 \cdot \pi \cdot H_{m0} / \left(g \cdot T_{m-1,0}^2\right)$, $T_{m\text{-}1,0}$ = spectrale golfperiode van de invallende golf.

Verder komen in de voorgestelde formules nog coëfficiënten voor die de invloed van enkele overslagreducerende maatregelen voorstellen. Zulke coëfficiënten beschrijven de ruwheid van de dijk ($\gamma_f$), de invalshoek van de golven ($\gamma_\beta$), de aanwezigheid van een berm bovenaan de dijk ($\gamma_b$) of de aanwezigheid van een verticaal stormmuurtje ($\gamma_v$).

### II. Testen en objectieven
Het experimentele onderzoek werd uitgevoerd in de golfgoten van de Afdeling Weg- en Waterbouwkunde van de faculteit Ingenieurswetenschappen aan de Universiteit Gent. De testen met niet-brekende golfcondities werden uitgevoerd in de grote golfgoot (schaal ≈ 1/30) op een gladde dijk met helling 1:2. De brekende golfcondities werden onderzocht in de kleine golfgoot (schaal ≈ 1/60) op een gladde dijk met helling 1:6.

De gevolgde testprocedure is dezelfde voor beide golfcondities. Aanvankelijk wordt een referentiesituatie zonder overslagreducerende maatregelen, zijnde de gewone gladde dijk, gecreëerd en uitvoerig beproefd. De resultaten van deze referentiesituatie worden vervolgens gebruikt om de invloed van verschillende overslagreducerende maatregelen te bepalen. In deze thesis werd uitvoerig de invloed van volgende maatregelen nagegaan: een berm (met helling 2%) bovenop de dijk, een verticale stormmuur (al of niet met parapet) of de combinatie van beide waarbij de stormmuur is geplaatst aan de landwaartse zijde van de berm (Fig. 1).

### IV. Resultaten en conclusies
Alle testen werden uitgevoerd op gladde structuren ($\gamma_f$ = 1) waarbij de invalshoek van de golven gelijk is aan 0, d.i. loodrechte inval. Aangezien getracht wordt zoveel mogelijk de situatie voor de Belgische kust te simuleren werd verder geopteerd voor golftreinen met een JONSWAP-spectrum en piekfactor 3.3 op diep water. De voornaamste resultaten van het onderzoek worden hieronder vermeld voor elke beproefde geometrie.

## A. Gladde dijk met berm onder een helling van 2%

Een schets van deze situatie is weergegeven in Fig. 2.
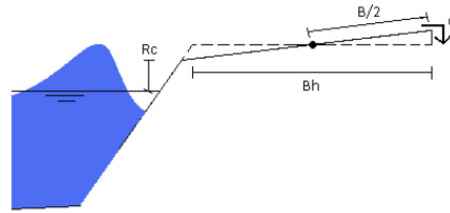


Fig. 2. Schets van configuratie met berm (helling 2%) en aanduiding van de voornaamste parameters in de formule

In niet-brekende golfcondities wordt gevonden, in tegenstelling met wat Formule 2 voorspelt, dat een berm bovenop de gladde dijk wel degelijk een overslagreducerend effect heeft. De formule voor niet-brekende golven wordt aangepast tot Formule 4. De $\gamma_b$-coëfficiënt om het effect van de berm in rekening te brengen wordt berekend aan de hand van Formule 5. Hierin is $L_0$ de golflengte op diep water $\left(= g \cdot T_{m-1,0}^2 / 2 \cdot \pi \right)$. $\gamma_b$ is gelijk aan 1 indien geen berm aanwezig is.

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \gamma_b \cdot \exp\left(-2.6 \cdot \frac{R_c}{H_{m0} \cdot \gamma_b}\right)$$

Formule 4

$$\gamma_b = 0.939 - 0.058 \frac{B_h^2}{L_0 \cdot R_c} \ \text{met} \ \frac{B^2}{L_0 \cdot R_c} \in [0.05\text{-}3.95]$$

Formule 5

Voor brekende golfcondities wordt gevonden dat de resultaten sterk onderhevig zijn aan schaaleffecten. Deze schaaleffecten zijn een gevolg van de grote bijdrage van de wrijvingsverliezen tot het totale energieverlies en de incorrecte schaling van deze wrijvingsverliezen door toepassing van het Froude-schaalmodel bij overslagproeven. De dikte van de overtoppende watertong is beperkt, wat inhoudt dat de bijdrage van de wrijvingsverliezen veel groter is in de kleine golfgoot dan in de grote golfgoot. Bijkomend en diepgaander onderzoek wordt aangeraden.

## B. Gladde dijk met verticale stormmuur

Een schets van deze configuratie is weergegeven in Fig. 3.
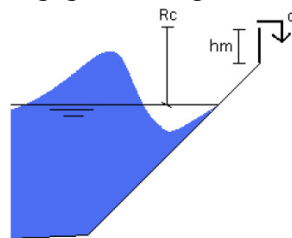


Fig. 3. Schets van configuratie met verticale stormmuur en aanduiding van de voornaamste parameters in de formule.

Net zoals bij de berm wordt gevonden dat Formule 2 onvoldoende rekening houdt met het effect van een verticale stormmuur bovenaan de dijk. De formule voor niet-brekende golfcondities wordt aangepast tot Formule 6. Onder brekende golfcondities blijft Formule 3 geldig. $\gamma_v$ kan berekend worden aan de hand van Formule 7 in beide golfcondities. $\gamma_v$ is gelijk aan 1 indien geen stormmuur aanwezig is.

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \exp\left(-2.6 \cdot \frac{R_c}{H_{m0} \cdot \gamma_v}\right)$$

Formule 6

$$\gamma_v = 0.939 - 0.367 \cdot \frac{h_{muur}}{R_c}$$

Formule 7

Met $h_{muur}/R_c \in [0.05, 0.90]$ in niet-brekende golfcondities en $h_{muur}/R_c \in [0.08, 0.60]$ in brekende golfcondities.

## G. Gladde dijk met berm en stormmuur
Een schets van deze configuratie is weergegeven in Fig. 4.



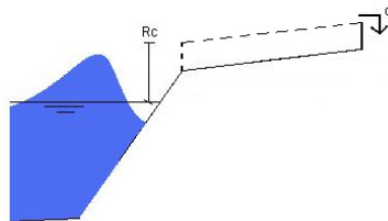Fig. 4. Schets van configuratie met stormmuur aan de landwaartse zijde van de berm (helling 2%) en aanduiding van de voornaamste parameters in formule

Hier wordt gevonden dat een combinatie van Formule 4 en Formule 6 in een formule gelijkaardig met Formule 3 het overslagdebiet overschat. De formule voor niet-brekende golfcondities wordt aangepast tot
Formule 8. De $\gamma_{bv}$-coëfficiënt om het gecombineerde effect van beide maatregelen te beschrijven wordt berekend aan de hand van
Formule 9. $\gamma_{bv}$ is gelijk aan 1 indien geen maatregelen aanwezig zijn.

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \gamma_b \cdot \exp\left( -2.6 \cdot \frac{R_c}{H_{m0} \cdot \gamma_{bv}} \right)$$

Formule 8

$$\gamma_{bv} = 1.148 \cdot \gamma_b \cdot \gamma_v - 0.173 \quad \text{met } \gamma_v \text{ volgens Formule 7 en } \gamma_b \text{ volgens Formule 5}$$

Formule 9

De resultaten van de testen met brekende golfcondities bleken onregelmatigheden te vertonen. De eerder vermelde schaaleffecten kunnen hiervoor opnieuw als verklaring ingeroepen worden.

## D. Gladde dijk met berm en stormmuur met parapet
Het effect van een parapet op een stormmuur werd reeds uitvoerig onderzocht in [3]. De resultaten van [3] worden gebruikt om het samengestelde effect van een berm (met helling 2%) en stormmuur met parapet te beschrijven. Er wordt gevonden dat de combinatie van $\gamma_{bv}$ en $\gamma_{parapet}$ het gemiddelde overslagdebiet onderschat. Formule 2 werd aangepast tot Formule 10 en $\gamma_{bv,parapet}$ wordt berekend aan de hand van
Formule 11.
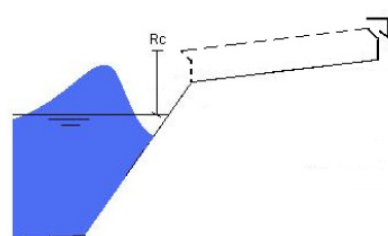


Fig. 5. Schets van configuratie met stormmuur, voorzien van parapet, aan de landwaartse zijde van de berm (helling 2%) en aanduiding van de voornaamste parameters in formule.

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \gamma_b \cdot \exp\left( -2.6 \cdot \frac{R_c}{H_{m0} \cdot \gamma_{bv,parapet}} \right)$$

<div align="center">

Formule 10

$$\gamma_{bv,parapet} = 1.447 \cdot \gamma_{bv} \cdot \gamma_{parapet} + 0.041 \text{ met } \gamma_{bv} \text{ volgens}$$

Formule 9 en $\gamma_{parapet}$ volgens [3]

Formule 11

</div>

## E. Opmerkingen en besluit

De vermelde theoretische formules laten een adequate theoretische voorspelling toe van de experimenteel bepaalde overslagdebieten. De gemiddelde procentuele afwijking bij de bepaling van het gemiddelde dimensieloze overslagdebiet bij gegeven dimensieloze vrijboord bedraagt 25% en 5% bij de bepaling van de dimensieloze vrijboord bij gegeven dimensieloos overslagdebiet. De standaardafwijkingen op deze waarden bedragen 20% respectievelijk 4%. De voorgestelde formules laten toe om in de toekomst dijkconfiguraties te ontwerpen die geijkt zijn op de situatie aan de Belgische kust en deze te beschermen tegen de superstormen. Voor diepgaandere bemerkingen bij de formules en de gehanteerde methodes wordt verwezen naar de eigenlijke thesis.

## Referenties

[1] Vlaams ministerie van Mobiliteit en Openbare Werken. 2010. Geïntegreerd Kustveiligheidsplan. (in opmaak).

[2]  van der Meer J.W.. 2002. Technisch Rapport Golfoploop en Golfoverslag bij dijken.

[3] Van Doorslaer K.. 2008. Reductie van golfoverslag over dijken door middel van een parapet (scriptie).

# FUNCTIONELE GENETISCHE VARIATIE BIJ DE EUROPESE PALING (*ANGUILLA ANGUILLA* L.)

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EST-gekoppelde microsatellieten zijn geschikte merkers voor onderzoek naar loci onder invloed van selectie. Tevens zijn microsatellieten bijzonder bruikbaar voor het ontrafelen van de structuur in sterk verwante populaties, wat een goed argument is voor hun gebruik in de analyse van de populatiestructuur van de Europese paling (*Anguilla anguilla* L.). Onderzoek met neutrale genetische merkers bracht geen uitsluitsel over het feit of de Europese palingpopulatie als panmictisch kan worden beschouwd. Een juiste kennis van de populatiestructuur is echter belangrijk bij het opstellen van een effectief beheersprogramma voor deze bedreigde soort.

De Europese paling is een katadrome soort waarvan de adulte zilverpalingen na hun verblijf in de estuaria en de rivieren, de Atlantische Oceaan oversteken om te paaien in de Sargassozee om nadien te sterven. De larven worden meegevoerd met oceaanstromingen om acht tot negen maand later aan te komen op het Europees continentaal plat, waar ze transformeren tot glasaal. De glasalen trekken de estuaria en rivieren op waar ze metamorfoseren tot gele paling om nadien, na een groeiperiode van enkele jaren als adulte zilverpaling terug te keren naar hun geboortegebied.
Deze studie onderzocht de functionele genetische variatie bij deze soort aan de hand van 21 EST-SSR's. Er werden stalen geanalyseerd van glasalen en zilverpalingen, afkomstig van zes staalnameplaatsen langs de Atlantische kust en één langs de Middellandse kust. Om te controleren voor temporele variatie werden ook stalen uit twee verschillende jaren gebruikt en van 471 adulte individuen werd de leeftijd bepaald door het aflezen van jaarringen in otolieten.

In deze studie werd geen aanwijzing gevonden voor significante verschillen in diversiteit of differentiatie tussen palingen uit verschillende staalnamelocaties of jaren. De globale $F_{ST}$ -,$R_{ST}$ - en $D_{est}$ -waarden waren lager dan 0,001 en tevens niet significant. Er werden ook geen significante verschillen gevonden in differentiatie tussen opeenvolgende cohorten. Bij glasalen werd een patroon van isolatie-door-afstand gedetecteerd dat niet stabiel bleef doorheen de tijd. Verder werd bij glasalen voor één van de 21 EST-SSR's (locus 57-AANCT446) een mogelijke invloed van directionele selectie opgepikt, die constant bleef doorheen de tijd en mogelijk verband houdt met de immuunrespons.

Het ontbreken van structuur in de populatie op basis van functionele genetische merkers zowel in onze studie als in een studie waar dezelfde EST-SSR's werden gebruikt (Pujolar *et al*., 2009b), samen met het meest recente onderzoek op basis van neutrale microsatellieten waar ook werd gecorrigeerd voor temporele variatie, laat vermoeden dat voor het beheer van deze soort een globale (Europese) aanpak erg belangrijk is.

# OPTIMALISATIE VAN GOLFENERGIECONVERTOREN VOOR DE VLAAMSE KUST

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## Inleiding

Anno 2010 is de energieproblematiek schrijnender dan ooit. De Westerse maatschappij wil niet langer afhankelijk zijn van de geïmporteerde fossiele brandstoffen uit soms politiek instabiele landen maar wil, milieubewust, zelf haar vraag naar energie bevredigen. Deze houding stimuleert het onderzoek naar hernieuwbare vormen van energie.

Hernieuwbare energie zit duidelijk in de lift, opent talloze deuren en laat het menselijk vernuft op volle toeren draaien. Deze ontwikkelingen en initiatieven scheppen hoop en kunnen de toekomst wat rooskleurig maken voor alle toekomstige generaties.

Eén van deze hernieuwbare energiebronnen is golfenergie, een duurzame energievorm met een hoog potentieel. Golfenergieconversie is dan ook een snelgroeiende, veelbelovende technologie die (ondanks de huidige energieproblematiek) nog in haar kinderschoenen staat.

## Inhoud en doel van de masterproef

In dit werk wordt de werking en het ontwerp van een veelbelovende type van golfconvertor, de *point absorber* (oscillerende vlotter), geoptimaliseerd voor operationeel beproeven aan de Vlaamse kust. De plannen voor een praktische uitwerking van een testopstelling liggen op tafel (cf. *Flansea; Flanders Electricity From the Sea*). Het door ons ontwikkelde numerieke simulatiemodel is hierbij een handige 'tool' die zeker in een eerste ontwerpfase een cruciale rol kan spelen.

De Vlaamse Kust kent een relatief energiearm zeeklimaat (in vergelijking met meer energierijkere zeeën voor de Portugese en Schotse kusten) maar is net daarom een ideale proeftuin voor golfenergieconvertoren. Het zwaartepunt van dit eerste energieproject ligt dus eerder bij het testen en optimaliseren, en niet zozeer bij de energieopbrengst. Eens de werking en de duurzaamheid van de WEC (*Wave Energy Convertor*) op punt staan, kan deze 'proeftuin' verlaten worden en uitgeweken worden naar de energierijkere locaties.
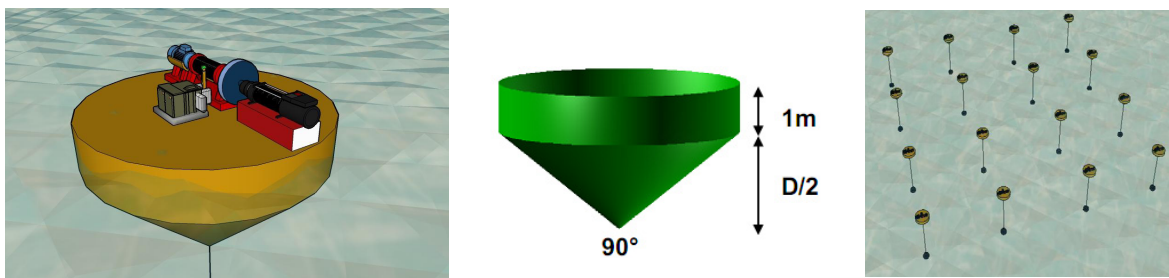


De masterproef is opgebouwd uit 2 verschillende optimalisatieprocessen:
- Simuleren en optimaliseren van de installatie van een proefopstelling voor de Vlaamse Kust. Hierbij wordt de plaatselijke beschikbare golfenergie begroot door middel van beschikbare meetdata. Uit deze gegevens wordt de beste locatie gekozen, en voor die locatie wordt vervolgens een boei ontworpen. Dit onderzoeksdeel is voornamelijk gebaseerd op reeds eerder verricht werk omtrent golfenergie. Daarna volgt een studie van de verticale boeibeweging voor vier verschillende systemen en dit in zowel het frequentie- als het tijdsdomein.
- Simuleren en optimaliseren van de installatie van een golfenergiepark (wave farm) voor de Vlaamse kust. Dit park wordt geplaatst in een energierijkere zee, op dus een grotere afstand van de kust, teneinde de energieopbrengst te maximaliseren. Voor dit golfenergiepark worden het aantal boeien, de afmetingen van de boei en de onderlinge configuratie onderzocht. Ook wordt rekening gehouden met de horizontale beweging van de boei.

## Numeriek krachtenmodel

Bij het numerieke simuleren van de boeibeweging werd er uitgegaan van een massa-veer-demper analogie. Hierbij werd er vertrokken vanuit een lineair systeem met 2 vaste referentiepunten. Gaandeweg wordt er afgestapt van dit vereenvoudigd lineair systeem en wordt een realistischer en zeewaardiger systeem gesimuleerd (1 vast referentiepunt mogelijk gemaakt door een kabelverankering in de zeebodem).



Lineair vereenvoudigd systeem          Realistisch systeem
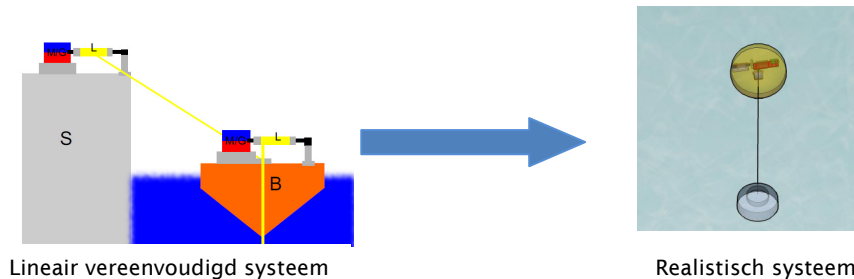
De totale kracht die invloed heeft op de boeibeweging wordt opgebouwd uit 2 componenten: de externe krachten en de PTO krachten.

$$m.a(t) = F_{EXTERNAL} + F_{PTO}$$

De externe krachten zijn zowel afhankelijk van de boeigeometrie als van het omliggende zeeklimaat en worden berekend via een eindige elementenmethode (software pakket *Wamit*). De kracht $F_{ex}$ is de excitatiekracht afkomstig van de invallende golf.

$$F_{EXTERNAL} = F_{terug} + F_{add} + F_{hyddamp} + F_{ex}$$

Het optimaliseren van de golfenergieconversie komt in se neer op het zoeken naar een ideaal krachtenverloop van de PTO (Power Take Off) kracht. Deze kracht wordt op de boei uitgeoefend via de ankerkabel en de lier van het PTO systeem. $F_{PTO}$ is de som van 2 aparte krachten met verschillend nut en verschillend berekeningalgoritme.

$$F_{PTO} = F_{power} + F_{tuning}$$

$F_{power}$ is een dempingskracht die de absorptie van golfenergie mogelijk maakt. Deze kracht is evenredig met de snelheid en kan vergeleken worden met de kracht uitgeoefend door een dynamo tegen een fietswiel.

$F_{tuning}$ is een controlekracht die de boeibeweging maximaliseert en is het sleutelbegrip van deze masterproef. Op onderstaande figuur zijn de verschillende seastates van het Oostendse golfklimaat weergegeven door een verticale lijn (seastate 6 en seastate 1 respectievelijk de donkerste lijn links en de lichtste lijn rechts).
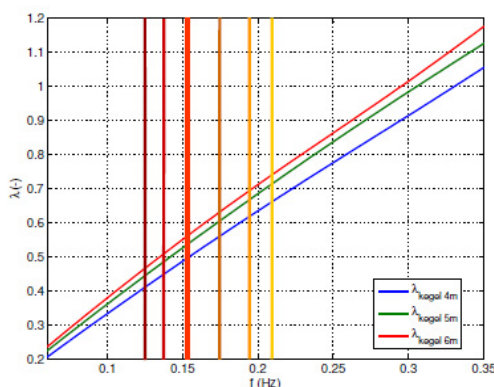


$$\lambda = \frac{\omega_{golf}}{\omega_n}$$

met
$\omega_n$: de natuurlijke boeifrequentie
$\omega_{golf}$: de dominante golffrequentie

$$\omega_n = \sqrt{\frac{k}{m + m_a(\omega)}} \ggg \omega_{golf} \quad \xrightarrow{\text{Toepassen van tuning}} \quad \omega_n = \sqrt{\frac{k}{m + m_a(\omega) + m_{sup}}}$$

Naar analogie van het veer-massa-demper systeem is het de bedoeling de verticale boeibeweging te optimaliseren (maximaliseren). Het is duidelijk dat de boei als het ware te wendbaar is voor de invallende golven: de (ongetunede) boei reageert het best op golven met hoge frequentie en dus golven met weinig energie. De boeibeweging als antwoord op golven met lage frequentie bevindt zich ver van resonantie. Door middel van tuning kan de natuurlijke frequentie van de boeibeweging 'gemanipuleerd' worden, zodat de energierijkere golffrequenties wel worden benut (zie

bovenstaande vergelijking). Deze controlekracht werd in dit werk op 2 verschillende manieren opgebouwd en onderzocht: via pulstuning (constante kracht) en tuning evenredig met de versnelling ($m_{sup}$ . a).

Het krachtenverloop in functie van de boeisnelheid wordt in onderstaande figuur verduidelijkt. Het tunen gebeurt hier door combinatie van eerder genoemde manieren: tuning evenredig met de versnelling (blauwe curves links en recht) en tuning door het aanleggen van een constante kracht (constante curve midden).

Vermits er enkel in de opwaartse beweging vermogenabsorptie mogelijk is (kabel), is de dempingskracht bij negatieve snelheden steeds nul.
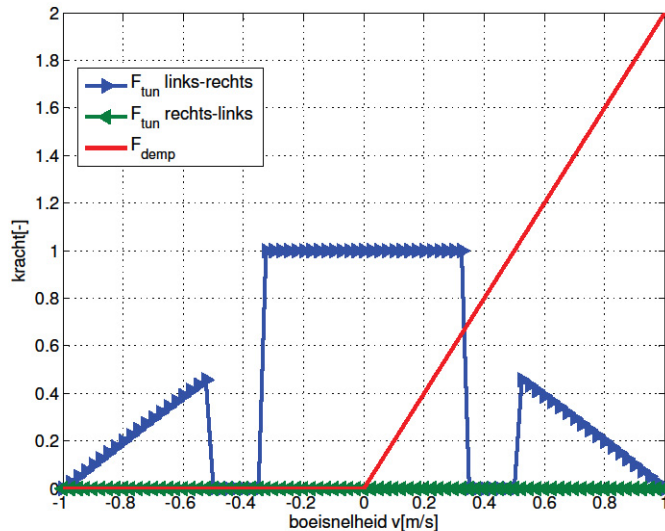


## De resultaten

Een volledig overzicht van de optimalisatieresultaten is hier weinig duidend en kan voor verwarring zorgen. Indien gewenst, kunnen de resultaten geraadpleegd worden in de masterproef zelf. Een conceptuele beschouwing is hier misschien wel nuttig.

Zoals reeds eerder werd aangehaald, ligt het zwaartepunt van deze masterproef in het onderzoek naar de verschillende manieren van tuning en dit toegepast op de golven aan de Vlaamse kust.

Onderstaande figuur maakt duidelijk dat de tuningkracht een significante invloed heeft op de boeibeweging: de verticale beweging is veel groter met tuning dan zonder. Dit impliceert een hoger toerental van de aandrijvende as waarop de lier is bevestigd en dus meer energieopbrengst.
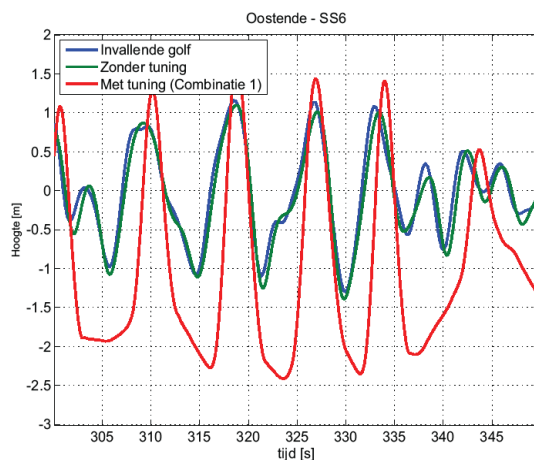
Onderstaande tabel tracht een notie te geven van de invloed van tuning op de energieopbrengst (boeidiameter 4m, zeediepte 7m, locatie Oostende).

| Seastate | %OC | No tuning | With tuning | % |
|---|---|---|---|---|
| Seastate 6 | 0.45 | 6007 W | 23.386 W | 389% |
| Seastate 5 | 1.09 | 5074 W | 19.859 W | 391% |
| Seastate 2 | 34,91 | 1074 W | 2.936 W | 273% |

Het uitbouwen van een golfenergiepark is vanzelfsprekend het streefdoel. Ook hier wordt er in deze masterproef dieper op ingegaan. Er wordt wel benadrukt dat deze berekeningen uitsluitend in het frequentiedomein zijn gebeurd (lineair). Indien meerdere configuraties (*grids*) met verschillende boeiafmetingen worden onderzocht is enkel het relatieve verschil van belang. Zware, tijdrovende berekeningen in het tijdsdomein zijn op dit moment om die reden overbodig.

De resultaten van de verschillende onderzochte configuraties zijn terug te vinden in hoofdstuk 8 van de masterproef.

## Besluit

Onderzoek naar golfenergieconvertoren is uiteraard niet begonnen met deze masterproef en zal er vast en zeker niet bij eindigen. Toch worden er in deze masterproef vernieuwende elementen en inzichten aangereikt die in verder onderzoek zeker noodzakelijk zijn.

Sinds de inlevering van de masterproef zijn, in het kader van het *Flansea* project, verdere stappen gezet naar de ontwikkeling van een testboei. Ook de auteurs hebben hier hun steentje bijgedragen door o.a. vakantiewerk bij *Flansea* partner DEME (Kris DB) en bijkomend onderzoek aan de Universiteit Gent (Dennis R). Het indienen van deze masterproef was dus geen eindpunt maar eerder een startpunt voor verdere betrokkenheid in de bijzonder boeiende wereld van de golfenergie.

# HET BESCHRIJVEN VAN PALEOCEANOGRAFISCHE VARIABILITEIT IN HET ZUIDEN VAN DE GOLF VAN CADIZ TIJDENS DE LAATSTE GLACIALE CYCLUS, EEN MULTI-PROXIE AANPAK

de Jonge Cindy

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## Introductie: situering en methodes

Het verstaan en beschrijven van klimaatveranderingen is een grote wetenschappelijke uitdaging, niet in het minst omdat milieuveranderingen ook een grote impact hebben op de mens. De belangrijke rol van klimaatonderzoek, paleoklimaat in het bijzonder, wordt ook geïllustreerd door het feit dat het een apart hoofdstuk vormt van het Nobelprijswinnende 4de verslag van het 'ipcc intergouvernementele panel over klimaatsveranderingen'. Modellen om het klimaat te voorspellen zijn complex, en worden gevalideerd met wat we weten van vroegere klimaatsveranderingen. Dit is niet enkel gebaseerd op recente instrumentale metingen, maar ook op geologische en klimatologische archieven zoals mariene en lacustriene sedimenten, ijskernen, druipstenen, koralen en boomringen.

Klimaatsreconstructies op glaciale/interglaciale tijdsschaal zijn vaak problematisch op het continent. Hier heeft erosie immers vrij spel, waardoor de meeste klimaatsarchieven onderbroken of onleesbaar geworden zijn. Mariene archieven bieden hier een excellent alternatief. In sommige gebieden laat de bodem van de oceaan een ongestoorde sedimentatie toe, waardoor veranderingen chronologisch behouden blijven. Bovendien zijn sites aan continentale randen niet alleen gevoelig aan continentale klimaatsveranderingen, maar ook aan oceanische. Gebieden met een hogere sedimentatie zijn ideaal voor het bestuderen van deze (geologisch gezien) korte tijdsschaal, aangezien de resolutie dan hoog genoeg is om snelle veranderingen te reconstrueren.

Gesteund door het Europese Wetenschapsfonds, werden verschillende bodemkernen genomen nabij het 'Pen Duick Escarpment', in het zuidelijke deel van de Golf van Cadiz, voor de kust van Marokko. Deze studie is gebaseerd op de eerste 12 meter van de langste kern die momenteel genomen is in dit gebied (30,3m), op een diepte van 642 meter.

De studie site wordt beïnvloed door twee belangrijke oceanische systemen. De invloed van Noord-Atlantische watermassa's op deze breedtegraad varieert naar de sterkte van het polaire front en dus over glaciale/interglaciale tijdsschalen. Ook de intensiteit van Mediterranean Outflow Water (MOW), het water dat via de Straat van Gibraltar uit de Middellandse Zee stroomt, kan worden geëvalueerd. Deze warme, hoog-saliene watermassa wordt geacht een van de belangrijkste drijfveren achter de thermohaline circulatie te zijn. De directe invloed als bodemstroom in het zuiden van de Golf van Cadiz staat echter momenteel nog ter discussie (Llave *et al.*, 2006; Van Rooij *et al.*, 2010).

Mariene sedimenten van het continentaal plat, bevatten zowel terrigene als oceanische componenten. De fossielen van het mariene milieu bevatten een myriade aan organische moleculen, afgeleid van mariene (algen, (cyano)bacteriën, archaea) en terrestrische organismen (hogere planten) die leefden ten tijde van afzetting. Deze zogenaamde biomarkers bevatten informatie die, indien ze goed gebruikt wordt, inzicht kan geven in voorbije klimaatscondities en veranderingen in het paleo-milieu. In het aquatische milieu is de temperatuur van het water één van de belangrijkste indicatoren om de herkomst van watermassa's te bepalen. Indirect, geeft dit ook informatie over de hoeveelheid nutriënten en de primaire productiviteit. Daarom werd de verzadiging van specifieke archaea-bacteriële membraanlipiden (glycerol dialkyl glycerol tetraethers; GDGTs) en van Haptophyte lipiden (alkenonen) bekeken, om zo respectievelijk de $TEX_{86}$ (Schouten *et al.*, 2002) en de $U^{K'}_{37}$ (reviewed in Volkman, 2000)te berekenen.

Naast het vergelijken en testen van laatstgenoemde biomarker proxies, werd ook de gelijkenis met $d^{18}O$-isotopen, afkomstig uit het kalkskelet van de foraminifeer *Globigerina bulloides*, geëvalueerd. De waarde van zuurstofisotopen is echter niet enkel gevoelig voor temperatuur, maar registreert ook lokale saliniteitsveranderingen.

Om op de informatie in het organisch materiaal, te kunnen afgaan, moet ook rekening gehouden worden met degradatie. Daarvoor werden niet enkel TOC en C/N metingen uitgevoerd, maar werd ook de BIT-waarde (branched isoprenoid tetraether index) berekend (Hopmans *et al.*, 2004). De BIT-waarde is een maat voor de input van terrigene biomassa, aangezien hij afgeleid wordt van de relatieve hoeveelheid vetten afkomstig van terrigene bodembacteriën.

Om klimaatsveranderingen op het continent te reconstrueren, werd de veranderende invloed van de verschillende transportmechanismes bestudeerd. Veranderingen in neerslag in de Midden-Atlas bergketen, die een invloed hebben op de hoeveelheid aangeleverde riviersedimenten, worden weerspiegeld in de hoeveelheid kleien. Droogtes benedenwinds, nabij de evenaar, worden dan weer aangetoond door de aanwezigheid van grover stof dat rijk is aan ijzer.

Door deze multi-proxie invalshoek wordt het mogelijk de situatie in oceanen direct te linken aan het continentale klimaat, waarbij we het probleem van correlatie, dat bij aparte archieven zou optreden, omzeilen. Dit maakt het mogelijk om ook bij snelle veranderingen, te reconstrueren welke leiden en welke met vertraging gebeuren.

## Resultaten en discussie
Datering van deze kern gebeurde door de stabiele zuurstofisotoop curve te vergelijken met die van de GRIP ijskern en de Ca/Fe curven visueel te linken aan die van nabije, gedateerde kernen.

De analyse van het niet-organische sediment, is vooral gericht op het onderscheiden van fluviatiele en eolische afzettingen. De verhouding tussen Fe en Al, een proxie voor droogte in de Sahara (e.g. Rogerson *et al.*, 2006), blijkt duidelijk te reageren op glaciale/interglaciale klimaatsveranderingen. Ook op korte tijdsschaal is een periodiciteit zichtbaar, maar datering laat momenteel niet toe deze te berekenen. Terwijl toenames in kalium in vorige studies gebruikt werd om de hoeveelheid sediment door rivieren aangebracht te evalueren (e.g. Yarincik, 2000), lijkt dit in ons geval niet terecht. Een toename in de totale hoeveelheid kleien zou immers resulteren in een kleinere gemiddelde korrelgrootte en dit is niet het geval.

Een eerste mogelijke verklaring is een kwalitatieve, eerder dan kwantitatieve verandering binnen de kleien. Aangezien kalium aanwezig is in Illiet, een mineraal typisch voor mechanisch verweerde kleien, kan zijn voorkomen in het sediment misschien gelinkt worden aan veranderingen in het brongebied of veranderingen in de genese van de kleifractie tijdens deze periodes. Aangezien de K/Fe-ratio hoge waarden vertoont in het begin van Marine Isotope Stage 1 (MIS1), MIS3 en in MIS5e, zou een mogelijke bron hier het smeltwater van de gletsjers kunnen zijn. Directe analyse van de kleifractie (XRD) is echter nodig om dit te bevestigen.

De relatieve hoeveelheid sediment aangebracht door rivieren, afgeleid uit een lagere gemiddelde korrelgrootte, is opvallend hoger tijdens periodes van maximale ijsbedekking. Dit kan verklaard worden door de sterkere erosie van rivieren tijdens periodes met een lagere zeespiegel.

De BIT-index, die eerder al succesvol gebruikt werd om de input van bodemmateriaal te reconstrueren, heeft hiervoor in onze site weinig nut. Aangezien de ratio bestaat uit mariene en terrigene moleculen, verliest die zijn informatie als de lipiden onderhevig zijn aan sterke degradatie. Hierdoor zullen mariene lipiden immers sneller aangetast worden, waardoor de verhouding zal verschuiven. Aangezien lage C/N waarden op een lage input van terrigeen materiaal wijzen, zal een hoge BIT-index tezamen met lage C/N waarden duiden op een sterke oxidatie van organisch materiaal.

De toestand van de watermassa boven onze site, afgeleid uit de evolutie van temperaturen, veranderde ook op glaciale/interglaciale tijdsschaal. We gebruiken drie verschillende proxies om de oppervlaktetemperatuur te bepalen. Een eerste groep lipiden (alkenonen, $U^{K'}_{37}$), wordt geproduceerd door fytoplankton, die de evolutie van de temperatuur van de fotische zone registreren. De Archaeale lipiden (GDGTs, $TEX_{86}$) worden over een groter diepteverloop geproduceerd. De zuurstofisotopen zijn afkomstig van foraminiferen wiens biotoop varieert in diepte tussen 300 en 600m. Het vergelijken van deze proxies biedt dus een inzicht in de verschillende lagen van de waterkolom ter hoogte van onze site.

Al deze proxies rapporteren koudere temperaturen tijdens glacialen en warmere tijdens interglacialen. Naast een constant temperatuurverschil tussen de verschillende proxies, dat mogelijk te wijten is aan een verschil in bloeiseizoen, zien we echter ook dat het verschil in temperatuur tussen de alkenonen en de GDGTs groter wordt tijdens koude periodes, met koudere op alkenonen- en warmere op GDGTs-gebaseerde reconstructies. Dit zou eenvoudig verklaard kunnen worden door de uitbreiding van het opwellinggebied dat momenteel beperkt aanwezig is voor de kust van Cadiz.

Dit zou de oppervlakte organismes in diepere en koudere waterlagen dwingen, terwijl de diepere Archaea naar warmere wateren getransporteerd worden en zo een warmer signaal geven. Eerdere micropaleontologische studies rapporteren echter geen opwellinggerelateerde organismen.

Een tweede verklaring is dat het verschil verklaard wordt door degradatie van de vetten. Meer verzadigde vetten zullen immers sneller aangetast worden, waardoor deze sedimenten een andere temperatuurprofiel zullen krijgen. De richting van verandering in alkenonen, waarbij degradatie een 'warm' effect heeft, zou verklaard worden door minder degraderende omstandigheden tijdens glacialen. Algemeen aanvaard wordt dat glacialen en Heinrich Events (HEs) inderdaad gepaard gingen met het vertragen van het thermohalien systeem, waardoor bodemstromen langzamer en dus minder reducerend zouden worden. Dit komt echter niet overeen met de situatie die geschetst wordt door de BIT-index en vooral de C/N ratio. Deze tonen (vooral in MIS 6 en MIS 8) zeer duidelijke indicaties dat bodemwaters tijdens de koude periodes meer zuurstof bevatten en meer materiaal aangetast werd dan tijdens warme periodes.

De offset tussen onze twee temperatuurproxies kan dan enkel nog verklaard worden door advectie vanuit verschillende brongebieden. De waterkolom ter hoogte van onze site is immers opgebouwd uit verschillende modi stabiele waterlagen die elk een eigen oorsprongsgebied hebben. De twee bovenste waterlagen hebben een subtropische oorsprong (op 40° and 30° N), terwijl de diepste modus in subpolaire breedtegraden zonk (ongeveer 50° N).
Laterale advectie van moleculen wordt verondersteld een grotere impact te hebben op alkenonen dan op GDGTs, maar eerdere resultaten zijn vaak niet eenduidig. Wat wel vaststaat, is dat een sterkere stroming moleculen sneller zal transporteren. Aangezien moleculen in de waterkolom een beperkte levensduur hebben, is de snelheid waarmee ze getransporteerd worden bepalend voor de afstand die ze kunnen afleggen. Deze verklaring voor de grotere offset komt inderdaad overeen met de actievere bodemstromingen die we eerder afgeleid hebben.

Om deze denkpiste te testen, bekeken we de relatie van de biomarkers met de stabiele zuurstofisotopen. Deze registreren immers de omgevingstemperatuur van foraminiferen. Deze laatste zijn veel minder gevoelig aan lateraal transport, omdat ze zwaar genoeg zijn dat ze nagenoeg direct zinken. Een correlatie met de stabiele zuurstofisotopen kan dus mogelijks een nieuw licht werpen. Correlaties van beide biomarker proxies met $\delta^{18}O$ waarden zijn zeer goed, naast een paar afwijkingen die verklaard kunnen worden door veranderingen in de globale $\delta^{18}O$ waarden. Zo herkennen we de toename in landijs in te hoge $\delta^{18}O$ waarden (ten opzichte van de correlatie) tijdens MIS5b, MIS6 en MIS8. Waar $\delta^{18}O$ waarden lager dan verwacht zijn tijdens bepaalde 'Heinrich Events', kan dit ook verklaard worden door een plotse afname van het globale volume ijs. De $TEX_{86}$ en $U^{K'}_{37}$ lijken dus te reageren op dezelfde temperatuurschommelingen dan de lokaal gevormde foraminiferen. Dit doet ons besluiten dat, mocht lateraal transport plaatsgevonden hebben, het een snel proces was. Mochten vetzuren van een verschillende ouderdom per diepte gevonden worden, zou er immers een verschil in temperatuurreconstructies zijn.

Een opmerking in deze context is ook dat geen invloed van veranderingen in saliniteit merkbaar zijn in de $\delta^{18}O$ record. Normaal zouden $\delta^{18}O$ waarden stijgen met stijgende saliniteit. Dit duidt aan dat de aanwezigheid van het MOW in onze site waarschijnlijk niet van die orde was dat onze record erdoor beïnvloed wordt. Evenzeer worden geen tetraonverzadigde alkenonen teruggevonden, die nochtans kenmerkend zijn voor het MOW. Dit is in tegenstelling met de hypothese dat MOW onze site zou bereiken onder de vorm van eddies (Foubert, 2008).

## Conclusies
Onze observaties zijn in lijn met vele 'klassieke' studies die de Noord-Afrikaanse passaatwinden beschrijven. Het continentale klimaat in NW Afrika wordt gestuurd door veranderingen in atmosferische patronen die ontstaan op hogere breedtegraad. Hierdoor kunnen we niet alleen glaciale/interglaciale veranderingen zien, maar ook meer lokale fenomenen, zoals Heinrich Events. Dit zien we vooral in de goed gefundeerde en uitgebreid geteste Fe/Al proxie, terwijl variaties in K/Fe iets minder voor de hand liggend zijn. Onze multi-proxie aanpak laat echter toe om deze kennis van het terrigeen systeem te linken aan oceanische systemen.

We kunnen bijvoorbeeld besluiten dat bodemstromingen, vooral tijdens MIS6 en MIS8 veel reducerender en dus waarschijnlijk sterker waren dan in de huidige situatie en bevestigen hierbij de hypothese van Van Rooij *et al.* (2010). De aanwezigheid van salien Mediterraan water wordt echter niet bevestigd.
Een ander aspect van deze studie belicht het belang van het simultaan bekijken van verschillende temperatuurproxies. De oceanografische condities in de Golf van Cadiz zorgen er immers niet alleen voor dat de $TEX_{86}$ temperaturen gevoelig hoger liggen, maar bovendien ook een -ietwat- ander verloop kennen dan de $U^{K'}_{37}$. Interpretatie van deze proxies moet dus met zorg gebeuren en idealiter

in het kader van een paleoceanografische reconstructie. Uit deze studie blijkt dat snel lateraal transport waarschijnlijk aan de oorsprong ligt van dit verschil.

Om deze studie te vervolledigen, zou een betere datering, gevolgd door een analyse van de golflengtes uitgevoerd kunnen worden. Op deze manier kunnen de cycliciteiten van onze geochemische data gelinkt worden aan reeds gepubliceerde data. Een analyse van de proxies op hogere resolutie zou bovendien de deuren openzetten om de korte, snelle klimaatsveranderingen beter in kaart te brengen.

## Dank

## Nota bene

De data betreffende de stabiele zuurstofisotopen en de C/N waarden heb ik te laat verkregen om opgenomen te worden in mijn manuscript, maar zij maakten wel deel uit van mijn verdediging.

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# OVERLEVEN IN HET MANGROVEBOS DOOR EEN BIJZONDERE HYDRAULISCHE STRUCTUUR. EEN HOUTANATOMISCHE VERGELIJKING TUSSEN MANGROVEBOMEN EN HUN NAUWST VERWANTEN

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Mangrove-ecosystemen zijn belangrijk omdat ze verschillende belangrijke ecologische en socio-economische functies vervullen, waaronder bescherming van kustzones tegen stormen en ondersteuning van de terrestrische zowel als de marine voedselketen (Duke *et al.*, 2007). Mangrovebossen verdwijnen wereldwijd echter met 1-2% per jaar desondanks hun functie (Duke *et al.*, 2007). Mangrovebomen leven in de ruwe omgeving van de intergetijde zone. Deze omgeving is onderhevig aan een ongewone combinatie van omgevingsfactoren: hoge temperaturen en periodieke overstromingen met zout water. In deze ecologische omstandigheden is het water moeilijk beschikbaar voor de bomen. Bovendien kan het zoutgehalte van het aanwezig water sterk fluctueren. Mangrovebomen vertonen een aantal aanpassingen aan de fysiologische eisen van hun omgeving zodat ze kunnen overleven: zoutexclusie en zoutsecretie, luchtwortels, viviparie en drijvende propagulen zijn enkele van die aanpassingen (Tomlinson, 1994). Het feit dat cavitatie, het ontstaan van een luchtbel in de waterkolom, sowieso al plaatsvindt onder mesofiele omstandigheden en dus zeker in de omstandigheden van het mangrovebos, maakt de aanwezigheid van mangrovebomen in deze voor bomen stresserende omgeving des te verrassender. Bomen kunnen zich echter aanpassen aan de cavitatiedruk via een veilig hydraulische architectuur (o.a. hoge vatendichtheid, kleine vaten en hoge vatgroepering).

Om te achterhalen hoe mangrovebomen in hun omgeving kunnen overleven, is het belangrijk om de hydraulische architectuur van deze soorten te kennen en die te vergelijken met de hydraulische structuur van hun meest verwante boomsoorten. Mangrovetaxa behoren tot verschillende evolutionaire groepen wat erop wijst dat ze een convergente evolutie vertonen in hun (morfologische) aanpassingen aan hun omgeving.

Het doel van deze studie is te bepalen of dat er naast de morfologische aanpassingen ook een (i) convergente evolutie is in de houtanatomische kenmerken van mangrovebomen en (ii) om te bepalen waarom dat de meest verwante binnenlandse soorten niet in de mangrove-omgeving kunnen voorkomen (Fig. 1). Dit zal onderzocht worden door vergelijking van houtanatomische kenmerken (vatdimensies, vatgroepering, vatendichtheid en vatwanddikte) tussen de mangroven hun meest verwante binnenlandse soorten. Het onderzoek draagt bij aan de kennis van het effect van de omgeving op de houtanatomische kenmerken van mangrovebomen en leidt tot inzicht in de evolutionaire aanpassing van bomen aan stresserende omgevingsomstandigheden.

Op basis van literatuurstudie werden de boomgeslachten opgezocht die fylogenetisch het meest verwant zijn aan de verschillende mangrovegeslachten. Dit duidde aan dat het genus *Heritiera* heel interessant was voor onze studie, aangezien er binnen dezelfde genus zowel mangrovesoorten alsook binnenlandse soorten bestaan. Daarnaast werd ook een vergelijking gemaakt tussen verschillende genera binnen de Malvaceae (*Sterculia* en *Heritiera*) en binnen de Rhizophoraceae (*Rhizophora / Ceriops / Bruguiera* versus *Gynotroches / Carallia / Pellacalyx*), telkens voor twee verschillende continenten (Afrika en Azië) (Fig. 1). De soorten die verder werden onderzocht werden uit deze genera geselecteerd op basis van: (i) het centrum van soortenrijkdom van de overeenkomstige families, (ii) de Köppen-Geiger klimaatsclassificatie-index en (iii) het habitat. De houtanatomische kenmerken werden gemeten met de beeldanalysesoftware AnalySIS op houtstalen uit de houtcollectie van het Koninklijk Museum voor Midden-Afrika in Tervuren.

De resultaten toonden aan dat er, in beide onderzochte families (Malvaceae en de Rhizophoraceae) een significant hogere vatendichtheid en significant lagere vatdiameter aanwezig was binnen de mangrovebomen, ten opzichte van de binnenlandse soorten. Dit wijst erop dat mangroven hun hydraulisch systeem veiligstellen voor cavitatie in vergelijking tot hun verwante zustertaxa. Er was een uitzondering op deze algemene trend in veiligheid: *Gynotroches axillaris* vertoonde afwijkingen

in vatendichtheid en vatgroepering. Deze afwijkingen kunnen te wijten zijn aan verschillende factoren gaande van de evolutionaire tot de klimatologische variatie.

Uit onze analyse konden we besluiten dat er een algemeen patroon aanwezig is in vatendichtheid (hoger) en vatdiameter (lager) in mangrovebomen ten opzichte van hun meest verwante boomsoorten, voor beide onderzochte families en continenten. Dit wijst op het feit dat mangrovebomen naar een veilig hydraulisch systeem streven om in hun dynamische omgeving te kunnen overleven. Anderzijds toonde de vatgroepering aan dat er alternatieve strategieën (efficiëntie *versus* veiligheid) aanwezig waren in beide families. De perspectieven naar toekomstig onderzoek, om deze bevindingen te ondersteunen, maar ook om deze te bevestigen, houdt in dat men meer stalen, meer families alsook meer houtanatomische kenmerken in rekening moeten gebracht worden.
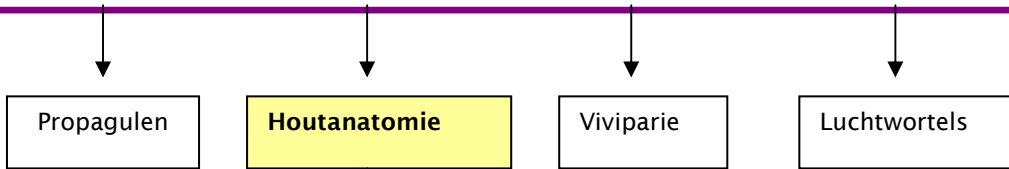
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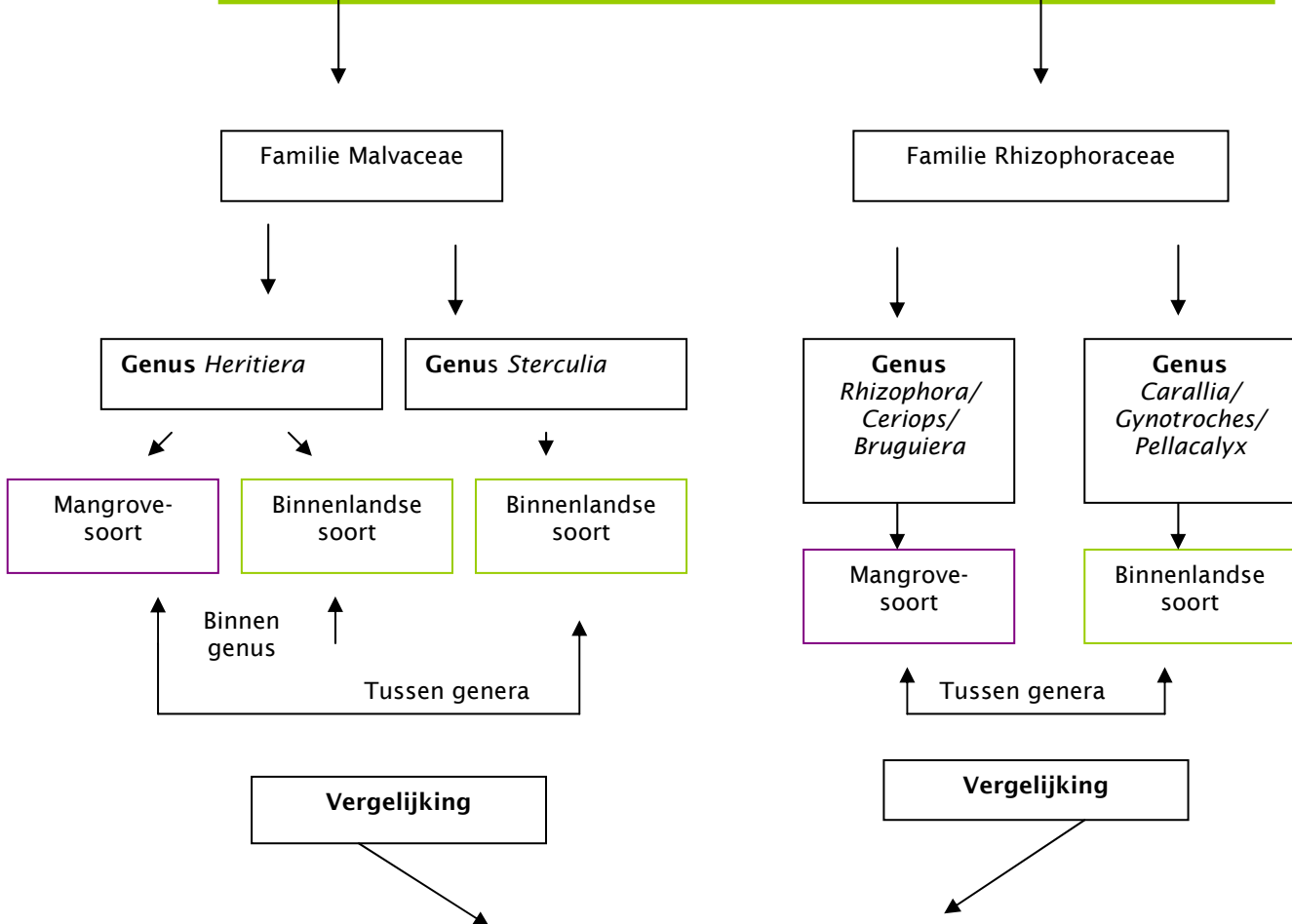
# DOEL

**Is er een convergente houtanatomie binnen de mangroven?**

**Waarom kunnen enkel mangrovebomen overleven in het intergtijdengebied?**

## Mangrovekenmerken

Propagulen

**Houtanatomie**

Viviparie

Luchtwortels

## VERGELIJKING MET BINNENLANDSE VERWANTEN

Familie Malvaceae

Familie Rhizophoraceae

**Genus** *Heritiera*

**Genu**s *Sterculia*

**Genus** *Rhizophora/ Ceriops/ Bruguiera*

**Genus** *Carallia/ Gynotroches/ Pellacalyx*

Mangrove- soort

Binnenlandse soort

Binnenlandse soort

Mangrove- soort

Binnenlandse soort

Binnen genus

Tussen genera

Tussen genera

**Vergelijking**

**Vergelijking**

**Besluit: mangroven hebben een veiliger watertransportsysteem dan hun binnenlandse verwanten (hogere vatendichtheid en kleine vaten), aangepast aan de hoge cavitatiedruk aanwezig in hun omgeving .**

Fig. 1. Overzicht van de verschillende onderzoeksaspecten van het voorgestelde onderzoek die hebben geleid tot een algemene conclusie over de aanpassingen van de houtanatomie van  mangroven aan de ecologische omstandigheden in het mangrove-ecosysteem in vergelijking tot hun meest verwante taxa.

# PROXIE *VERSUS* MODEL-PROXIE VERGELIJKING: HOLOCENE EVOLUTIE VAN HET KLIMAAT IN DE ATLANTISCHE REGIO

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De initiële stap van deze thesis was het creëren van een uitgebreide database bestaande uit temperatuurreconstructies van het zeeoppervlak van de Atlantische Oceaan gedurende het Holoceen. In totaal zijn data van vijf verschillende, vaak gebruikte, proxie methods verzameld in deze database. De vijf proxies zijn alkenonen, Mg/Ca in planktonische foraminiferen, en faunale assemblages van dinocysten, diatomeeën en planktonische foraminiferen. De eerste twee methodes worden gebruikt om gemiddelde jaarlijkse temperaturen weer te geven (via calibraties), terwijl de andere gebruikt worden om winter- en zomertemperaturen te reconstrueren (via transferfuncties). De thesis bestaat uit vier delen: (1) een vergelijking tussen de verschillende proxies; (2) de Holocene temperatuurveranderingen en de gerelateerde oceaanstromingsveranderingen en atmosferische veranderingen; (3) analyse van de data op kortere tijdschaal (100 jaar) en de relatie met zonneactiviteit; (4) de vergelijking van de proxie data met het ECBILT-CLIO-VECODE paleoklimaatmodel.

Het bestuderen van de verschillen qua gemiddelde Holocene temperaturen, temperatuurevolutie en temperatuurvariabiliteit tussen de verschillende proxie data brengt verschillende trends aan het licht. Een seizoenale voorkeur in productiviteit en groeiseizoen is een goede verklaring voor de anomaal hoge temperaturen in alkenoon datasets van hogere breedtegraden. Afwijkende temperatuurtrends en een tekort aan seizoenale variabiliteit in reconstructies gebaseerd op planktonische foraminiferen (faunaal en Mg/Ca) afkomstig van vooral mid- en hoge latitudes suggereren dat er een invloed is van thermocliene temperaturen. Dit komt tevens overeen met studies die stellen dat de gemiddelde leefdiepte van planktonische foraminiferen dieper is dan van de overige microfauna gebruikt voor temperatuurreconstructies. Deze bevindingen betekenen dus dat, vooral op hogere breedtegraden, de interpretatie van minstens drie van de vijf methodes zou moeten aangepast worden.

Vier verschillende periodes in het Holoceen konden vaak teruggevonden worden in de data. Een eerste periode tussen ongeveer 11500 en 9500 jaar BP is geassocieerd met een grote variabiliteit in temperatuur in de hogere breedtegraden en een opwarmende trend in zo goed als de ganse Atlantische regio. De temperatuurtoename en hoge variabiliteit kunnen geassocieerd worden met de opstart van de thermohaliene circulatie en initiële instabiliteit door het periodiek snel afsmelten van ijs. Een tweede periode strekt zich uit van ongeveer 9500 tot 8000 jaar BP. Deze periode wordt gekenmerkt door een kleine temperatuurafname in de meeste gebieden van de Noord Atlantische Oceaan (0,5-1,5°C), terwijl het noordwesten van de Atlantische Oceaan een plotse temperatuurstijging ondergaat. Deze temperatuurstijging is het duidelijkst (~6°C) in het gebied ten westen van de Reykjanes Rug (ten zuiden van IJsland). Een mogelijke oorzaak voor deze plotse verplaatsing in warmteverspreiding is het (plots) noordwaarts opschuiven van de Golfstroom onder de invloed van een maximum in insolatie op hogere breedtegraden gedurende de zomer en een hoge temperatuursgradient tussen oost Canada (gletsjers) en de warme Atlantische wateren. Rond 8000 jaar BP is er opnieuw een plotse verandering in temperatuurevolutie. De 8,2 ka BP event en de start van het vormen van Labrador Sea Water zijn de mogelijke triggers van deze temperatuuromslag. De periode tussen 8000 en 5500 jaar BP wordt gekenmerkt door tegengestelde temperatuursveranderingen ten opzichte van de tweede periode. De start van convectie in de Labradorzee en een afname in insolatie gedurende de zomer hebben geleid tot een meer zuidwaarts traject van de Golfstroom. De doorzetting in de afname van zomerinsolatie en het afsmelten van de Laurentide Ice Sheet zijn waarschijnlijk de oorzaak van een laatste grote reorganisatie van de oceanische- en atmosferische circulatie rond 5500 jaar BP. De temperatuuromslag rond 5500 jaar BP wordt geweten aan een drempelwaarde die bereikt wordt tijdens de zuidwaartse verplaatsing van de Golfstroom. De laatste periode tussen 5500 jaar BP en de pre-industriële tijd, is in het algemeen een periode van grillige temperatuurdaling in bijna gans de Atlantische regio. Gedurende de laatste 8000 jaar treedt de grootste temperatuurdaling op in het noordoosten van de Atlantische Oceaan. Dit en nog enkele andere veranderingen in temperatuur en neerslag suggereren een trend naar een positieve North Atlantic Oscillation index, wat een meer zonaal weerpatroon inhoudt.

Een gedetailleerde analyse van de temperatuurvariabiliteit op 100-jarige tijdschaal leidde tot de ontdekking van gemiddeld 200 jaar en ongeveer 500 jaar cycli. Beide periodiciteiten duiden op een verband met zonneactiviteit. De eerste komt waarschijnlijk overeen met de ~205 jaar de Vries zonnecyclus. Een vergelijking van de ~500 jarige cyclus met uitgesproken minima in zonneactiviteit suggereert ook een verband tussen beide. Een spectrale analyse is echter nodig om het bestaan van deze cycli te bevestigen.

Het ECBILT-CLIO-VECODE model is in staat om gemiddelde temperatuursveranderingen over een brede latidunale band te voorspellen, maar faalt op het gebied van lokale veranderingen. Het feit dat het model de zuidwaartse verschuiving van de Golfstroom niet simuleert, leidt waarschijnlijk tot de anomaal hoge temperaturen in de Atlantische regio tussen voornamelijk 50 en 60°N. Van alle modellen aanwezig in de PMIP2 database is het enkel het Australische CSIRO-Mk3L1.1 model dat erin slaagt om de zuidwaartse migratie van de Golfstroom op te pikken.

**APPLICANT**
**VLIZ North Sea Award 2010**

# EFFORT ALLOCATION OF THE DUTCH BEAM TRAWL FLEET

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This thesis addresses the question how fishers allocate their activities in space and time. Understanding the mechanisms governing the dynamics of fishing fleets is important to understand how fishers respond to management measures and changes in their environment. This knowledge can be used by fisheries managers to design efficient management measures. The study focuses on demersal fisheries exploiting a mixed bag of bottom dwelling flatfish.

The results in the thesis show that the fisheries respond to the seasonal changes in distribution of their main target species sole and plaice. Area specialization of fishers as well as interference competition among vessels play a role in shaping the spatial distribution of the fleet within the constraints put by management. A dynamic state variable model was developed to study the effect of management constraints on fishing effort allocation and discarding. The model evaluates the trade-offs and constraints that individual skippers face in their fishing operation.

Management measures change the trade-offs and constraints shaping the choices of individual fishers, resulting in changes in spatial distribution of the fleets as well as other aspects of fleet behaviour. It is shown that the beam trawl fleet has shifted its fishing effort increasingly south, as a result of the increasingly restrictive plaice quota. This has resulted in an increased catchability for sole and young plaice, and an incentive for individuals to discard marketable fish.